National Aeronautics and Space Administration

BUDGET ESTIMATES

FISCAL YEAR 1967

Volume II

RESEARCH AND DEVELOPMENT

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1967 ESTIMATES

RESEARCH AND DEVELOPMENT

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT

GENERAL STATEMENT

The program of research and development and supporting activities of the National Aeronautics and Space Administration is directed toward maintaining the United States in a position of world leadership in aeronautics and space. The major program elements designed to achieve this objective are:

MANNED SPACE FLIGHT: The attainment of a capability for manned space operations and exploration through extended earth orbital flights, development of rendezvous and docking techniques, and manned lunar landing and return.

SPACE SCIENCE AND APPLICATIONS: An unmanned space flight program directed toward scientific investigations of the Earth, Moon, Sun, planets, stars and interplanetary space; and the development of technology and spacecraft systems that can be used in operational systems, such as meteorology and communications.

ADVANCED RESEARCH AND TECHNOLOGY: An effort required to provide the fundamental knowledge and the technological base for the future aeronautics and space programs.

TRACKING AND DATA ACQUISITION: The effort required for the operational support of the NASA manned and unmanned flight programs.

MANNED SPACE FLIGHT

The greatest portion of the FY 1967 request is for the support of the manned space flight program. The development of a capability for manned space operations with a supporting base of engineering, scientific and production capacity remains unchanged as the basic objective of this program. Within this basic objective there is a specific goal of landing men on the lunar surface for limited lunar exploration and returning them safely to earth in this decade. Projects Gemini and Apollo continue to be the hard core of the present flight and ground test and development effort. Supplementing these projects are studies and supporting development activity which are directed toward the exploitation of the hardware and techniques developed by Gemini and Apollo.

Gemini has already established man's capability for useful activities in space for periods of up to two weeks. In FY 1967 its flight operations will be completed. These flights will provide Apollo with important development information on space navigation, guidance, rendezvous and docking techniques.

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In addition to continuation of the ground test activities, FY 1967 Apollo efforts will expand into manned spacecraft flight tests using the Saturn IB launch vehicle, and the initial development flights of the Saturn V launch vehicle.

In the area of advanced flight missions, studies and advanced component development will be continued. The aim of this effort will be to exploit and extend the capability of the Apollo spacecraft.

SPACE SCIENCE AND APPLICATIONS

In the FY 1967 budget request the next major program is that of space science and applications. Part of the scientific program is concerned with unmanned space flights, which are used to study the environment and surface of the Earth, Moon, and planets, as well as the intervening space environment. The flight projects concerned with the above objectives include sounding rockets, Geophysical satellites, Explorers, Pioneer probes, Mariners and Surveyor. The project involved with the study of the Sun is the Orbiting Solar Observatory; while the purpose of the Orbiting Astronomical Observatory is to study the stars. The biosatellite program will continue development so as to launch its first flight in 1966. In the area of applications, project Nimbus will continue to support the present and future requirements of the operational weather satellite systems for the Weather Bureau. Effort will also continue in the development of the Applications Technology Satellite which will give useful information for application to meteorology and communications as well as scientific spacecraft systems.

ADVANCED RESEARCH AND TECHNOLOGY

The advanced research and technology effort constitutes a continuing overall program aimed at meeting the technology goals of the nation with particular attention to providing the technical base for carrying out attractive future aero-space missions. This effort covers the spectrum of activity from basic research to improve our fundamental knowledge of physical and life science phenomena, through applied technology to improve our practical capability for developing advanced systems. The specific areas of effort in the advanced research and technology program are basic research, biotechnology and human research, electronics and control, nuclear systems and space power, chemical propulsion, space vehicle research and technology, and aeronautics.

TRACKING AND DATA ACQUISITION

The tracking and data acquisition effort is directed toward providing the necessary support required by the increasing activity of the NASA space flight programs. During FY 1967 increased numbers of launches are scheduled for both the manned and unmanned space flight programs, thereby requiring additional effort by the world-wide network of tracking stations. Additionally, the program provides for supplementing and maintaining the tracking and data acquisition capability of the network as required.

TECHNOLOGY UTILIZATION

The technology utilization program provides for the distribution and dissemination of the scientific, technological and engineering information and concepts resulting from NASA programs so as to permit their fullest use in accomplishing national objectives. In order to assure fulfillment of this basic objective, several subsidiary objectives must be realized. They are: 1. Establishing effective mechanisms and systems for assuring that all new knowledge is identified, collected, evaluated and made available in the most useful manner; and 2. Establishing effective mechanisms for announcing and disseminating this new knowledge in order to assure the widest possible application and utilization thereof.

FINANCING

The FY 1967 budget to support the research and development program, which is discussed in detail in this volume, is $4,246,600,000. This compares with a program totaling $4,511,644,000 for FY 1966.

Expenditures for the current fiscal year are estimated at $4,520,000,000 and $4,340,000,000 for FY 1967

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1967 ESTIMATES

OFFICE OF MANNED SPACE FLIGHT — GEMINI PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Gemini program objectives are to develop an operational capability in manned space flight and through this capability to conduct specific experiments and tests which support Apollo, Department of Defense programs, and scientific investigations. In the Gemini program, the U.S. is developing and demonstrating the capability for long-duration flights of at least 14 days, rendezvous and docking, post-docking maneuvers, extravehicular activity, and controlled reentry.

The Gemini spacecraft systems are substantially more sophisticated and versatile than those used in Mercury. The spacecraft includes a number of subsystems used for the first time in manned space flight: ejection seats; fuel cells; on-board propulsion; rendezvous radar; inertial guidance; and controlled reentry. The inertial guidance system used for rendezvous also provides an alternate capability in the event of failure in the launch vehicle primary guidance system. In-flight experiments are conducted as part of a planned program to utilize the full payload and operational capabilities of Gemini.

By the end of calendar year 1965, 7 of the 12 planned flights had been successfully conducted. Gemini I, II, and III were flight qualification missions; Gemini IV, V, and VII were long-duration flights that proved man's ability to perform useful tasks in space for extended periods of time. Man's operational capability outside the confines of a spacecraft was demonstrated by the extravehicular activity conducted during the Gemini IV mission. The rendezvous of spacecraft 6 with spacecraft 7 represented a major step in developing the operational skills and techniques that are vital to the Apollo missions. The experiments program conducted on the 5 manned missions during calendar year 1965 have significantly increased our medical and scientific knowledge of the Earth and near-space environment.

Extensive extravehicular activity is planned for the remaining Gemini flights (VIII through XII) both to evaluate life support systems and maneuvering units for the astronauts, and to demonstrate the ability to perform specific operational tasks in space. The DOD maneuvering unit will also be evaluated as a cooperative NASA/DOD effort.

Delivery of the major flight hardware has continued at a rapid pace in support of the intensive operational activity underway. By the end of calendar year 1965, 7 flight spacecraft, 7 Gemini Launch Vehicles, 2 Gemini Agena Target Vehicles and 3 Atlas SLV-III had been delivered. By mid-calendar year 1966, deliveries will total 10 spacecraft, 10 GLV, 4 Atlas SLV-III, and

5 Gemini Agena Target Vehicles. The remainder of the Gemini hardware, including 2 spacecraft, 2 Gemini Launch Vehicles, 1 Gemini Agena Target Vehicle and 2 Atlas SLV-III will be delivered to the Kennedy Space Center during FY 1967.

Upon completion of the remaining Gemini missions, the United States will have developed a sound operational capability in manned space flight; will have demonstrated a capability for manned flights of at least 14 days' duration; rendezvous; docking and post-docking maneuvers; extravehicular activity; and controlled reentry, all of which are essential to Apollo.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Spacecraft.....	$165,300,000	$107,211,000	$19,100,000
Launch vehicles.....	115,400,000	88,600,000	8,500,000
Support.....	27,700,000	30,800,000	13,000,000
Total.....	$308,400,000	$226,611,000	$40,600,000

Distribution of Program Amount by Installation:

	1965	1966	1967
Manned Spacecraft Center.....	$308,050,000	$226,211,000	$40,300,000
NASA Headquarters.....	350,000	400,000	300,000

BASIS OF FUND REQUIREMENTS:

Spacecraft

	1965	1966	1967
Spacecraft.....	$165,300,000	$107,211,000	$19,100,000

Under the McDonnell contract, major items being provided for the Gemini program include: 12 flight spacecraft; 6 non-flying "boilerplate" spacecraft for use in development and qualification testing of subsystems; 5 static articles, non-flying reentry articles used primarily for various structural, thermal and flotation tests; a complete flight-quality spacecraft for simulated space missions in an environmental chamber (Project Orbit); an electrical systems test unit for integrated testing of engineering models of electrical and electronic equipment; a compatibility test unit (a non-flying spacecraft configured for checking flight-qualified models of all subsystems for operation and compatibility with the ground equipment before the all-systems test flight); 2 mission simulators; 1 translation and docking trainer; systems trainers; target vehicle docking adapters; and specialized ground equipment, test hardware, and spares. With the exception of the flight spacecraft and target docking adapters, delivery of the above items was completed during FY 1965. Seven Gemini spacecraft had completed flight missions by the end

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of calendar year 1965. Three spacecraft have been delivered in FY 1966 and two are scheduled for delivery prior to the end of the fiscal year. The last two spacecraft are well into the production phase at the McDonnell plant in St. Louis, Missouri, in preparation for delivery in FY 1967.

Launch Vehicles

	1965	1966	1967
Launch vehicles.....	$115,400,000	$88,600,000	$8,500,000

Three separate vehicles are required for the Gemini program: the Gemini Launch Vehicle (GLV), the Atlas SLV-III, and the Gemini Agena Target Vehicle. The GLV, which places the spacecraft in orbit, is an Air Force Titan II intercontinental ballistic missile which has been modified for manned flight. The modifications include incorporation of redundant electrical power supply and flight control systems, a malfunction detection system to warn the astronauts of a failure requiring abort, and replacement of the Titan II inertial guidance system with the radio guidance system used successfully in Mercury. The Atlas SLV-III which places the Gemini Agena Target Vehicle in orbit, is an Air Force Standard Atlas Launch Vehicle. The Gemini Agena Target Vehicle is an Agena-D modified to provide (1) additional maneuverability in orbit; (2) command communications compatible with the spacecraft and ground station network; and (3) a docking mechanism. The modifications include changes to the electrical power supply, telemetry, spacecraft command subsystems, and the propulsion system. To facilitate rendezvous maneuvers, the main engine was modified to provide a five-time restart capability while in orbit. A secondary propulsion system was added to provide for smaller velocity changes and propellant orientation for main engine start. All three vehicles are procured for the Gemini program under the direction of the Manned Spacecraft Center through the Space Systems Division (SSD) of the Air Force Systems Command. SSD is procuring the GLV under five major contracts; Martin-Marietta is the contractor for the vehicle; Aerojet supplies the engines; General Electric produces the guidance system; Burroughs fabricates the computer; and Aerospace Corporation is responsible for systems engineering. For the Atlas SLV-III and the GATV the Space Systems Division of the Air Force has principle contracts with General Dynamics/Convair Division and Lockheed Missiles and Space Company, respectively.

To support the planned missions of the Gemini program, 12 Gemini Launch Vehicles and 6 Atlas/Agena vehicles are required. FY 1965 and prior year funds provided for the development and qualification tests prescribed for components and subsystems of the GLV peculiar to Gemini, as well as delivery and checkout of 6 flight vehicles. FY 1966 funds provide for delivery of 4 additional GLV while the FY 1967 funding covers delivery of the final 2 GLV.

One Atlas was delivered in December 1964 to validate and check out Launch Complex 14. This vehicle was utilized on the Gemini VI mission. FY 1966 funds provide for delivery and checkout of 3 Atlas vehicles during FY 1966 and delivery and checkout of the last 2 during FY 1967.

One Gemini Agena Target Vehicle was lost in an unsuccessful orbit insertion attempt in October 1965. Four additional GATV will be delivered in FY 1966 and one is scheduled for delivery in FY 1967.

Support

	1965	1966	1967
Support.....	$27,700,000	$30,800,000	$13,000,000

The manned missions planned in FY 1966 and FY 1967 place heavy emphasis on crew operations, flight operations, and spacecraft and launch vehicle support.

Crew operations funds provide for three types of effort: (1) astronaut training, (2) mission simulators, and (3) specialized in-flight devices:

Astronaut Training - Gemini astronaut training includes academic instruction; water, jungle, and desert survival; zero-gravity indoctrination; and flight in high-performance jet aircraft.

Mission Simulators - Each primary and backup flight crew member receives at least 125 hours of simulator training before a mission. The simulators are modified prior to each mission to update the configuration and procedures for that specific mission.

Specialized in-flight devices, such as camera mounts, sextants, timers, tools, and exercising equipment, are also being developed and procured. These items are required for performing experiments and carrying out flight plans.

Spacecraft and Launch Vehicle Support funds provide for procurement and qualification testing of components and subsystems, including life support systems and extravehicular equipment.

In the area of space medicine and life support, development and qualification of the light-weight pressure suit has been completed. This suit was worn by both astronauts during the 14-day Gemini VII mission. Development of the Extravehicular Life Support System chest pack for future mission extravehicular activity was also completed in FY 1966.

Astronauts will perform in-flight experiments during all FY 1966 and FY 1967 Gemini missions. Medical experiments will provide data on psychological and physiological reactions to the space environment and the astronauts' ability to perform operational tasks during space flight. Engineering experiments performed during FY 1966 will measure the space radiation environment just outside the orbiting spacecraft and measure the direction and amplitude of the Earth's magnetic field relative to the spacecraft. Scientific experiments will provide data in a number of fields, including the effects of weightlessness on cell tissue and the nature of interplanetary dust. In addition to these experiments, NASA is conducting for DOD technological experiments which will evaluate the astronauts' ability to observe objects on Earth and in outer space and to navigate their spacecraft during periods in which there is little ground control.

Flight operations activities cover three main areas: (1) mission planning, (2) flight control, and (3) recovery.

Mission planning entails organizing and coordinating the group activities necessary to conduct manned missions successfully. Included are network tracking and data handling, trajectory design and analysis, and real-time computer program design and implementation.

Flight control to support the FY 1966 and FY 1967 missions is essentially the management of heterogeneous groups responsible for vehicle and life systems, vehicle dynamics, crew safety, network operations required to support manned space flight, and mission control.

Recovery activities for the manned missions are concerned with reentry and recovery of astronauts and spacecraft. Primary and secondary recovery areas are assigned for each mission; however, unforeseen circumstances may require a recovery anywhere along the flight path. Therefore, ships, aircraft, and para-rescue teams are required for contingency recovery areas.

Recovery support is provided most effectively and economically by agencies of the Department of Defense (DOD). To conduct these operations, DOD provides ships, aircraft, and men to support each recovery. Typical support forces are the same for both rendezvous and long-duration flights; however, costs are higher for long-duration flights, since the recovery forces are on station for longer periods.

Requirements for the DOD recovery support, which is the largest element in the flight operations budget, depend directly on the number of flights scheduled for a given year. Ship and aircraft costs are calculated on the average deployment times and other factors associated with each type of mission. The FY 1966 and FY 1967 funding requirements also take into account the effect of minimal delays in launch operations and re-cycle times.

OFFICE OF MANNED SPACE FLIGHT APOLLO PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The goal of the manned space flight program is to provide a broad national capability for manned space exploration, which will achieve and maintain a position of leadership for the United States. A specific objective in acquiring this capability is to land men on the moon and return them safely to earth within this decade. The Apollo Program will not only meet the specific objective, but will also create a broad base of operational capability in manned space flight and the associated skills and technology; a valuable complex of development, manufacturing, test, and operational facilities; and an experienced Government and industrial team.

To accomplish the objective, the Apollo Program requires the development of a highly reliable spacecraft, capable of supporting three men in space for periods up to two weeks, docking in space, landing on and returning from the lunar surface, and safely re-entering the earth's atmosphere. The program includes three large launch vehicles - the Saturn I, which completed its flight series in July 1965; the Saturn IB; and the Saturn V. The Saturn IB and V are being developed and qualified for manned space flight.

The Apollo Program is divided into unmanned flights, manned earth orbital flights, and manned lunar flights. Unmanned Apollo Saturn IB flights will verify the structural integrity and compatibility of the spacecraft and adapter in relation to the launch vehicle; the satisfactory firing and restarting of the spacecraft engines and the safe recovery of the spacecraft command module; and the capability of the guidance and navigation system to perform re-entry at earth orbital speeds.

Manned earth orbital flights on the Saturn IB will include operations with the command and service modules and the lunar excursion module. The command module will be manned in the long-duration missions lasting up to 14 days. Both crew and equipment will be exposed to the rigors of the space environment. An unmanned lunar excursion module will be remotely controlled and evaluated for the purpose of checking the reliability of its systems and the performance of the descent and ascent engines in the space environment. Rendezvous and docking of the command and service modules with an unmanned lunar excursion module will also be accomplished. Rendezvous, docking, and post-docking maneuvers will be refined and the navigation and guidance system, rendezvous trajectories and ground support network will be validated in subsequent earth orbital flights.

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The Saturn V will be used initially in unmanned earth orbital qualification flights. Unmanned re-entry of the command module at 36,000 feet per second will be demonstrated to qualify the command module heat shield.

Manned earth orbital flights, using the Saturn V launch vehicle, will be conducted with a fully loaded space vehicle to simulate the lunar mission. All phases of crew operations and equipment performance will be validated during these Apollo Saturn V flights. Manned lunar flight is planned before the end of this decade.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Spacecraft.....	$1,009,898,000	$1,170,600,000	$1,200,600,000
Saturn I.....	40,265,000	800,000	---
Saturn IB.....	262,690,000	274,185,000	216,400,000
Saturn V.....	964,924,000	1,177,320,000	1,191,000,000
Engine development.....	166,300,000	134,095,000	111,000,000
Mission support.....	170,542,000	210,385,000	255,200,000
Total.....	$2,614,619,000	$2,967,385,000	$2,974,200,000

Distribution of Program Amount by Installation:

John F. Kennedy Space Center, NASA.....	$55,610,000	$120,509,000	$163,905,000
Manned Spacecraft Center.....	1,100,973,000	1,249,371,000	1,320,500,000
Marshall Space Flight Center.....	1,430,516,000	1,569,135,000	1,461,795,000
Goddard Space Flight Center.....	389,000	425,000	500,000
Ames Research Center..	39,000	230,000	250,000
Langley Research Center.....	1,200,000	700,000	---
Lewis Research Center.	1,160,000	---	---
NASA Headquarters.....	24,087,000	24,515,000	24,750,000
Western Operations Office.....	645,000	2,500,000	2,500,000

BASIS OF FUND REQUIREMENTS:

Spacecraft

	1965	1966	1967
Command and service modules.....	$577,834,000	$615,000,000	$586,900,000
Lunar excursion module....	242,600,000	310,800,000	388,300,000
Guidance and navigation...	81,038,000	115,000,000	90,000,000
Integration, reliability, and checkout.....	24,763,000	34,400,000	38,900,000
Support.....	83,663,000	95,400,000	96,500,000
Total.....	$1,009,898,000	$1,170,600,000	$1,200,600,000

The Apollo spacecraft is composed of three basic units: the command module, which houses the three astronauts and the necessary control systems for in-flight maneuvers, life support, and guidance and navigation; the service module, which contains additional utilities and life support supplies, as well as the primary propulsion system for altering the spacecraft course; and the two-stage lunar excursion module, which is designed to carry two of the three Apollo astronauts down to the moon's surface and back to the command and service modules in lunar orbit.

The spacecraft modules are currently undergoing extensive development and qualification testing on the ground in preparation for Saturn IB and Saturn V flights. Unmanned flights on the Saturn IB will begin in calendar year 1966 and will be followed by manned missions in earth orbit during calendar year 1967. Unmanned flights on the Saturn V launch vehicle will also begin during calendar year 1967 and manned flights are planned for calendar year 1968, leading to a lunar landing mission before the end of the decade.

Command and Service Modules (CSM)

In December 1961, the Space and Information Systems Division of the North American Aviation Corporation was selected as prime contractor to design, develop, and fabricate the command and service modules of the Apollo spacecraft. North American was also assigned responsibility for design and fabrication of the spacecraft launch-vehicle adapter; integration of test, scientific, and other government-furnished equipment into the spacecraft; assembly and test of the spacecraft; and support of spacecraft preparation for flight. In addition to the work of North American as the CSM prime contractor, funding for this activity includes the effort related to the development, procurement, integration and installation of flight experiments and experimental hardware into the CSM.

BASIS OF FUND REQUIREMENTS:

Spacecraft

	1965	1966	1967
Command and service modules.....	$577,834,000	$615,000,000	$586,900,000
Lunar excursion module....	242,600,000	310,800,000	388,300,000
Guidance and navigation...	81,038,000	115,000,000	90,000,000
Integration, reliability, and checkout.....	24,763,000	34,400,000	38,900,000
Support.....	83,663,000	95,400,000	96,500,000
Total.....	$1,009,898,000	$1,170,600,000	$1,200,600,000

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In FY 1965, definition of the detailed design requirements for the Block I and Block II CSM was completed. The Block I configuration is used in the ground test program and initial unmanned and manned flights in earth orbit. The Block II configuration is similar in most respects, but has upgraded subsystems to provide a capability for lunar missions.

Delivery of ground test boilerplate CSM was completed in FY 1965. These boilerplates are used in a comprehensive ground test program, including structural, dynamic, water and land impact, flotation, acoustic, launch escape, and integrated system and subsystem testing. Three boilerplate CSM were used on micrometeoroid experiments flown on Saturn I launch vehicles.

In FY 1966, a heavy ground test program is being conducted, using CSM components and subsystems, boilerplate CSM, and five production-type CSM which are being delivered during the year. Testing is conducted at the contractors' plants, the Manned Spacecraft Center (MSC), the White Sands Test Facility (WSTF), and at other Government installations.

The first Block I flight CSM has been delivered to the John F. Kennedy Space Center (KSC) for an unmanned flight test on a Saturn IB in calendar year 1966. Five additional Block I flight CSM are in various phases of assembly, systems installations, and checkout in preparation for shipment to KSC. These CSM will be used for unmanned and manned flights on Saturn IB and V launch vehicles during 1966 and 1967.

Manufacture of Block II CSM began in 1965 and Block II development tests are underway. Block II CSM will be available in FY 1966 for an intensive ground test program, including structural, environmental, and integrated systems tests. A Block II CSM will undergo manned thermal-vacuum tests at MSC. During the second half of FY 1967, the first Block II flight-CSM will be delivered to KSC for checkout in preparation for flight. Ten additional Block II flight-CSMs will be in the process of assembly, systems installation, and checkout. These Block II flight-CSMs will be used in earth-orbit rendezvous missions on Saturn IB and for lunar mission simulation and lunar missions on Saturn V.

Lunar Excursion Module (LEM)

The Lunar Excursion Module study and design effort was initiated by Grumman Aircraft Engineering Corporation (GAEC) in mid-FY 1963. As with the CSM, funding is included for the effort related to the experiments and related hardware that will be carried in the lunar excursion module. During FY 1964, preliminary designs were established; mock-up reviews were held; and subsystem development was started. Descent engine firings began. By the end of the fiscal year, four heavy-weight propulsion rigs had been delivered for use in the LEM test program.

LEM design was established and frozen following detailed design, review, and examination of a mock-up version at the Grumman plant. Major subsystem development, fabrication, and testing are now underway. Ascent and descent propulsion system tests are in progress at White Sands Test Facility (WSTF) and Arnold Engineering Development Center (AEDC). A LEM test article (LTA) has been delivered to Marshall Space Flight Center (MSFC) for vibration testing with both the Saturn IB and the Saturn V. A second LTA was sent to North American Aviation for structural tests with the LEM/S-IVB stage adapter. Additional LTA, propulsion rigs, and test modules are in manufacture and checkout to meet ground test requirements. Assembly of the first LEM flight article has begun.

In FY 1967, the major portion of the ground development and qualification test program will be completed. LTA will be subjected to structural, thermal-vacuum, and propulsion testing. Ground qualification testing of key systems, including electric power, reaction control, communications, propulsion, landing gear, and environmental control, will be concluded. During FY 1967, the first flight LEM will be completed, delivered to KSC, and tested on a Saturn IB launch vehicle. Ten additional flight LEM will be in manufacturing and checkout. By the end of the fiscal year, two of these LEM will be delivered to KSC in preparation for flight.

Guidance and Navigation (G&N)

The Guidance and Navigation (G&N) System for the Apollo command and service modules and the lunar excursion module was designed by the Massachusetts Institute of Technology and is being built by the A.E. Electronics Division of General Motors and its subcontractors, Raytheon and Kollsman Instrument. Block I G&N systems will be used for ground testing and earth-orbital flights. Ground qualification testing and delivery of flight units will be completed during FY 1966. Flight qualification of the system and its use in manned Apollo Saturn IB flights will occur during FY 1967.

Design and development of a lighter Block II G&N system, which will be used on both the command module and the lunar excursion module for lunar flights, will be completed during FY 1966. In addition, engineering models will undergo extensive ground testing. Three Block II G&N units will be delivered for CSM environmental and qualification testing. G&N systems for initial Apollo Saturn IB flights will also be delivered during FY 1966.

Eight Block II command module and six LEM G&N systems are scheduled for delivery in FY 1967. The intensive ground test program, leading to complete system qualification and demonstration of reliability, will be underway throughout the fiscal year.

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Integration, Reliability, and Checkout

The Automatic Checkout Equipment (ACE) for the Apollo spacecraft is being designed, developed, fabricated, installed, and operated by the General Electric Company. In support of the GE effort, equipment contracts have been negotiated with the Control Data Corporation and Radiation, Inc.

The basic design of ACE ground stations was completed in FY 1964. Five stations became operational during FY 1965; three at North American Aviation; one at the Manned Spacecraft Center (MSC); and one at the Kennedy Space Center (KSC). During FY 1966, three additional stations became operational: two at Grumman and one at KSC. Two more stations will be installed and checked out by the end of this fiscal year. FY 1967 funding provides for completion of two more ACE stations, making a total of twelve; operation of all the stations; and related engineering changes and spare parts to maintain the operational equipment.

In addition to ACE hardware and related support, funding is provided for engineering support to MSC. This support includes spacecraft specification maintenance and review; systems performance analysis; test planning and analysis; reliability and quality assurance; trend analysis of failure reports; critical parameter studies and technical problem analysis; mission planning and analysis; post-flight data processing and analysis documentation; simulation and training; and interface control. As the program progresses, emphasis will shift to support of hardware verification, mission accomplishment, and analysis of flight results. FY 1967 funding continues this effort at a level consistent with the increased rate of hardware deliveries and frequency of Apollo missions.

Support

Apollo spacecraft support funds cover the requirements for test operations and support, including Little Joe II launch vehicles, logistic support, instrumentation, and scientific equipment.

Funds are required to conduct spacecraft development tests at the Manned Spacecraft Center (MSC), the White Sands Test Facility (WSTF), and other government test laboratories, such as the Arnold Engineering Development Center (AEDC). Testing at MSC facilities includes manned and unmanned thermal-vacuum testing in the large environmental chamber, component qualification and reliability testing, and electronic systems compatibility tests. The FY 1967 effort will focus on Block II CSM and LEM qualification testing.

Spacecraft launch escape system tests, using Little Joe II vehicles, were conducted at WSTF during FY 1965 and 1966, and propulsion systems testing is in progress. LEM ascent and descent testing will be emphasized at WSTF during FY 1966 and 1967. The LEM propulsion system and reaction control system will also be tested under simulated space-environment conditions in test cells at AEDC.

Spacecraft support funding also provides for development and procurement of spacesuits and related life support equipment, such as survival equipment, personal hygiene systems, and bioinstrumentation. Major effort in FY 1966 and 1967 relates to development, manufacture, and test of a spacesuit and portable life support system for use on the lunar surface.

Logistic support funding for FY 1967 covers transportation of spacecraft between installations, reimbursement to the Department of Defense for inspection services, and procurement of spacecraft fuels and propellants used at MSC, WSTF, KSC, AEDC, and contractor sites.

Instrumentation and scientific equipment funding for FY 1967 provides for development and procurement of specialized flight research and test instrumentation for spacecraft development flight testing. Typical instrumentation equipment includes signal conditioners, sensors, transducers, telemeters, transmitters, transmitting antennas, and ground support equipment. Scientific equipment includes special cameras, magnetometers, seismographs, and radiation-measuring devices.

Saturn IB

	1965	1966	1967
1st stage (S-IB).....	$74,432,000	$63,450,000	$56,200,000
2nd stage (S-IVB).....	58,936,000	61,340,000	52,600,000
Vehicle instrument unit.....	35,841,000	40,780,000	36,050,000
Ground support equipment.....	40,999,000	24,170,000	7,430,000
H-1 engine procurement.....	11,900,000	9,200,000	4,000,000
J-2 engine procurement.....	11,980,000	14,000,000	7,700,000
Vehicle support.....	28,602,000	61,245,000	52,420,000
Total.....	$262,690,000	$274,185,000	$216,400,000

The two-stage Saturn IB is essentially an uprated version of the highly successful Saturn I, which completed its flight series in July 1965. The Saturn IB provides the capability for earth orbital flights of Apollo spacecraft, and also, in the unmanned flights, serves as a test bed for Saturn V components, including the S-IVB stage which will be the 3rd stage of Saturn V. The 1st stage (S-IB), a modified version of the 1st stage of the Saturn I, is being developed by the Chrysler Corporation. It is powered by an uprated set of eight H-1 engines, produced by the Rocketdyne Division of North American Aviation, and is capable of developing approximately 1.6 million pounds of thrust. The Douglas Aircraft Company is developing the 2nd stage (S-IVB). This stage is similar in basic design to the 2nd stage of the Saturn I, but has increased propellant capacity. In addition, a single J-2 engine, capable of approximately 200,000 pounds of thrust,

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replaces the six RL-10 engines capable of about 90,000 pounds of thrust. The J-2 is produced by Rocketdyne. The Saturn IB payload capability through the first five flight vehicles will be about 35,000 pounds in low-earth orbit. The sixth flight vehicle will have a payload capability of approximately 36,000 pounds and the remaining flight vehicles will have a payload capability of about 38,000 pounds.

The first Saturn IB launch is planned for calendar year 1966. In calendar year 1967, four additional flights are planned which include long-duration manned missions.

1st Stage (S-IB)

Development of this stage was initiated in FY 1963. Fabrication, assembly and checkout of the flight stages is performed by the Chrysler Corporation at the Michoud Assembly Facility, Louisiana. Ground testing is conducted at the Marshall Space Flight Center. During FY 1964 and 1965, assembly of the first six flight stages was in process and static firing of the first flight stage was successfully conducted. Parts qualification testing is scheduled for completion during FY 1966.

Flights of the stage, planned for calendar year 1966, will verify the systems design. The first flight stage was delivered to the Kennedy Space Center (KSC) early in FY 1966. A second flight stage has completed static test. Two more flight stages are scheduled to arrive at KSC by the end of FY 1966, following completion of checkout and static test. Stages five through eleven are in various phases of manufacture, checkout, and static test. In addition, long-lead hardware for the twelfth stage is being procured during FY 1966.

FY 1967 funding provides for completion and delivery to KSC of the fifth through eighth flight stages and completion of manufacturing, checkout and static test on the ninth and tenth. By the end of the fiscal year, the eleventh stage will be undergoing static test and the twelfth stage will be in checkout.

2nd Stage (S-IVB)

Basic development efforts for this stage are funded in the Saturn V project. Procurement and the engineering design effort and modifications required to adapt the stage for use in the Saturn IB project are funded in this portion of the budget. Design of the stage began in FY 1963. During FY 1964 and 1965, fabrication of battleship, dynamic, structural, and facility checkout ground test articles was completed. Ground testing will be essentially completed during FY 1966.

Two flight stages completed static test at the Sacramento Operations Test Facility and were shipped to the Kennedy Space Center. By the end of the fiscal year, the third and fourth flight stages will be at KSC in preparation for launch. The fifth and sixth stages will be through the assembly process. The fifth flight stage will enter static test and the sixth will have completed in-factory checkout prior to static test. Five additional stages will be in various phases of fabrication, assembly, and in-factory checkout.

FY 1967 funding for the S-IVB will support continued production, test, and delivery of flight stages, as well as pre-launch checkout at KSC. The third and fourth stages, delivered to KSC in FY 1966, will be readied for flight. The fifth and sixth flight stages will complete static test and will be shipped to KSC for checkout and launch. The seventh and eighth flight stages will be through manufacturing, checkout, and static test in preparation for delivery to KSC by the end of FY 1967. The remaining flight stages will be in various phases of fabrication, assembly, in-factory checkout, and static test during FY 1967.

Vehicle Instrument Unit

Primary guidance, control, measuring, and telemetry systems are contained in the instrument unit (IU), which is being assembled and tested by International Business Machines Corporation (IBM) in Huntsville, Alabama. The components and configuration of the IU for the Saturn IB are essentially the same as those for the Saturn V. The IU design, established during FY 1965, will be verified during FY 1966 by extensive structural, dynamic and vibration testing. Component qualification is also scheduled for completion during FY 1966. In addition, IU Guidance and Control Laboratories will be established for field support at the Kennedy Space Center. Four Saturn IB flight units will complete manufacture and checkout.

The fifth flight unit will be nearing completion of final assembly and the sixth will be in structural assembly by the end of FY 1966.

FY 1967 funding provides for completion of final assembly, checkout, and shipment of the fifth unit; assembly, checkout and shipment of the sixth, seventh and eighth units; component fabrication and assembly of the ninth unit; initiation of assembly of the tenth unit; and hardware procurement for the last two units.

Ground Support Equipment

The automatic checkout equipment and procedures for the Saturn IB will serve as a test system for the Saturn V. Development of a checkout and

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flight hardware simulator (breadboard) was started in FY 1963 and was followed in FY 1964 by initial procurement of hardware. During FY 1965, engineering development was continued and components testing for automatic checkout and associated ground support equipment was underway. Mechanical support equipment (MSE) and electrical support equipment (ESE) for Launch Complex 34 and Launch Complex 37B are being delivered in FY 1966 in preparation for Saturn IB launches.

FY 1967 funding covers engineering improvements and updating of MSE and ESE. Engineering effort will be provided by the General Electric Company on ESE and the Chrysler Corporation Space Division on MSE.

H-1 Engine Procurement

By the end of FY 1966 a total of 92 engines will have been delivered.

FY 1967 funds cover delivery of 22 engines in FY 1967. Estimates for all fiscal years include the flight hardware as well as spares, support hardware and services, and propellants for acceptance testing.

J-2 Engine Procurement

Fourteen engines will have been delivered by the end of FY 1966 and work will be started on engines to be delivered in FY 1967.

Delivery of six engines is required during FY 1967. Estimates for all fiscal years include spares, support hardware and services, and propellants for acceptance testing.

Vehicle Support

Vehicle support includes funds for studies, services, and equipment common to more than one stage. FY 1967 funding provides for engineering services; reliability tests; fabrication services; transportation; propellants; expendable supplies and equipment; and launch pad refurbishment. This funding also covers contract administration, audit, quality assurance, and inspection services performed by other Government agencies.

Saturn V

	1965	1966	1967
1st stage (S-IC).....	$243,137,000	$227,500,000	$215,600,000
2nd stage (S-II).....	190,192,000	255,800,000	257,700,000
3rd stage (S-IVB).....	130,300,000	162,800,000	160,400,000

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	1965	1966	1967
Vehicle instrument unit....	$74,900,000	$72,500,000	$73,600,000
Ground support equipment...	63,254,000	104,500,000	73,800,000
F-1 engine procurement.....	68,100,000	67,400,000	85,800,000
J-2 engine procurement.....	57,965,000	74,700,000	75,200,000
Vehicle support.....	137,076,000	212,120,000	248,900,000
Total.....	$964,924,000	$1,177,320,000	$1,191,000,000

The Saturn V is composed of three stages and an instrument unit. This launch vehicle is capable of placing a payload of approximately 280,000 pounds into low earth orbit and approximately 95,000 pounds into a translunar trajectory. The Boeing Company/Aerospace Group Division is fabricating the 1st stage (S-IC); North American Aviation, Inc./Space and Information Systems Division, the 2nd stage (S-II); and the Douglas Aircraft Company/Missile and Space Division, the 3rd stage (S-IVB). International Business Machines/ Federal Systems Division is producing the Saturn V instrument unit and North American Aviation, Inc./Rocketdyne Division is manufacturing the F-1 engine, used in the 1st stage, and the J-2 engine, used in both the 2nd and 3rd stages.

FY 1966 represents a period of intensive development ground testing of Saturn V hardware. As an example, the S-IC all-systems stage has successfully passed a number of static test firings at the Marshall Space Flight Center (MSFC). In August 1965, the all-systems ground test stage was fired for full-duration (2½ minutes) at the thrust level of 7.5 million pounds. Heavy emphasis is also being placed on the activation of Saturn V facilities, including the S-IC and S-II acceptance test stands at the Mississippi Test Facility and Launch Complex 39 at the Kennedy Space Center (KSC).

The FY 1967 funding requirements for the Saturn V support a critical period of continued ground testing, both development and qualification, and the first Saturn V launches from Launch Complex 39, KSC. The initial unmanned missions are designed to qualify the vehicle systems under actual flight conditions.

Dynamic testing of the entire Apollo/Saturn V space vehicle, including the three stages, the instrument unit, and the spacecraft, will be carried out at MSFC. Static testing of 1st and 2nd stages will be conducted at the Mississippi Test Facility and 3rd stage testing will be conducted at the Sacramento Test Operations site in preparation for shipment to KSC.

1st Stage (S-IC)

The Marshall Space Flight Center, with Boeing's assistance, will complete manufacture of the structural test components, the first ground test stage

and the first two flight stages at Huntsville, Alabama. Boeing will manufacture two ground test stages and 13 flight stages at the Michoud Assembly Facility, Louisiana.

During FY 1966, ground testing will continue. The two ground test stages to be used for dynamic tests and facilities checkout have been completed by Boeing. Assembly, checkout and acceptance testing of the first two flight stages at Marshall Space Flight Center will be completed. By the end of the fiscal year, a third flight stage will be in checkout at Michoud and the fourth through seventh stages will be in assembly.

In FY 1967, funding will provide for the following activities: preparation for launch of flight stages at the Kennedy Space Center; completion of the structural, dynamic and Launch Complex 39 checkout ground test programs; completion of assembly, checkout, and acceptance tests at MSFC and shipment to Kennedy of the third flight stage; completion of assembly, checkout and acceptance testing at the Mississippi Test Facility of the fourth flight stages; various phases of manufacturing, checkout and test on the fifth through tenth flight stages and hardware procurement for the eleventh through fourteenth flight stages.

2nd Stage (S-II)

In FY 1965, the battleship stage was completed and tests were started. Common bulkhead tests were initiated and fabrication and assembly of the all-systems and facilities checkout ground test stage, as well as the first three flight stages, were in progress. Qualification and reliability tests for stage components were also begun during this period.

FY 1966 activity is marked by an intensive ground test effort. Structural and common bulkhead tests were conducted during the first half of FY 1966. In addition, the all-systems stage was shipped to the Mississippi Test Facility in preparation for facility and propulsion tests. As a result of the structural failure of the S-II dynamics test stage, the all-systems stage will subsequently be shipped to the Marshall Space Flight Center for dynamic testing. The facility checkout stage is scheduled for delivery to KSC for activation of Launch Complex 39. Fabrication and assembly of the first S-II flight stage will be accomplished. The second through seventh flight stages will be in manufacture and checkout, and hardware procurement for the eighth and ninth stages will be initiated.

FY 1967 funding provides for rigorous qualification testing of the S-II; delivery of the first three flight stages to KSC; preparation for launch of two of the stages at KSC; completion of acceptance testing on the fourth flight stage; continuation of fabrication, assembly, and checkout of the

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FY 1967 funding provides for rigorous qualification testing of the S-II; delivery of the first three flight stages to KSC; preparation for launch of two of the stages at KSC; completion of acceptance testing on the fourth flight stage; continuation of fabrication, assembly, and checkout of the

fifth through seventh stages; initiation of fabrication on the eighth through twelfth stages; and initial hardware procurement for the remaining three stages.

3rd Stage (S-IVB)

The 3rd stage of the Saturn V is the S-IVB stage, which is also used on the Saturn IB. The stage used for the Saturn V vehicle has the capability of engine restart to achieve lunar escape velocity. Although used on the Saturn IB, basic development of this stage is funded in the Saturn V project. By the beginning of FY 1965, qualification testing was in progress; assembly of the battleship and structural test stages had been completed; and the structural test program had been initiated. Structural assembly of the all-systems, dynamics, and facilities checkout stages was also under way.

In early FY 1965, the decision was made to modify the ground test program by deleting the all-systems stage requirement and using the hardware as a facility checkout stage. Facility checkout stage hardware was used to meet other requirements, such as the MSFC stage simulator. Ground test stages were completed in time to support the Saturn IB requirements. The battleship hot-firing test program at the Sacramento Test Facility was also initiated, and fabrication of the first two Saturn V flight stages at Huntington Beach, California, was started.

During FY 1966, the battleship testing was completed. Saturn V dynamic testing at the Marshall Space Flight Center with the facility checkout stage is in progress. Post-manufacturing checkout of the first two Saturn V flight stages at Huntington Beach, California, and acceptance testing of the first flight stage at Sacramento will be completed during FY 1966. Fabrication and assembly of the four additional flight stages will also be underway during this period.

FY 1967 funding provides for completion of the ground test program; delivery of the first three flight stages to KSC; completion of fabrication and assembly of the third, fourth, fifth and sixth flight stages; completion of post-manufacturing checkout of the third, fourth and fifth flight stages and acceptance testing of the third and fourth flight stages; initiation of fabrication and assembly on the seventh through eleventh stages; and hardware procurement for the remaining four stages.

Vehicle Instrument Unit

The Saturn V instrument unit is essentially the same as the Saturn IB. The units are assembled and given final checkout at the Huntsville, Alabama facility of International Business Machines Corporation. Extensive testing; structural, dynamic, environmental and vibration, is being conducted during FY 1966.

During FY 1967, Saturn V instrument unit manufacturing (fabrication, assembly, and checkout) operations will be in full swing. Four units will be delivered to KSC. In addition three more units will be in process of manufacture.

Ground Support Equipment

The General Electric Company is under contract for design, fabrication, checkout, and logistic support of the Saturn V electrical support equipment (ESE). The Boeing Company is contractor for a Saturn V equipment management system which provides a master record for all vehicle ground support equipment. Boeing is also responsible for the integration and logistic support of all mechanical support equipment. The Radio Corporation of America is providing the computer systems and Sanders Associates the display systems for use at Launch Complex 39.

Fiscal years 1964 and 1965 funds were used for design and initiation of long lead-time procurement of mechanical and electrical checkout equipment for use at Launch Complex 39. In addition, installation and testing of an electrical checkout equipment and flight hardware simulator (breadboard) at Marshall Space Flight Center was in progress. Funds were also used to develop and procure special test equipment and components, such as hardware for the umbilical/swing arm test facility.

During FY 1966, the Saturn V breadboard at MSFC is being completed (installation and checkout of the equipment) and is being used to test and develop operating procedures for the electrical ground support equipment. By the end of the fiscal year delivery, installation and checkout of the Saturn V GSE for use on the first launch umbilical tower, the first high-bay and the low-bay of the vehicle assembly building, the first firing room of the launch control center, the first launch pad and the necessary support areas will be nearly complete in preparation for the first Saturn V launch. Delivery and installation of Apollo Saturn V - peculiar equipment for the second launch umbilical tower, high-bay areas, firing room and launch pad will be well along. FY 1966 funds will also be used for logistic support of certain ground equipment.

FY 1967 funding provides for completion of installation and checkout of equipment in these areas and for delivery and start of installation of equipment in a third launch umbilical tower, high-bay and firing room. In addition, FY 1967 funding will cover engineering improvements, updating and necessary changes and improvements to the mechanical and electrical support equipment, and continuation of logistic support.

F-1 Engine Procurement

By the end of FY 1966 a total of 38 engines will have been delivered. FY 1966 funding also covers hardware procurement for deliveries in FY 1967.

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F-1 Engine Procurement

By the end of FY 1966 a total of 38 engines will have been delivered. FY 1966 funding also covers hardware procurement for deliveries in FY 1967.

FY 1967 estimates provide for delivery of 24 engines and procurement of additional long-lead hardware. These funds also cover procurement of spares, support hardware, services, and propellants for acceptance testing of the engines scheduled for delivery.

J-2 Engine Procurement

By the end of FY 1966 a total of 56 engines will have been delivered. FY 1966 funding also covers hardware procurement for deliveries in FY 1967. Funding in FY 1967 will provide delivery of 37 J-2 engines and the procurement of long-lead hardware. Funds in all fiscal years cover spares, support hardware, support services, and propellants for engine acceptance testing.

Vehicle Support

Vehicle support funds are required to provide services and equipment that are common to more than one stage of the vehicle. Fiscal years 1965 and 1966 funding included instrumentation, recording and data reduction equipment for the Saturn V dynamic test stand at Marshall Space Flight Center; transportation costs which include use of marine vessels and aircraft for movement of stages, engines and components; activation and operation of the Mississippi Test Facility; operation of the Slidell Facility; range safety and tracking devices; propellants; systems integration; and computation services, engineering services, quality control and inspection, contract administration, audit and property administration services by other government agencies. In FY 1966 and 1967 initiation of S-II testing at the Mississippi Test Facility (MTF) will require increased plant and technical support activities at that location. Funding also includes propellants used in testing the stages.

During FY 1967, acceptance testing of S-II stages will continue at MTF and S-IC testing will begin. This activity will increase plant and support and propellant requirements.

In addition, dynamic testing at MSFC will be in progress during FY 1967. Systems integration will continue at essentially the FY 1966 level to insure proper interface control of all stages, systems, and structures. Reliability and flight evaluation programs will also be funded during FY 1967.

Engine Development

	1965	1966	1967
H-1 engine.....	$6,550,000	$6,450,000	$5,500,000
RL-10 engine.....	14,470,000	1,900,000	---
F-1 engine.....	62,396,000	41,290,000	41,000,000
J-2 engine.....	49,102,000	41,750,000	37,900,000
Propellants and related engine support.....	33,782,000	42,705,000	26,600,000
Total.....	$166,300,000	$134,095,000	$111,000,000

Funds in this project provide for the development of engines to be used for Saturn launch vehicles. Procurement of the flight engines is funded under the appropriate launch vehicle project.

H-1 Engine

The H-1 engine, which is being developed by the Rocketdyne Division of North American Aviation, Inc., is used in clusters of eight per stage to propel the first stage of the Saturn IB vehicle. This engine uses liquid oxygen and RP-1 (kerosene) as propellants.

Development of the H-1 engine was initiated by the Department of Defense in September 1958 as a 165,000 pound thrust improved version of the Thor-Jupiter engine. The responsibility for development of the engine was transferred to NASA in 1960. The 165,000 pound thrust engine was used successfully in the first four Saturn I launches and a 188,000 pound thrust version of the engine was used on the remaining six launches of the Saturn I. A 200,000 pound thrust version has been developed and will be used on the first five Saturn IBs. A 205,000 pound thrust version will be used on subsequent Saturn IBs.

In FY 1966, the development program consists of testing, flight evaluation, and production and launch support. This effort includes engineering capability for design and development; ground test capability and retrieval, evaluation, and reporting of Saturn IB flight data. Efforts are also being devoted to calibrating and determining the reliability of the H-1 engine at the 205,000 pound thrust level for the sixth and subsequent Saturn IB flights.

The FY 1967 funding will provide for field support, including the static tests required for quick-response to problems. This effort includes component and engine system testing to supplement problem analysis for the engine and ground support equipment. The flight-worthiness of the engine for manned missions will also be verified periodically. In addition, the FY 1967 funding provides for maintaining the test engines in a configuration appropriate for solution of problems that are encountered. Updating and improvement of procedures and evaluation of static test and flight data will also be accomplished.

F-1 Engine

The F-1 engine is being developed by the Rocketdyne Division of North American Aviation at Canoga Park, California. The F-1 will be used in a cluster of five engines in the 1st stage of the Saturn V. Each engine is capable of producing 1,500,000 pounds of thrust, using liquid oxygen (LOX) and kerosene (RP-1) as propellants.

Development of the F-1 engine began in January 1959 when a contract was awarded to Rocketdyne for development, through preliminary flight rating tests (PFRT) of a LOX/RP-1 rocket engine. Test firing of the F-1 engine was accomplished in June 1961. Since that time, F-1 engines have achieved rated thrust and duration (150 seconds) runs well over 400 times. The final release of the design of the flight rating test engine was made in the first quarter of FY 1964, and testing was completed in the second quarter of FY 1965. A comprehensive qualification test series was begun to qualify the engine for manned flight and is scheduled to be completed in the second quarter of FY 1967.

During FY 1966 and FY 1967, about 700 separate engine system ground tests will be performed. These tests are part of the approximately 1,600 planned engine system tests that will be performed as part of the development effort to reach required maturity before qualification of the engine for manned flight. Major efforts for FY 1967 include: component qualification; demonstration of recovery from induced combustion instability; high specific-impulse performance and qualification tests operation and engineering support for static and flight testing; and design and operational simplification to improve engine-system flexibility. To maintain this extensive testing effort in FY 1967, five new engines will be built; eight rebuilt; and the equivalent of 2-1/2 engines in test components produced.

J-2 Engine

The J-2 engine is being developed by the Rocketdyne Division of North American Aviation at Canoga Park, California, for use in upper stages of the Saturn IB and Saturn V vehicles. This engine, using liquid hydrogen and liquid oxygen as propellants, is designed to develop 200,000 to 205,000 pounds of thrust. In the Saturn IB vehicle, one J-2 engine will be used in the 2nd stage (S-IVB). In the Saturn V, a cluster of five J-2 engines will be used in the 2nd stage (S-II) and one J-2 engine will be used in the 3rd stage (S-IVB).

Development of the J-2 engine began in September 1960 with the award of the development contract to Rocketdyne. In October 1962, the engine achieved its first full thrust (250 second duration) run. The first 500-second duration run, necessary to meet the requirements of the Saturn IB and V, was successfully conducted in November 1963. Other accomplishments during FY 1964 included demonstration of gimbal capability, nominal performance, propellant utilization system, and the first PFRT-type engine test.

During FY 1965, 465 ground tests were performed for a cumulative duration of 44,152 seconds. During the same period, nine new engines were built and 31 engines were rebuilt or overhauled. Accomplishments included completion of PFRT, demonstration of engine-vehicle interface, demonstration

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of reliability, and demonstration of maximum mixture ratio capability. In FY 1966, 790 ground tests for an approximate duration of 80,000 seconds are planned. Ten new engines will be built and 33 rebuilt or overhauled. The flight rating tests were completed early in the fiscal year. Testing for qualification of the 200,000 pound thrust engine will be completed in the second quarter of the fiscal year. The engine will make its initial flight on a Saturn IB in FY 1966.

In FY 1967, 700 ground tests for an approximate run-time of 70,000 seconds will be performed. Eight new engines will be built and 25 rebuilt or over hauled. Qualification of a 205,000 pound thrust engine will be completed in mid-fiscal year.

Propellants and Related Engine Support

Propellants and ancillary chemicals required for the contractor test efforts are procured and provided as government-furnished material. The primary products used are liquid oxygen, liquid hydrogen, kerosene, liquid nitrogen, and gaseous helium. NASA procures propellants from both private producers and from the Air Force under a NASA/DOD support agreement.

The FY 1967 engine development tests will require approximately 180,000 tons of liquid oxygen, 7,000 tons of liquid hydrogen, 14 million gallons of kerosene, 37,000 tons of liquid nitrogen, and 44 million cubic feet of helium. Funds in FY 1967 will also provide for services and equipment associated with contractor effort; and contract administration, audit, property administration, and quality and inspection services provided by government agencies.

Mission Support

	1965	1966	1967
Operations.....	$96,717,000	$104,180,000	$154,405,000
Systems engineering.....	19,925,000	26,000,000	26,000,000
Supporting development.....	53,900,000	32,205,000	32,895,000
Apollo applications.....	---	48,000,000	41,900,000
Total.....	$170,542,000	$210,385,000	$255,200,000

Mission support provides for the over-all launch, flight, crew, and recovery operations; program-wide systems engineering; supporting development necessary for the successful accomplishment of manned space flights; and project definition experiment development, and maintenance of hardware production capability for Apollo applications.

Operations

Operations include the activation and operation of pre-flight and launching facilities, mission control, flight crew training and actual flight operations, including recovery. As the frequency of Apollo flights increases, more effort, materials, and supplies are required to support the operational phase of the program.

FY 1966 funds are providing for the following activities: activation of the launch operations and instrumentation facilities, and pre-flight activities required at the John F. Kennedy Space Center (KSC) in support of the initial Apollo Saturn IB missions; support of KSC contractor services, including major items of equipment for these contractors, and reimbursement to the Air Force; the mission control efforts for Apollo Saturn IB missions; continued support of astronaut training and flight crew requirements; operation and updating of mission simulators and trainers; mission planning and analysis; contractor support in the development of real-time computer programs for flight missions and flight monitoring; test evaluation and procurement of retrieval and location equipment; remote-site operations; and reimbursement to the Department of Defense for recovery support forces.

The FY 1967 funding provides for the increased operational services required to support Apollo Saturn IB manned flights and the initial Saturn V missions. The requirements also cover the improvements necessary for, as well as the increased cost of operating the Mission Control Center at Houston, which will be supporting Apollo Saturn IB and Saturn V flights. The funding also provides for the procurement and operation of three lunar landing training vehicles for use by the astronauts.

Systems Engineering

Systems engineering provides for integrated technical support, review, and analysis of manned space flight missions. These services include the development of functional and performance standards for the program, consistent with mission objectives; mission planning; test objectives and integration; program and systems specifications; trajectory analysis; checkout effectiveness; and technical documentation. Bellcomm and General Electric are the principal systems engineering contractors.

During FY 1967, greater emphasis will be placed on a quick-response capability for validation and analysis of flight data on a time scale compatible with the increased frequency of Apollo missions. The FY 1967 funding also covers contract administration and related services of the Department of Defense, as well as non-recurring maintenance and rehabilitation of government-owned industrial plants.

Supporting Development

Supporting development involves individually selected engineering efforts which support the Apollo Program and have potential use in advanced manned missions. Individual tasks are initiated in support of the on-going projects and provide for the development of backup or improved hardware or manufacturing, test, and evaluation techniques when a potential problem is identified. The objective is improved performance, improved confidence, and reduced cost. In addition to providing backups which could be substituted for their mainstream counterparts, supporting development also provides for the development of long-lead systems for potential use in the future. The character of the work varies with each task, depending on the state of development of the hardware or technique, and is strongly influenced by the nature of the mainstream difficulty. In some cases, the potential problem may be best overcome by developing new hardware or techniques; and in other cases by modification of the mainstream approaches through better definition of specifications.

Each task is planned so that the backup can be available for incorporation into the mainstream projects on a schedule compatible with development and operational milestones. Work initiated during previous years is resulting in delivery of developed hardware during FY 1966. For example, a mechanical damping device has been fabricated to control combustion instability; a TV camera has been qualified for use on the lunar surface; and design information is available for any potential desired increase in spacecraft shielding. During the last few months, development was started on a basic small-thrust engine that can be used, with minor variations, on the Apollo spacecraft and the upper stage of both the Saturn IB and Saturn V. This versatility will permit an optimum production rate for the basic engine, which will lower unit costs and increase reliability. During FY 1967, work in support of Apollo will be largely concerned with backup hardware, including the small-thrust engine, with the performance potential for desired Apollo mission objectives. The major portion of the funds will be used to complete the development of Apollo-type hardware which can replace mainstream counterparts with minimum disruption. For example, coating material for both heat protection and temperature control will be qualified; antenna performance will be demonstrated in preparation for production hardware; and astronaut equipment, such as a portable tape recorder, will be qualified for use on the lunar surface.

Apollo Applications

In FY 1967, no new manned programs are planned for initiation. However, planning is directed toward maximum utilization of the inherent capabilities of the current Apollo Saturn space vehicles, facilities, and government-industrial teams.

The FY 1966 applications effort is devoted to continued project definition. This effort provides the detailed planning options necessary for conducting

applications missions beginning as early as mid-1968, if early success in the Apollo program makes this possible. FY 1966 funding is providing for definition of payloads, space vehicle modifications, detailed mission and support plans, and payload integration.

Apollo applications missions are being planned to permit extended lunar exploration and long-duration earth orbital operations--both low-altitude and synchronous. Early applications missions would utilize the basic Apollo Saturn space vehicle configuration, while later missions would incorporate the subsystem modifications essential to refined mission requirements. The planning for exploitation of this capability is based on the principle of holding open as many options as feasible until the Nation is in a position to select the next major space effort.

To hold these planning options open, FY 1967 funding maintains the continuity of the production capability of the basic Apollo spacecraft and Saturn launch vehicles and continues project definition and payload development.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1967 ESTIMATES

OFFICE OF MANNED SPACE FLIGHT — ADVANCED MISSIONS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objective of the Advanced Missions program is to examine advanced manned space flight mission concepts. Included are: logical extensions of the national space capability through analysis of present hardware systems for growth potential; development of requirements for future systems; provision of guidance for research and technology activities; provision of technical information and cost data upon which future program decisions can be based; and initiation of the definition, preliminary design and specification of probable future missions.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Advanced missions studies.....	$26,000,000	$10,000,000	$8,000,000
Total.....	$26,000,000	$10,000,000	$8,000,000

Distribution of Program Amount by Installation:

John F. Kennedy Space Center, NASA.....	$500,000	$600,000	$600,000
Manned Spacecraft Center.....	9,625,000	3,600,000	2,600,000
Marshall Space Flight Center..	5,473,000	5,500,000	4,500,000
Langley Research Center.....	1,200,000	---	---
NASA Headquarters.....	8,930,000	300,000	300,000
Western Operations Office.....	272,000	---	---

BASIS OF FUND REQUIREMENTS:

Advanced Missions Studies

	1965	1966	1967
Advanced studies.....	$26,000,000	$10,000,000	$8,000,000

Advanced studies provide the basis for the planning and selection of future manned space flight missions. Specific areas of investigation include manned earth orbital, lunar, and planetary missions. FY 1965 studies concentrated

on the uses of Apollo-developed hardware in extending manned exploration of the moon and near-earth environment and led to the pre-development effort now underway for Apollo applications. During FY 1965, no funds were allocated for planetary studies and only a modest number of studies beyond Apollo applications were implemented in the earth orbital, lunar, and supporting vehicle systems areas.

During FY 1966, advanced studies are continuing to stress potential activities in the earth orbital and lunar exploration areas and include planning studies in the planetary/interplanetary category. Completed manned earth orbital mission studies have confirmed the feasibility of earth orbiting space stations. Alternate configurations, which make maximum use of current, as well as basically new, spacecraft configurations, have been examined. Additional studies of candidate scientific and technological experiments for the space stations are also being conducted.

The FY 1967 effort will be directed toward preliminary systems definition of the more promising space station concepts. Configurations under review include a long-term station not requiring resupply, using the present family of subsystems and launched with a Saturn V, and an optimized space station capable of supporting planetary flight. Preliminary systems definition will also be conducted on a ferry/logistic system for use with these concepts. Particular attention will be given to the description and definition of experiment modules which can be used in conjunction with the various space station concepts and which can be operated by the crew of the space station. In addition, efforts will continue on the selection and description of candidate experiments for advanced missions, and the constraints of these experiments on the space station and the logistic system will be assessed. The ultimate growth capability of such a space station into a planetary mission module will be considered and a new and larger spacecraft with inherently greater experimental man-hour capabilities will be studied.

Manned lunar mission studies are directed toward identifying and defining the most effective exploration systems. Included are studies of both improved Apollo-type and direct flight systems, alternate shelter and mobility concepts, and definition of orbital and surface experiments.

The FY 1967 effort will emphasize the definition of an extended lunar exploration plan and the accompanying conceptual designs. The results of comparative evaluations of shelter and mobility concepts, as well as various modes of payload delivery to the lunar surface, will be combined with the recommendations of the scientific community to formulate a comprehensive lunar exploration effort. This work will provide the basis for decisions concerning the initiation of program definition for an advanced lunar exploration system.

Manned planetary mission studies have established the feasibility of a number of mission modes and system concepts for Mars and Venus flybys and

Mars landing missions. Although the flyby missions may be considered within the reach of Apollo-based technology, it appears that effective accomplishment of the Mars landing mission will require improved levels of technology. The complexity of the missions and the extensive resources required for such undertakings require detailed analysis of the various options before a program is initiated.

FY 1967 planetary mission studies will provide more detailed analysis of system feasibility, system concepts, and technological requirements. Major emphasis will be placed on manned planetary spacecraft concepts that can be applied to the broadest range of missions and launch dates. The studies recognize the requirement for unmanned programs to provide the scientific and engineering data essential for the design of future manned systems. Studies of objectives, schedules, and costs will be necessary so that the most promising system concepts can be identified for detailed engineering design.

Launch vehicle studies to support earth orbital, lunar, and planetary manned missions will also be conducted during FY 1967. These studies will stress preparation for systems definition of improved Saturn vehicles, as well as reusable transport concepts. The related requirements for operational and support facilities will also be studied.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1967 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS — PHYSICS AND ASTRONOMY PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objective of the Physics and Astronomy program is to increase our knowledge of the space environment of the earth, the sun and its relationship to the earth and the interplanetary medium, and the fundamental physical nature of the universe. In order to achieve this objective, research programs have been undertaken to intensively study the upper atmosphere, the ionosphere, the earth's magnetosphere, the region beyond the boundaries of the magnetosphere, solar radiation and the solar wind and their interactions with these regions, cosmic rays from beyond the solar system, radiation from stars and other celestial bodies in areas of the spectrum which cannot be observed from the earth's surface, and the geodetic figure of the earth.

While the objective of the program has been divided into three major areas, they are by no means independent of each other. Knowledge gained in one area contributes to the understanding of the others. Many studies contribute directly to knowledge in all three areas. The practical applications of the knowledge gained in this program can be clearly demonstrated in terms of support for other national programs such as meteorology, communications, manned space flight, and cartography. However, the program is primarily intended to be a basic research program dedicated to the expansion of human knowledge. As such, it is integrated with the programs of educational and scientific research institutions throughout the United States and in many foreign countries. Substantial efforts are made to insure that the results of the research are made generally available on a basis that will make the knowledge most useful to facilitate future advancements in technology, scientific research, and education.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Supporting research and technology/Advanced studies..	$21,057,000	$23,800,000	$22,900,000
Solar observatories.....	16,597,000	24,500,000	11,900,000
Astronomical observatories.....	32,644,000	24,600,000	29,200,000
Geophysical observatories.....	30,352,000	28,600,000	23,400,000
Explorers.....	21,565,000	21,400,000	23,000,000
Sounding rockets.....	16,867,000	18,500,000	19,000,000
Data analysis.....	---	2,100,000	2,000,000
Total.....	$139,082,000	$143,500,000	$131,400,000

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Distribution of Program Amount by Installation:

	1965	1966	1967
Marshall Space Flight Center..	$755,000	$62,000	$25,000
Goddard Space Flight Center...	110,244,000	108,498,000	100,961,000
Jet Propulsion Laboratory.....	334,000	452,000	500,000
Wallops Station.....	1,090,000	2,550,000	3,400,000
Ames Research Center.....	1,557,000	2,586,000	2,563,000
Flight Research Center.....	10,000	5,000	15,000
Langley Research Center.....	2,226,000	2,272,000	1,100,000
NASA Headquarters.....	22,866,000	27,075,000	22,836,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology/Advanced Studies

	1965	1966	1967
Particles and fields.....	$6,714,000	$6,900,000	$6,900,000
Ionospheres and radio physics...	988,000	1,300,000	1,300,000
Interplanetary dust and cometary physics.....	833,000	1,200,000	1,200,000
Solar physics.....	2,382,000	2,800,000	2,800,000
Astronomy and geodesy.....	2,926,000	3,300,000	3,300,000
Spacecraft technology.....	300,000	350,000	350,000
Interdisciplinary space science.	2,179,000	2,850,000	2,850,000
Advanced studies.....	450,000	1,200,000	1,000,000
Manned space science.....	4,285,000	3,900,000	3,200,000
Total.....	$21,057,000	$23,800,000	$22,900,000

The objectives of the Supporting Research and Technology program are to provide a sound theoretical base for the flight programs; to initiate development of instrumentation for future experiments; to provide laboratory data as a basis for evaluation of flight data; to conduct ground based balloon and aircraft observations for correlation with flight program results; and to provide scientific experiments and scientific support for the manned space flight program.

Particles and Fields

Work in this area concerns the development of new instruments for measuring the direction, magnitude and time variations of magnetic fields and for measuring the energy, direction and mass of charged particles. It also consists of theoretical research and ground and balloon-borne observations which will aid in the interpretation of space measurements.

OFFICE OF SPACE SCIENCE AND APPLICATIONS — PHYSICS AND ASTRONOMY PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objective of the Physics and Astronomy program is to increase our knowledge of the space environment of the earth, the sun and its relationship to the earth and the interplanetary medium, and the fundamental physical nature of the universe. In order to achieve this objective, research programs have been undertaken to intensively study the upper atmosphere, the ionosphere, the earth's magnetosphere, the region beyond the boundaries of the magnetosphere, solar radiation and the solar wind and their interactions with these regions, cosmic rays from beyond the solar system, radiation from stars and other celestial bodies in areas of the spectrum which cannot be observed from the earth's surface, and the geodetic figure of the earth.

While the objective of the program has been divided into three major areas, they are by no means independent of each other. Knowledge gained in one area contributes to the understanding of the others. Many studies contribute directly to knowledge in all three areas. The practical applications of the knowledge gained in this program can be clearly demonstrated in terms of support for other national programs such as meteorology, communications, manned space flight, and cartography. However, the program is primarily intended to be a basic research program dedicated to the expansion of human knowledge. As such, it is integrated with the programs of educational and scientific research institutions throughout the United States and in many foreign countries. Substantial efforts are made to insure that the results of the research are made generally available on a basis that will make the knowledge most useful to facilitate future advancements in technology, scientific research, and education.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Supporting research and technology/Advanced studies..	$21,057,000	$23,800,000	$22,900,000
Solar observatories.....	16,597,000	24,500,000	11,900,000
Astronomical observatories.....	32,644,000	24,600,000	29,200,000
Geophysical observatories.....	30,352,000	28,600,000	23,400,000
Explorers.....	21,565,000	21,400,000	23,000,000
Sounding rockets.....	16,867,000	18,500,000	19,000,000
Data analysis.....	---	2,100,000	2,000,000
Total.....	$139,082,000	$143,500,000	$131,400,000

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Distribution of Program Amount by Installation:

	1965	1966	1967
Marshall Space Flight Center..	$755,000	$62,000	$25,000
Goddard Space Flight Center...	110,244,000	108,498,000	100,961,000
Jet Propulsion Laboratory.....	334,000	452,000	500,000
Wallops Station.....	1,090,000	2,550,000	3,400,000
Ames Research Center.....	1,557,000	2,586,000	2,563,000
Flight Research Center.....	10,000	5,000	15,000
Langley Research Center.....	2,226,000	2,272,000	1,100,000
NASA Headquarters.....	22,866,000	27,075,000	22,836,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology/Advanced Studies

	1965	1966	1967
Particles and fields.....	$6,714,000	$6,900,000	$6,900,000
Ionospheres and radio physics...	988,000	1,300,000	1,300,000
Interplanetary dust and cometary physics.....	833,000	1,200,000	1,200,000
Solar physics.....	2,382,000	2,800,000	2,800,000
Astronomy and geodesy.....	2,926,000	3,300,000	3,300,000
Spacecraft technology.....	300,000	350,000	350,000
Interdisciplinary space science.	2,179,000	2,850,000	2,850,000
Advanced studies.....	450,000	1,200,000	1,000,000
Manned space science.....	4,285,000	3,900,000	3,200,000
Total.....	$21,057,000	$23,800,000	$22,900,000

The objectives of the Supporting Research and Technology program are to provide a sound theoretical base for the flight programs; to initiate development of instrumentation for future experiments; to provide laboratory data as a basis for evaluation of flight data; to conduct ground based balloon and aircraft observations for correlation with flight program results; and to provide scientific experiments and scientific support for the manned space flight program.

Particles and Fields

Work in this area concerns the development of new instruments for measuring the direction, magnitude and time variations of magnetic fields and for measuring the energy, direction and mass of charged particles. It also consists of theoretical research and ground and balloon-borne observations which will aid in the interpretation of space measurements.

leadtimes to meet a variety of scientific mission objectives, as well as for specialized explorers to conduct experiments requiring unique spacecraft designs. Also included are studies aimed at defining the role of man in astronomical observations from space and in defining systems concepts for carrying out these observations.

Interplanetary mission studies include the development of a concept and preliminary design of a Galactic Pioneer capable of extending interplanetary exploration out beyond the orbit of the planet Jupiter. Also included are studies leading to the development of small probes capable of transmitting signals and a limited amount of data back to earth from distances as close as 0.4 AU to the sun. Studies of scientific payloads for these small probes include solar corona studies, interplanetary plasma studies, and comet simulation studies.

Manned Space Science

Manned Space Science includes the planning, design and development of scientific investigations; procedures and equipment for manned orbital space experiments, analysis of data collected from these experiments; and supporting activities including the selected scientific training of astronauts. Studies in the fields of solar physics, ionospheres, astronomy, relativity, gravity, and interplanetary particles and fields are among the scientific investigations being developed for Gemini and Apollo missions.

Applied research on the space environment is undertaken to meet specific needs for information on space phenomena in the design and development of safe and reliable manned space flight systems. Environmental data is supplied for the Apollo program, including information regarding solar flares and the resulting solar proton radiation, other space radiation, meteoroids, and micrometeoroids. Theoretical and laboratory studies are conducted to evaluate the potential hazard which these space phenomena may present to manned space flight. Fiscal year 1967 funds will be utilized to continue work begun in prior years.

Solar Observatories

	1965	1966	1967
Orbiting Solar Observatory (OSO):			
Spacecraft	$4,814,000	$6,013,000	$6,800,000
Experiments	4,383,000	3,687,000	5,100,000
Subtotal OSO	$9,197,000	$9,700,000	$11,900,000

Ionospheres and Radio Physics

Ionospheres and radio physics involves ground-based observations, theoretical studies and instrument development relating to the ionized regions of the atmospheres of the earth and other planets and of interplanetary space.

Interplanetary Dust and Cometary Physics

Interplanetary dust and cometary physics involves the study of extraterrestrial particulate matter; its behavior, structure, composition, and origins; and its significance in providing information on the physical properties of the solar system and the galaxy.

Solar Physics

Solar physics involves ground, aircraft, and balloon-borne observations; theoretical studies; and instrumentation development related to orbital observations of the sun.

Astronomy and Geodesy

Astronomical research and technology efforts include theoretical studies of stellar astrophysics; laboratory spectroscopy; research on optical materials; advanced development of instruments; and ground-based balloon and aircraft observations. Work is also being done leading to the development of extremely precise gyroscopes which could be used in a zero G satellite for tests of Einstein's Theory of Relativity. Theoretical studies in celestial mechanics and geodesy are also included.

Spacecraft Technology

Studies of materials and techniques suitable for future interplanetary spacecraft, which would make close approaches to the sun or operate at great distances from the earth, are being conducted. In addition, work is being initiated in improved electronic and power supply components for explorer satellites.

Interdisciplinary Space Science

This area provides for support of the Space Science Board and for research fellowships administered by the National Academy of Science, which provide an opportunity for selected fellows to work with scientists at the Goddard Space Flight Center in theoretical and laboratory research.

Advanced Studies

Studies to establish the concepts, characteristics and feasibility of future earth orbital and interplanetary missions are funded in this area. Earth orbital mission studies include feasibility studies of small modular scientific satellites which could be assembled with comparatively short

	1965	1966	1967
Advanced Orbiting Solar Observatory (AOSO):			
Spacecraft	$5,831,000	$10,497,000	---
Experiments	1,569,000	3,324,000	---
Ground operations	---	979,000	---
Subtotal AOSO	$7,400,000	$14,800,000	---
Total OSO and AOSO	$16,597,000	$24,500,000	$11,900,000
Delta (Launch Vehicle Procurement Program)	($761,000)	($1,000,000)	($1,700,000)
Total (including Launch Vehicles)	($17,358,000)	($25,500,000)	($13,600,000)

The objective of the Solar Observatory program is to promote advancement in the study of solar physics through the use of current space techniques. These techniques permit expansion of scientific solar research by eliminating the atmospheric distortions which are normally prevalent with ground-based observations. Accordingly, freedom from atmospherically scattered light is obtained and many more decades of the electromagnetic spectrum can be observed. The solar observatories are designed to provide a thorough investigation of the sun, the rapid changes, as well as the long-term changes in solar radiation during a solar cycle and to probe into the underlying causes of these changes by analyzing regions of activity. The Orbiting Solar Observatories operated during the period of minimum solar activity with the flight of OSO I and OSO II in 1962 and 1965 respectively. Continuous program effort will be pursued with OSO into the period of maximum solar activity in 1968-69.

Orbiting Solar Observatories are stabilized platforms capable of pointing scientific instrumentation to an accuracy of greater than 1 arc minute at the center of the solar disc in order to study the solar ultraviolet light, gamma rays and X-rays, which are absorbed in the earth's atmosphere. Orbiting Solar Observatories are scheduled to be launched between 1965 and 1969 at approximately nine month intervals. This will give reasonable assurance of continuous coverage of solar phenomena as the sun reaches the period of maximum activity.

The first solar observatory, OSO-I, was launched on March 7, 1962, and provided over 2,000 hours of observation of the solar spectrum in the ultraviolet and X-ray regions. Orbiting Solar Observatory-II was successfully launched on February 3, 1965. All spacecraft systems operated at or above their design goals and the spacecraft was commanded "off" after more than nine months of near-perfect operation. All but one of nine experiments provided data during the more than 4100 orbits the spacecraft covered during its useful lifetime. These data are currently being analyzed and publication of scientific results is expected shortly.

Orbiting Solar Observatory-C, the third solar observatory, was launched August 25, 1965. Unfortunately, a malfunction in the third stage of the Delta launch vehicle prevented the booster from placing the spacecraft into orbit. Using spare experiments from the OSO-C, a re-flight of the mission is now scheduled for the middle of 1966. Experiment selection through the seventh OSO mission has been completed. Selection of proposed experiments for the last OSO in the current series (OSO-H) will take place shortly after July 1, 1966.

Management responsibility for the OSO project has been assigned to the Goddard Space Flight Center. The spacecraft are being procured through contracts with the Ball Brothers Research Corporation.

Fiscal year 1965 funds provided for completion, launch, data acquisition and analysis of OSO-II which was launched February 3, 1965, and for completion and launch of the third observatory in August 1965.

In addition, FY 1965 funds were utilized for initiation of experiment development for a follow-on observatory.

Fiscal year 1966 funds provide for continuing work on the fifth observatory, for completion of the hardware and launch of the fourth observatory, and for initiation of work on the three follow-on spacecraft and experimental packages. Fiscal year 1967 funds will provide for completion of data analysis on OSO-II and the fourth observatory, launch and initial data analysis on the fifth observatory, and for continuing hardware effort on the follow-on OSO's.

Fiscal year 1964 and prior funding for the OSO project, including launch vehicles, was $40,715,000. Fiscal year 1968 and later funding required to complete this eight flight program, including launch vehicles, is estimated at $24,800,000.

Astronomical Observatories

	1965	1966	1967
Spacecraft and support.....	$23,170,000	$17,205,000	$23,100,000
Experiments.....	9,474,000	7,395,000	6,100,000
Total Spacecraft and Support.	$32,644,000	$24,600,000	$29,200,000
Atlas-Agena (Launch Vehicle Procurement Program).....	(9,072,000)	(16,703,000)	(9,057,000)
Total (including Launch Vehicles).....	($41,716,000)	($41,303,000)	($38,257,000)

The Orbiting Astronomical Observatory (OAO) is designed to provide a precisely stabilized observatory above the atmosphere so that fundamental

information about the universe can be obtained through astronomical observations particularly in those extensive regions of the electromagnetic spectrum which do not penetrate the earth's atmosphere; and through high resolution observations in the visible and shorter wave length regions of the electromagnetic spectrum which are disturbed when they pass through the earth's refracting and scattering atmosphere. The OAO program is developing a standardized spacecraft that can be precisely stabilized to 0.1 arc second for long observational times, and can carry a wide variety of telescopic instruments weighing up to 1,000 pounds. The first five observatories will carry instruments of increasing capability, starting with exploratory sky mapping surveys and low resolution instruments and progressing to larger apertures, high resolution, and capability of viewing faint celestial objects.

The first OAO (OAO-A1), to be launched in early 1966, will carry ultraviolet photometers and spectrometers developed by the University of Wisconsin for studies of stars and nebulae. In addition, there is a package of three astronomical instruments designed for sky surveys in the X-ray and gamma ray spectral regions. These have been developed by Lockheed Research Laboratories, the Goddard Space Flight Center and the Massachusetts Institute of Technology.

The second OAO (OAO-B), scheduled for flight in early 1967, will carry a 36 inch aperture telescope designed to obtain spectrophotometric data on stars, nebulae and galaxies in the ultraviolet region of the spectrum with a capability of resolution up to 2 angstroms.

The third OAO (OAO-A2), to be launched in 1967, will consist of the refurbished prototype spacecraft carrying Smithsonian Astrophysical Observatory and University of Wisconsin experiments. The Smithsonian experiment consists of four telescopes with television imaging photometers to map the sky in the ultraviolet. The Wisconsin experiment will duplicate the scientific instruments developed for OAO-A1, but will be programmed to view other sky regions.

The fourth OAO (OAO-C), to be launched in 1968, will consist of a 32 inch aperture reflecting telescope combined with a grating spectrograph to study the composition and physical condition of interstellar material and to obtain high dispersion ultraviolet spectra of stars with resolutions up to 0.1 angstrom. This observatory will also carry telescopes developed by the University College, London, England, with the University of Leicester to study the X-ray emission of stars and nebulae. These will probably be the first focusing collimators to be used for studying galactic X-rays.

The OAO-D observatory is planned for launch in late calendar year 1969. This observatory will be utilized primarily for observing very faint celestial objects by guest observers. The lifetime of this observatory will thus be utilized in a variety of short-term viewing programs, just as ground observatories are now used.

Management responsibility for the OAO project has been assigned to the Goddard Space Flight Center. The spacecraft are being developed under prime contracts with the Grumman Aircraft Engineering Corporation.

Development of the OAO was initiated in 1960. This development required major advances in the state-of-the-art, especially in spacecraft stabilization and control, and command and data handling. After great effort, major component development problems were solved and the prototype OAO was ready for qualification in FY 1965. These extensive systems tests took place throughout FY 1965 and were performed with outstanding success. Also, FY 1965 funds provided for the assembly and integration of the OAO-A1 flight observatory, and for manufacture of the components for OAO-B. The contracts for refurbishment of the prototype spacecraft (OAO-A2) and for the OAO-C, a new spacecraft, were awarded in late FY 1965. Fiscal year 1965 funds provided for continuation of work on all experiments through OAO-C, and included the initiation of the repeat Wisconsin experiment for OAO-A2.

In FY 1966 the functional and environmental flight acceptance tests of the OAO-A1 observatory were successfully completed. Fiscal year 1966 funds will provide for final preparations, launch, and initial flight operations and data analysis of OAO-A1. Fiscal year 1966 funds will also provide for assembly and initial flight acceptance tests of the spacecraft and flight experiments for OAO-B. The prototype telescope for OAO-B has been successfully qualified in FY 1966. Also, FY 1966 funds provide for refurbishment of the OAO-A2 spacecraft and for the manufacture of components for OAO-C spacecraft, as well as continued support for manufacture of experiments for these missions.

Fiscal year 1967 funds will provide for continued data analysis of OAO-A1, and will provide for completion of flight acceptance tests, launch support, operations and initial data analysis for the OAO-B mission. The refurbishment and flight acceptance test of OAO-A2 observatory will be performed, and the manufacture and assembly of the flight spacecraft and flight experiment for OAO-C will be completed. Fiscal year 1967 funds will also provide for initiation of the OAO-D observatory, deferred from FY 1966. The FY 1967 funding level represents a buildup toward the level required to support a schedule of one OAO flight per year.

Fiscal year 1964 and prior year funding, including launch vehicles, was $129,040,000. Fiscal year 1968 and later funding required to complete five missions is estimated to be $66,300,000 including launch vehicles.

Geophysical Observatories

	1965	1966	1967
Spacecraft	$19,961,000	$16,971,000	$14,531,000
Experiments	10,391,000	11,629,000	8,869,000
Total Spacecraft and Support	$30,352,000	$28,600,000	$23,400,000
Thor-Agena (Launch Vehicle Procurement Program)	(2,164,000)	(3,795,000)	(3,595,000)

	1965	1966	1967
Atlas-Agena (Launch Vehicle Procurement Program).....	(2,134,000)	(6,271,000)	(3,154,000)
Total (including Launch Vehicles).....	($34,650,000)	($38,666,000)	($30,149,000)

The Orbiting Geophysical Observatory program has as a prime objective the accomplishment of a series of scientific measurements required to correlate the geophysical phenomena occurring in the near-earth environment with the effluent activity of the sun and interplanetary space. There is increased evidence that this environment has a fine, highly-variable structure of electromagnetic fields and particles which is strongly dependent on events or processes occurring at different locations. Correlative measurements aboard the same satellite obtained over a variety of spatial locations are required if we are to understand this environment. Successful accomplishment of the OGO program will undoubtedly contribute substantially to this understanding and to evaluation of the hazards of manned space travel. There remains, always, the possibility of the discovery of new physical phenomena having potential application to the advancing of earth-bound technology.

Support of these scientific objectives requires the development of spacecraft capabilities to accommodate the many diversified instruments used for the correlative studies. In essence, this requirement establishes the need for an orbital laboratory-type environment where viewing directions, electric power, thermal control, and data handling systems are shared by many experimenters in investigating related problems.

To achieve the planned scientific objectives, OGO missions are scheduled alternately for low altitude, nearly-polar orbits, and highly-elliptical, low inclination orbits at approximately nine month intervals.

The OGO-I mission, launched in 1964, identified design problems with appendage deployment which were corrected on the OGO-II mission launched in 1965. However, the nature of the OGO-I problem prevented detection of an anomalous behavior of the earth horizon sensors to cold clouds which was discovered on the OGO-II flight. Corrections for the OGO-II problem are being incorporated on OGO-B which will be the third OGO mission. In addition to verifying the functional and operational aspects of the OGO spacecraft design, the OGO-I and II missions have provided significant scientific data. Twenty-five presentations of OGO-I results have already been given by the experimenters at various scientific symposia and the number of papers presented, or currently planned for either presentation or publication, is over forty-five.

The next mission will be OGO-B which is in the final phase of environmental testing. Orbiting Geophysical Observatory-B carries essentially the same complement of experiments as OGO-I and will be placed in a similar highly-elliptical orbit during the second quarter of 1966.

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The fourth (OGO-D) and fifth (OGO-E) missions are both scheduled for launch in 1967. The OGO-D is in the final stages of integration and will continue the low earth studies started by OGO-II. Fabrication of spacecraft assemblies and experiments for the OGO-E mission is underway.

Procurement has been initiated for refurbishing of the prototype spacecraft for the OGO-F mission, to be launched in 1968, for which an experiment has been evaluated.

Management responsibility for the OGO project has been assigned to the Goddard Space Flight Center. The spacecraft development and fabrication is under contract to Thompson Ramo Wooldridge Corporation.

Funding prior to FY 1965 provided for design and development of the basic spacecraft; fabrication and testing of a prototype; and fabrication, integration, and test efforts on three flight spacecraft; development and initiation of fabrication of experiments for the first four missions.

This effort was continued in FY 1965 with the launch of the first OGO (OGO-A). The appendage release system redesign was incorporated in OGO-C and final preparations made for launch of this mission. Fabrication of spacecraft for the OGO-D and E missions and initiation of OGO-E experiment development was started. The OGO-I data analysis was supported. To accomplish the program within available manpower resources at the Goddard Space Flight Center, missions OGO-D and beyond were rescheduled from approximately six month intervals to nine month intervals. As a consequence, selection of experiments for OGO-F was delayed until FY 1966. In addition, the spacecraft contractor was assigned the added responsibility of experiment handling and testing for the later missions.

Fiscal year 1966 funds provided for the launch of OGO-C (II); continuation of data analysis for OGO-I and OGO-II; final preparations for the launch of OGO-B; continuation of work on OGO-D and E; and initiation of OGO-F experiment development.

Fiscal year 1967 funds are for completion and launch of OGO-D; continuation of observatory testing and launch preparations for OGO-E; and refurbishing the prototype spacecraft for OGO-F. They will also provide for continued support of data analysis for the first four OGO missions; the completion of OGO-E experiment development; and support of experiment development for the OGO-F mission.

Fiscal year 1964 and prior year funding for OGO was $122,712,000, including launch vehicles. Fiscal year 1968 and later funding needed to complete six missions is estimated to be $27,300,000, including launch vehicles.

Explorers

	1965	1966	1967
Geophysical and interplanetary explorers	$16,570,000	$13,120,000	$12,300,000
Astronomy explorers	1,100,000	5,030,000	9,100,000
Geodetic explorers	3,895,000	3,250,000	1,600,000
Total Explorers	$21,565,000	$21,400,000	$23,000,000
Scout (Launch Vehicle Procurement Program)	(3,527,000)	(6,300,000)	(3,829,000)
Delta (Launch Vehicle Procurement Program)	(10,450,000)	(4,817,000)	(11,683,000)
Thor Agena (Launch Vehicle Procurement Program)	(8,839,000)	(6,746,000)	(2,913,000)
Total (including Launch Vehicles)	($44,381,000)	($39,263,000)	($41,425,000)

The Explorer satellites are the smallest of NASA's scientific spacecraft, being launched on Scout, Delta and Thor Agena launch vehicles. Explorers are specifically designed to provide for specialized scientific investigations and are flown in orbits especially selected for the investigations involved. These Explorer spacecraft and their experiments, developed by various NASA centers, industry, universities and cooperating foreign countries, are used for investigations of the earth's environment, solar-terrestrial relationships, solar-interplanetary relationships, astronomical observations, and for geodetic measurements.

The shorter development times associated with these small spacecraft is reflected in the large number of successful missions accomplished (31) from the founding of NASA through 1965. These missions have provided substantial portions of our present knowledge about the earth's environment, including the ionosphere, the atmosphere, micrometeoroid environment, the radiation belts, the earth's magnetic field and some of the principal effects of solar radiation on the atmosphere. As a result of these efforts and other related investigations, the picture of the interactions between solar activity, the interplanetary medium, and the immediate environment of the earth is becoming clearer.

While Explorer spacecraft do not possess the stabilization and control feature, or the high data rates, required for detailed and comprehensive astronomical investigations of the Sun, stars and planets, they do provide an effective and economical means of making exploratory measurements in the radio, X-ray and ultraviolet regions. The first Radio Astronomy Explorer is under development for launch in 1967 to study planetary and celestial

low frequency radio sources. Development of a small X-ray Astronomy Explorer is being initiated to exploit the recent discovery of stellar X-ray sources.

In November 1965, the first Geodetic Explorer was launched marking the commencement of a cooperative geodetic program with participation by the Department of Defense, the United States Coast and Geodetic Survey, universities and other research organizations in the U.S. and cooperating foreign countries. Explorer XXIX (Geos A) is the first of two similar active satellites in the program containing apparatus for optical and electronic geodetic measurement techniques. A passive satellite consisting of an ECHO type balloon with beacons, designated PAGEOS-A, will be launched into a high altitude circular orbit in 1966 to supplement the active satellite program. Comparison studies are planned to evaluate the various techniques employed and to provide a check on the accuracy of individual measurements. The program is planned to continue.

In FY 1965 the major emphasis in the Explorer program was on the development of Interplanetary Explorers and on the joint Canadian-US Satellite for Ionospheric Studies. Fiscal year 1965 funds also provided for the initiation of the Radio Astronomy Explorer (RAE) and the OWL Explorers, a pair of satellites designed to make simultaneous measurements of high latitude geophysical phenomena in out-of-phase orbits. Development efforts on active and passive geodetic satellites, initiated in prior years, were also continued.

In FY 1966 increased emphasis is being given to Astronomy Explorers with major funding of the RAE and initiation of the X-ray Astronomy Explorer. A Scout launch vehicle was also provided for the launch of a Solar Explorer developed by the Naval Research Laboratory. Development of Geophysical and Interplanetary Explorers is being continued at a reduced level of effort, and the Geodetic Satellite program is being continued at a level effort.

The FY 1967 program provides for further reduction of the level of effort in Geophysical and Interplanetary Explorers, providing only for continuation of launches of Interplanetary and Energetic Particles Explorers and international cooperative programs in the 1968-1969 time period. The program in Astronomy Explorers will provide for continuation of observations into the 1968-1969 time period with emphasis on X-ray and radio observations of the Sun. Geodetic investigations will be continued using the four satellites in the currently approved program.

Sounding Rockets

	1965	1966	1967
Experiments	$7,403,000	$6,700,000	$6,700,000
Rocket development	594,000	852,000	1,024,000
Attitude control systems	1,018,000	3,543,000	3,400,000
Engineering support	476,000	442,000	440,000
Test and evaluation	209,000	246,000	250,000
Ground instrumentation	3,332,000	3,004,000	3,233,000
Rocket procurement	3,835,000	3,713,000	3,953,000
Total	$16,867,000	$18,500,000	$19,000,000

Sounding rockets have proven to be the only effective means of making scientifically valuable studies of the upper atmosphere at altitudes above 20 miles and below the perigee altitudes of earth satellites. These rockets are relatively small and inexpensive vehicles, capable of carrying wide varieties of instrumentation for the study of the atmosphere, ionosphere, energetic particles, astronomy and solar physics. The relatively low cost and short lead times make research with sounding rockets extremely useful for carrying out new experiments and testing new instruments soon after the ideas are developed by the nation's scientists.

Sounding rockets have been used to measure atmospheric density and temperature; to analyze the various gases present in the upper atmosphere, and responses of the atmosphere to varying solar activity. Chemicals released from sounding rockets for wind and temperature measurements launched from various sites all over the world have improved our knowledge about the dynamics of the ionospheric region. Recoverable sounding rocket payloads have been used to collect extraterrestrial dust originating in meteor streams, comets, and asteroids. Noctilucent clouds formed by the condensation of ice about this dust have been probed by flights from Sweden and Ft. Churchill, Canada; interplanetary dust has been sampled by rockets recently over White Sands, New Mexico.

The aurora and airglow have been investigated by rocket probes containing spectrophotometers, filter photometers, and particle detectors.

Ionospheric experiments have been carried out with sounding rockets and have proved extremely valuable both for scientific investigations of the physics of the ionosphere and for calibrating instrumentation on satellites already in orbit by simultaneously measuring the same region of the ionosphere. Instruments have been developed to measure electron concentrations and temperature, electromagnetic waves, ionic and neutral mass spectra, magnetic fields, and E region currents. Flights to measure these parameters have been made from many launching sites with a wide global distribution.

Sounding rockets are now being effectively utilized for astronomical observations of the sun and the stars in the X-ray and ultraviolet regions of the spectrum made possible due to the development of improved attitude control systems.

Management responsibility for sounding rocket support activities has been assigned to the Goddard Space Flight Center. Rocket experiments are managed at several NASA centers, with NASA Headquarters retaining responsibility for experiments developed at universities, by researchers in industry, at other agencies and in other countries.

About 125 major sounding rockets of the Nike Cajun/Apache, Aerobee and Javelin types, and 12 of the Arcas type were launched during 1965 from sites in the United States, Canada, Brazil, India, Surinam, New Zealand, Norway, Pakistan, and from shipboard launchings from a converted Navy aircraft transport. This Mobile Launch Expedition, planned as part of the International

Year of the Quiet Sun, provided a very successful series of launchings into the atmosphere and ionosphere in geographical regions which could not be reached by land-based rockets. A large volume of new and useful data about the "equatorial electrojet," a system of electrical currents circulating in the ionosphere near the geomagnetic equator, and on other ionospheric phenomena was obtained during this expedition.

Sounding rocket projects are planned to be continued in FY 1966 and 1967 in many areas where experimentation has begun, including atmospheric and ionospheric measurements, cosmic dust collections, chemical releases in the upper atmosphere; and X-ray, ultraviolet and infrared observations of celestial sources and the sun. Increases in the program for FY 1966 and FY 1967 are largely due to the development and increased use of improved attitude control systems and to an increased use of the larger, more expensive vehicles to carry stabilized payloads, as well as heavier payloads, with several instruments for a number of simultaneous measurements.

Data Analysis

	1965	1966	1967
Operation of the data center ...	---	$300,000	$600,000
Research tasks	---	1,800,000	1,400,000
Total	---	$2,100,000	$2,000,000

A National Space Science Data Center has been established at the Goddard Space Flight Center to provide for the collection, cataloging, storage and dissemination of reduced data from space sciences flight experiments. Data collected will be made available at a cost commensurate with reproduction and distribution cost to those interested in using the data for further research. To encourage the full use of the data obtained on NASA flight programs, support will be provided for scientific research efforts which make use of the data. Proposals for research are being competitively evaluated, and support is being provided for those efforts which can be expected to contribute the most to the total advancement of knowledge in space science. Fiscal year 1967 funds will provide for operation of the Data Center at a level consistent with the input of reduced data and for support of data analysis efforts.

OFFICE OF SPACE SCIENCE AND APPLICATIONS LUNAR AND PLANETARY PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objective of the Lunar and Planetary program is the scientific exploration of our solar system utilizing unmanned and manned spacecraft and earth-based research. Immediate objectives include the exploration of the moon, the planets Venus and Mars, and the intervening interplanetary space. The fulfillment of long range objectives will see the eventual exploration of the outer planets and their moons, comets, asteroids and corresponding planetary and interplanetary deep space environment. The ultimate achievement of these objectives will provide data to better explain the origin, history and mechanisms of development of our solar system and may provide evidence of the existence of forms of life elsewhere in the solar system.

The lunar program consists of three types of missions. The first of these, the Ranger program, has now been completed, yielding over 17,000 photographs of the lunar surface. The photographs have provided a much better understanding of the nature of the surface of the moon. However, information such as the composition and bearing strength of the lunar surface is dependent upon the next series of missions to the moon. The Surveyor program is intended to soft land a series of unmanned spacecraft with a complement of instruments on the surface of the moon for making first hand observations and obtaining physical measurements of that body. Many of the difficult developments required have been completed and its first flight is planned for later this year. After landing, each Surveyor spacecraft will survey the immediate area to determine the suitability of that site for later manned missions. The Lunar Orbiter program was conceived and initiated to supplement the information obtained by Ranger and to work in a team relationship with Surveyor in conducting scientific investigations, and locating and certifying suitable landing sites for Apollo. The Lunar Orbiter will be capable of photographing all regions of the moon and therefore, will be a useful tool in continuing lunar exploration. Scientific instruments and techniques are also being developed for lunar studies utilizing man's capabilities and the payload return capabilities of the Apollo program.

The Planetary and Interplanetary programs have experienced a high degree of success with the Mariner II flyby of Venus, the Mariner IV photographic mission to Mars and the most recent successful launching of the Pioneer VI spacecraft to an orbit around the sun. Each of the planetary missions have yielded a wealth of scientific information. Mariner II provided new data on the physical characteristics of the atmosphere of Venus. Mariner IV produced the first close up photographs of the Mars surface and, in addition, performed many important scientific measurements permitting a considerably better understanding of the nature of that planet. Pioneer VI and additional

Pioneer launches during FY 1966-1968 are planned to measure interplanetary phenomena at extended distances from earth. The next steps in the evolution of planetary exploration will be fly-by missions to Venus and Mars in 1967 and 1969 respectively utilizing the Mariner IV design. Development efforts will also be continued leading to the detailed exploration of these planets under the Voyager program now being planned for a first operational mission during the 1973 Mars opportunity.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Supporting research and technology/Advanced studies....	$24,140,000	$38,600,000	$40,100,000
Ranger.....	11,037,000	1,000,000	---
Surveyor.....	81,814,000	111,637,000	90,400,000
Lunar orbiter.....	49,500,000	52,400,000	24,600,000
Mariner.....	17,368,000	18,000,000	26,100,000
Voyager.....	7,168,000	17,000,000	10,000,000
Pioneer.....	15,000,000	12,700,000	6,700,000
Total.....	$206,027,000	$251,337,000	$197,900,000

Distribution of Program Amount by installation:

	1965	1966	1967
Manned Spacecraft Center.....	$2,608,000	$14,400,000	$15,200,000
Marshall Space Flight Center...	435,000	375,000	300,000
Goddard Space Flight Center....	1,267,000	1,164,000	1,200,000
Jet Propulsion Laboratory.....	126,580,000	156,607,000	136,700,000
Ames Research Center.....	15,734,000	12,763,000	7,000,000
Langley Research Center.....	50,050,000	53,115,000	23,200,000
Lewis Research Center.....	97,000	---	---
NASA Headquarters.....	9,256,000	12,913,000	14,300,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology/Advanced Studies

	1965	1966	1967
Lunar and planetary science.....	$12,285,000	$12,000,000	$12,000,000
Advanced technical development..	6,151,000	6,800,000	6,800,000
Advanced studies.....	2,059,000	2,500,000	2,500,000
Manned lunar science.....	3,645,000	17,300,000	18,800,000
Total.....	$24,140,000	$38,600,000	$40,100,000

Activities funded under Supporting Research and Technology provide for essential support of approved flight missions as well as the necessary feasibility studies and other advanced work required to establish future missions.

The Lunar and Planetary Science program provides the means of developing new concepts and ideas for scientific investigation of the moon and planets to the stage where they can be proposed as flight experiments for future missions. The activities which are performed provide scientific data for the design and calibration of flight experiments and for the analyses of the results of experiments already performed. Laboratory, theoretical, and observational research in this area is being performed at NASA centers, other government facilities, universities, and industrial concerns.

The moon and planets are being observed with optical and radio instruments in order to obtain information needed for the design of spacecraft and the selection of experiments for lunar and planetary flight missions. The nature and bearing strength of the lunar surface and the variation of pressure with altitude in the Martian atmosphere continue to be the most important problems currently under investigation. Adequate knowledge of the characteristics of the lunar surface is essential for safe manned exploration and for the successful performance of soft landing unmanned scientific payloads. The characteristics of the Martian atmosphere have become of increased concern during the past year due to the occultation experiment of Mariner IV which gave the surface pressure, a value near five millibars. A series of spectroscopic observations completed during 1965 gave values between 10 and 15 millibars. Both of these values are dependent on assumptions which may or may not be valid. It is therefore planned to conduct more comprehensive and definitive studies on this problem in 1967, the next period of closest approach of the planet Mars.

The Advanced Technical Development program involves the development of equipment and technology needed for flyby, orbiting, and landing missions to Mars and other planets. Successful completion of these missions requires equipment which will be extremely reliable and able to survive both a rigorous sterilization and long exposure in a deep space environment. It must also make the greatest possible use of the capability of the improved launch vehicles which will be available in a few years. In the FY 1966 program primary emphasis has been placed on the areas of communications, power management and the sterilization of spacecraft components to prevent contamination of Mars. Mariner IV data on the atmospheric pressure on Mars has confirmed the need for the increased attention given in FY 1966 to landing technology to ensure safe landing on the surface of the planet. The FY 1967 funds will enable the continued effort in support of Mars exploration. Efforts will continue on communications, power, and sterilization, and will also place emphasis on high impact technology. With the identification of technology requirements for a Jupiter mission, derived in the advanced studies area, plans will be made to develop this technology in FY 1967.

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Planning for the future in Lunar and Planetary programs requires the continued study of advanced missions. The cataloging of possible missions to the planets is a continuing process as new flight techniques and increased booster capabilities evolve. Fiscal year 1966 funds were utilized in surveying the potential of trajectories which swing-by one planet enroute to a different target planet, in terms of the reduction of trip time to the target and energy required. Included in this survey were Mars, Venus, Mercury, Jupiter, Saturn, and other outer planets. In FY 1966 spacecraft conceptual design studies were initiated to meet the most important lunar and planetary scientific objectives. Highest on the list after Venus and Mars are flights to Jupiter. Some work was also conducted in regard to missions to comets and asteroids. Fiscal year 1967 funds will be used to continue the surveying of possible missions and the generation of concepts for the exploration of the Moon, Venus, Jupiter, comets, and asteroids. In addition, a preliminary study will be conducted to determine the feasibility of a planetary probe to Saturn.

The planning of scientific investigations and the design and development of equipment for manned lunar missions is accomplished by the Manned Lunar Science program. Early manned missions to the moon will stress the observation of natural phenomena, collection of representative samples and emplacement of monitoring equipment. To achieve these goals a lunar surface experiment package capable of conducting geophysical investigations and the environmental measurements; geological surveying systems; equipment and procedures for sampling lunar surface material; and earth-based laboratories for the analysis of return lunar surface samples are being developed. Applied research on the lunar environment is currently underway in order to meet specific needs for information about lunar phenomena required to design and develop safe, reliable manned space flight systems. Lunar mapping required in the planning, development, training and execution of manned and unmanned missions is also being undertaken.

Surveyor

	1965	1966	1967
Spacecraft	$74,479,000	$105,400,000	$82,800,000
Experiments	2,523,000	3,437,000	4,000,000
Ground operations	4,812,000	2,800,000	3,600,000
Total Spacecraft and Support	$81,814,000	$111,637,000	$90,400,000
Atlas-Centaur (Launch Vehicle Procurement Program)	(40,064,000)	(50,000,000)	(50,000,000)
Total (including Launch Vehicles)	($121,878,000)	($161,637,000)	($140,400,000)

The Surveyor system is being developed to soft land an unmanned spacecraft on the lunar surface and make measurements of the nature of that body. A successful landing will yield significant information on landing technology and the surface characteristics which affect the landing. After landing on the surface, each Surveyor spacecraft will survey the immediate area as a possible site for later manned landings.

The major objective of Surveyor is to provide the information which will assure the high confidence required before manned landings can be attempted. Since the Surveyor design concepts are basically the same as those being used on Apollo, the successful landing and operation of a Surveyor in the lunar environment will demonstrate the overall feasibility of later manned landings and many Surveyor spacecraft elements which are also basic to the Apollo Lunar Excursion Module (LEM); e.g., radar altimeter, radar doppler velocity sensors, closed-loop terminal guidance system, variable thrust rocket engines, leg-type landing gear, S-band communications, and tracking to lunar distances. Data obtained on surface characteristics such as roughness, bearing strength, and dust coverage will have direct application in the planning for manned missions.

The Office of Space Science and Applications, NASA Headquarters, is responsible for overall management of the Surveyor program. Responsibility for project management is assigned to the Jet Propulsion Laboratory. The Surveyor spacecraft system is being developed by the Hughes Aircraft Company. Major subcontractors are Thiokol/Elkton for the main retro-rocket, Thiokol Reaction Motors Division for the vernier propulsion system, and Ryan Electronics for the attitude and velocity-sensing radars.

Effort during 1965 was devoted primarily to conducting the tests required to confirm the design of the spacecraft and to identify and correct any existing weak areas. While significant progress was made, including the first successful descent test using the Surveyor closed-loop landing system (radars, vernier engines, and interconnecting control circuits), delays were encountered which made desirable an overall review of how Surveyor could best meet the needs of the Apollo program. Of major concern were the problems associated with developing the 2200 pound spacecraft for missions A through D while simultaneously uprating the design to 2500 pounds for missions E, F, and G. It was concluded that every effort should be taken to maximize the probability of early success with the 2200 pound spacecraft, especially since a significant portion of the data required by Apollo can be obtained with the lighter design. The additional information attainable with the 2500 pound spacecraft may be necessary in the event of encountering a lunar surface which is marginal for manned landings. It would be obtained after the successful accomplishment of the preliminary lightweight missions. Based on the above, the program was redirected whereby missions E, F, and G were converted from 2500 to 2200 pound spacecraft.

Fiscal year 1966 funds are being used to complete testing and to launch the first flight spacecraft (Mission A). Assembly and testing of the second flight spacecraft will also be completed. Hardware has been ordered through

mission G, and a reliability improvement program implemented. Effort is being continued at a modest level on design and development of pacing items for the 2500 pound spacecraft, now planned for flights H through J.

Fiscal year 1967 funds will be used to launch missions B, C, and D. The spacecraft for missions E, F, and G will be assembled and placed under test. Detailed engineering and hardware procurement will be undertaken for three 2500 pound spacecraft. Prior to FY 1965, funds in the amount of $216,433,000 were applied to the Surveyor program, including launch vehicle procurement. Funding for FY 1968 and to completion is estimated to be $157.1 million.

Lunar Orbiter

	1965	1966	1967
Spacecraft.....	$48,756,000	$49,020,000	$20,300,000
Experiments.....	---	140,000	2,300,000
Ground operations.....	744,000	3,240,000	2,000,000
Total Spacecraft and Support...	$49,500,000	$52,400,000	$24,600,000
Atlas-Agena (Launch Vehicle Procurement Program).....	(9,102,000)	(17,059,000)	(4,567,000)
Total (including Launch Vehicles).....	($58,602,000)	($69,459,000)	($29,167,000)

The Lunar Orbiter will team with landed Surveyors to conduct unmanned scientific investigations of the moon prior to the Apollo period. The Orbiter will photograph the lunar surface in both medium and high resolution. High resolution Orbiter photographs from a single Lunar Orbiter mission will be comparable in quality to the final Ranger pictures, but will cover a much greater area, equivalent to a belt of terrain about one mile wide extending from Washington to Los Angeles. The medium resolution photographs will overlap to provide stereo coverage, and in combination with the high resolution photographs, which are taken simultaneously, will permit topographic mapping of extensive portions of the moon. The selenodetic data which will be obtained from the Lunar Orbiter flights will be significant and useful: analysis of orbits will give more precise knowledge of the lunar gravitational field, which is related to its mass distribution, surface shape, internal structure, and possible seismic activity. The improved gravitational and shape data will benefit Apollo guidance calculations.

The Lunar Orbiter is an attitude stabilized spacecraft, relying primarily on solar panels to supply power. Its design and development made maximum use of existing technology; much was developed under the Ranger, Mariner, and other earlier NASA and Department of Defense space programs. The Lunar Orbiter must perform more maneuvers than Ranger or Mariner. Following launch, the spacecraft propulsion system is required to function three or four times--one or two midcourse maneuvers to ensure proper lunar intercept, a firing to reduce velocity to inject the spacecraft into an elliptical orbit about the

moon, and a final firing to lower the perilune of the orbit to as low as 28 miles from the lunar surface. The attitude control system must maintain a Sun-Canopus orientation to provide communications and solar power, and must reorient the spacecraft to set the camera axis vertical each time a strip terrain is to be photographed.

The Boeing Company is the spacecraft systems contractor under the management of the Langley Research Center. The Radio Corporation of America is providing the power system and much of the communications system and Eastman Kodak is developing the photo system. The Lewis Research Center is responsible for the launch vehicle system and the Jet Propulsion Laboratory will manage the tracking and data acquisition system.

The first flight spacecraft and the ground test spacecraft have been assembled and are being tested. The balance of this fiscal year's funds will provide for assembly of all five flight spacecraft, completion of prototype testing and the launching of the first flight spacecraft.

The funds requested for FY 1967 will provide for three additional launches, support post-launch operations, initiate data analysis for the first four missions, and provide for the payment of performance incentive fee to the systems contractor.

Fiscal year 1964 and prior year funding for Lunar Orbiter, including launch vehicles, was $30,268,000. About $3,300,000 will be required in FY 1968 for mission operations and data analysis.

Mariner

	1965	1966	1967
Spacecraft	$10,487,000	$11,260,000	$16,000,000
Experiments	2,274,000	3,400,000	4,000,000
Ground operations	4,607,000	3,340,000	6,100,000
Total Spacecraft and Support	$17,368,000	$18,000,000	$26,100,000
Atlas-Agena (Launch Vehicle Procurement Program)	(4,583,000)	(2,544,000)	(7,267,000)
Total (including Launch Vehicles)	($21,951,000)	($20,544,000)	($33,367,000)

The objectives of the Mariner program are to conduct initial investigations of the planets Venus and Mars, and to develop the medium size (400-800 pound) fly-by spacecraft and instruments required for such exploration. Accomplishments to date include the December 14, 1962, Mariner II fly-by of Venus which provided the first direct temperature and magnetic field measurements from near the planet. This was followed by the Mariner IV flight past Mars on July 14, 1964, that resulted in the first close-up view of the planet showing a

cratered surface similar to that of the moon. Mariner IV further detected a negligible magnetic field around Mars and found the atmospheric pressure considerably lower than had been previously believed. In addition to the information gained at encounter, the Mariners provided almost a year's accumulation of data on the interplanetary environment including energetic particle flux, magnetic fields and micrometeorite distribution.

Although the Mariner IV spacecraft is presently beyond the limits of telemetry communication, its carrier signal is still being received from over 210 million miles distance, and it is still believed to be operating properly. Attempts will be made to re-establish two-way communications when the spacecraft approaches the earth in 1967. If these attempts are successful, additional valuable information on the space environment and its effects on spacecraft systems will be obtained.

With the postponement of first Voyager flights until 1973 necessitated by the reduced funding level, additional Mariner missions are under development to obtain additional planetary data during intervening opportunities. The additional Mariner missions consist of one flight to the planet Venus in 1967 and two flights to Mars in 1969. The Venus mission will be conducted by modifying the spare spacecraft from the Mariner IV project to perform a Venus fly-by using the Atlas-Agena launch vehicle. The 1969 Mars missions will be planetary fly-bys using the Atlas-Centaur launch vehicle. The Mars 1969 spacecraft will be based on the Mariner IV design modified to carry improved experiments and make the maximum possible contribution to the Voyager program.

Overall management of this program is the responsibility of the Office of Space Science and Applications. Project management responsibility has been assigned to the Jet Propulsion Laboratory. The Lewis Research Center is responsible for the launch vehicles.

Fiscal year 1965 funding supported pre-launch, launch, and the major portion of the in-flight operations for the Mariner 1964 missions. Fiscal year 1966 funding covered operations immediately preceeding and through the Mars encounter of Mariner IV. Most of the experiment data analysis and publication of final project reports will be completed with current fiscal year funds. In addition, work is being initiated on the Mariner 1967 Venus and Mariner 1969 Mars missions.

Funding requested for FY 1967 will provide for activities associated with the return of Mariner IV and related data analysis; the modification of the spare Mariner IV spacecraft for the Venus mission, its testing and preparation for launch; completion of systems design and initial fabrication of the prototype and flight hardware for the 1969 Mars mission.

Funding for the Mariner program in FY 1964 and prior, including launch vehicles, amounted to $173,216,000. Planned funding for FY 1968 to completion through the 1969 Mars missions is $88,800,000.

Voyager

	1965	1966	1967
Mission design.....	$1,661,000	$2,000,000	1,500,000
Spacecraft system.....	4,718,000	8,000,000	500,000
Capsule system.....	789,000	7,000,000	8,000,000
Total.....	$7,168,000	$17,000,000	$10,000,000

The capability for detailed study of the near planets is being developed through the Voyager project, now planned for flight missions to Mars beginning in 1973. The primary objective of these missions is to obtain detailed information on atmospheric, surface, and body characteristics, with special emphasis on the possible existence and nature of life on the planet. A secondary objective is to further our knowledge of the interplanetary medium between the planets Earth and Mars by conducting scientific and engineering measurements while in transit.

To meet the above objective, a spacecraft is required having the capability to orbit the planet and land a scientific payload on the surface. As presently conceived, this spacecraft would consist of three modules; the bus-orbiter module, the retro-propulsion-module, and the entry capsule module. Definition studies have indicated the desirability of launching two of the Voyager spacecraft on a single Saturn V launch vehicle to take advantage of this vehicle's weight lifting capability and planned reliability. Although the system is being developed to explore the planet Mars, it will provide a basic capability which can be applied to the future exploration of other planets by automated spacecraft.

Overall management of this program is the responsibility of the Office of Space Science and Applications. The Jet Propulsion Laboratory has been assigned management responsibility for Voyager project.

Based on conceptual studies carried out in FY 1964, a project definition effort was initiated in FY 1965 directed toward a decision for initiation of flight hardware development in FY 1967. This schedule would have made possible first flights at the 1971 Mars opportunity. However, first flights have been rescheduled for the 1973 Mars opportunity. The additional time will be used to further define the mission, the spacecraft system specifications and the capsule system. Particular emphasis will be placed upon the capsule. This additional effort should make possible a more sophisticated capsule landing system for the 1973 mission than had previously been planned for 1971.

Fiscal year 1965 funds provided for the initiation of spacecraft system definition effort which included the selection of three industrial contractor teams to conduct preliminary design studies of the bus-orbiter and retro-propulsion-modules. Capsule design studies were conducted in-house by the Jet Propulsion Laboratory supported by the Langley and Ames Research Centers.

Fiscal year 1966 funds are being applied to completion of the contractor design efforts and continuation of the in-house design studies, with particular emphasis on the capsule system design problems.

The funding requested for FY 1967 will be used to continue the overall mission design studies, the capsule design studies, and supporting activities leading to detailed system design and breadboard tests planned to be initiated in FY 1968.

Pioneer

	1965	1966	1967
Spacecraft.....	$13,189,000	$6,300,000	$4,300,000
Experiments.....	1,456,000	5,200,000	1,500,000
Ground operations.....	355,000	1,200,000	900,000
Total Spacecraft and Support.	$15,000,000	$12,700,000	$6,700,000
Delta (Launch Vehicle Procurement Program).....	(3,521,000)	(5,583,000)	(1,001,000)
Total (including Launch Vehicles).....	($18,521,000)	($18,283,000)	($7,701,000)

The objectives of the Pioneer project are to investigate the interplanetary environment and the propagation of solar and galactic phenomena through this medium. Correlation with similar measurements performed near the earth with satellites are required to attain the full objective. Pioneer spacecraft will be launched during the period of increasing solar activity over the next several years.

The current series of Pioneers weigh about 140 pounds and are launched with the Thrust-Augmented Improved Delta. The first of these Pioneer VI, was successfully launched in December 1965. Four additional Pioneer spacecraft are scheduled to alternate between missions towards and away fron the sun, approaching as close as 0.8 A.U. and going as far away as 1.2 A.U. from the sun. (1 A.U. is equal to the mean earth to sun distance, 92,900,000 miles.)

The Pioneer experiments are designed to measure the solar wind flux, magnetic fields, and the electron density in space; the energy spectra, fluxes, and direction of arrival of solar and galactic cosmic rays will also be observed. To perform these measurements special care is being taken in the design and construction of the Pioneer spacecraft to make it magnetically clean; the residual spacecraft magnetic field is less than one one-hundred-thousandth of the earth's field. Instrumentation to measure micrometeorite impacts will also be included in third, fourth and fifth Pioneers of the current series.

Responsibility for overall management of this program rests with the Office of Space Science and Applications, with the Ames Research Center responsible for project management. The spacecraft are being procured through contract with Thompson-Ramo Wooldridge Corporation. The Jet Propulsion Laboratory is responsible for tracking and data acquisition systems management and the Goddard Space Flight Center for launch vehicle systems management.

Fiscal year 1965 funds provided for assembly and testing of the prototype spacecraft, and the fabrication, assembly and initial tests for the first two flight spacecraft. Fiscal year 1966 funds cover the final testing, launch and post-launch operations for the first flight spacecraft, the final testing and launch preparation for the second spacecraft, and the assembly and initial testing of the subsystems for the third, fourth and fifth spacecraft.

Funds requested for FY 1967 will support the launch and post-launch operations for the second spacecraft, final testing and launch preparation for the third spacecraft, and integration and acceptance tests for the fourth spacecraft. Funding for FY 1964 and prior, including launch vehicles, amounted to $23,219,000. It is now estimated that $9.0 million in FY 1968 will complete funding for the first five missions.

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RESEARCH AND DEVELOPMENT

FISCAL YEAR 1967 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS — SUSTAINING UNIVERSITY PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The basic objective for the formation and continuing development of the Sustaining University Program is NASA's desire to strengthen the universities while seeking their help in accomplishing the Agency's mission. NASA supports the training of graduate students in space-related disciplines, the construction of urgently needed facilities at universities engaged to a significant degree in space-oriented research or research potentially applicable to the space program, and the conduct of a variety of multidisciplinary research. Attainment of this objective will help replenish the national manpower supply of highly trained people, make available suitable laboratory facilities in which space-related research may be conducted efficiently, and broaden the national base of research upon which technological progress ultimately depends.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Training.....	$25,000,000	$25,000,000	$22,000,000
Research facilities.....	10,000,000	8,000,000	7,000,000
Research.....	11,000,000	13,000,000	12,000,000
Total.....	$46,000,000	$46,000,000	$41,000,000

Distribution of Program Amount by Installation:

Jet Propulsion Laboratory...	$3,000	---	---
Lewis Research Center.....	11,000	---	---
NASA Headquarters	45,986,000	$46,000,000	$41,000,000

BASIS OF FUND REQUIREMENTS:

Training

	1965	1966	1967
Training.....	$25,000,000	$25,000,000	$22,000,000

The objective of the training grants program is to increase the supply of scientists and engineers highly trained to meet the challenge of national

space goals. By providing opportunities for predoctoral graduate research training, many qualified students are being trained to provide staff leadership for space-related activities in the nation's industries, government research centers, and universities. The result is more effective research in industry and laboratory, and a regenerative training process in the universities. The university phase is sustained by the Summer Faculty Fellowships for young staff members of unusual promise.

The predoctoral research training is designed to yield 1,000 Ph.D.'s annually in science and engineering from an annual input of about 1,300 candidates. Most of these graduates will devote their careers to some aspect of the space program. In September 1965, some 1,275 students began their tenure as NASA sponsored trainees. About 1,335 students will begin their three-year training in September 1966, and it is planned to start another group of about 1,000 in 1967.

Since the inception of the program, 104 students have received the Ph.D. degree. The academic fields in which the degrees were earned are: 56 in the physical sciences, 31 in engineering, 12 in the life sciences, and 5 in other specialized areas with emphasis on space-related problems. Since receiving their degrees, the students have made the following career choices: (a) university research and/or teaching - 65; (b) postdoctoral fellowships or Fulbright awards - 15; (c) employed in government laboratories - 4; (d) employed in industrial laboratories - 20.

In addition to the predoctoral program, a limited number of special training activities will be supported. These activities will be directed toward select groups who will make unique contributions to the space effort. The Summer Faculty Fellowship Program provides an opportunity for about 150 young college or university faculty members to participate in ongoing research projects at a NASA center and concurrently engage in related seminar or classroom discussions at a nearby university. Six NASA centers and twelve universities will participate in this program in 1966.

In addition to summer training for faculty, NASA will sponsor a few summer programs for exceptionally talented undergraduates who are to be chosen on a national basis to participate in an exploratory program in space science or in space technology. In FY 1966 three programs will be supported involving about 150 undergraduate students. Subject to the availability of funds, NASA plans to continue to sponsor these types of specialized training programs in FY 1967.

Research Facilities

	1965	1966	1967
Research facilities.....	$10,000,000	$8,000,000	$7,000,000

The objective of this portion of the program is to provide needed laboratory space for those universities already heavily committed to the space program.

For the nation to reap the maximum benefit from university participation in the space program, adequate facilities in which to perform laboratory research and to develop experimental packages are needed on campus. Good faculty researchers cannot participate fully in programs which keep them off campus and away from their students. However, sufficient facilities made available on campus allows not only for full faculty participation, but also provides excellent opportunities for students to work together with their professors on important space projects. Existing academic buildings, in addition to being overcrowded with the burgeoning student population, are not equipped nor suitable for these space program efforts, hence new campus facilities are urgently needed.

To date a total of seventeen buildings spread throughout the nation's universities have been completed under this program. These completed facilities represent one-half million gross square feet of new area in use or planned for university space research. The facilities completed to date typify the two general types needed by universities in order to contribute their unique input of knowledge and trained individuals to NASA's programs. Highly specialized facilities are provided specifically for certain types of research, such as that involved with propulsion or the preparation of experiments to be carried on satellites. The rocket test stand facilities constructed at Purdue University with a NASA facilities grant are an example of this type of real property which is not normally associated with university buildings, but which is essential to conduct modern research while training future scientists and engineers in such a fundamental aerospace field as propulsion. The other general need toward which NASA facilities are directed is illustrated by the space sciences laboratories built by the University of Pittsburgh. These facilities provide at Pittsburgh, for the first time, a suitably designed and equipped building in which investigators from many departments in the University can work together on the complex problems inherent in space ventures. In the Pittsburgh building, the professors and staff responsible for passing along to the community they serve the useful technology resulting from the space program,work alongside the professors and staff producing the knowledge and interpreting the research results. This particular project points up a prime objective of NASA facilities grants, that is, to provide facilities which are urgently needed and involve the largest possible productive segment of the University in the space program.

In responding to the space-oriented research facilities needs of the nation's universities, NASA has funded grants in most of the major geographical areas of the country, and has cooperated with the other agencies

in the federal government charged with assisting universities in their building program. Cooperative projects have been undertaken with the National Science Foundation, the National Institute of Health, and the Office of Education. Each of these agencies has its separate responsibilities to higher education, and when facilities projects have encompassed more than one of these responsibilities, the agencies have acted in concert without duplication of effort. Despite these combined efforts, the total needs of universities for adequate space in which to conduct graduate training and research are so numerous that many have remained unsatisfied.

The FY 1967 request of $7 million will permit acquisition of about two hundred thousand (200,000) square feet of new laboratory space.

Research

	1965	1966	1967
Research.....	$11,000,000	$13,000,000	$12,000,000

The purpose of research grants is to expand and improve the capabilities of the nation's universities to conduct research in space and aeronautical science and technology.

Research grants are awarded to:

Universities not currently participating in the national space programs. Such grants provide research opportunities which will encourage the development of new research talents and interests responsive to project or discipline challenges likely to be encountered in the exploration of space and;

Universities deeply involved in the space program, to augment and fill gaps in existing work and to consolidate related research activities.

Although the size, scope, and specific nature of each grant differs according to the capabilities of each institution, there is a general pattern common to all of them. This pattern has the following characteristics:

Attention is concentrated on an individual or group which serves as a focal point for space-related activity in the university.

The funding and research descriptions are flexible enough to permit shifts of emphasis within the program to areas of greatest importance as the research progresses.

The choice of specific method of attack rests with the university and the individual investigators, thus affording the institution an opportunity to utilize its resources in the most efficient manner and assuring the continued flow of research ideas.

Forty multidisciplinary research grants now exist in 40 universities, located throughout the country. Each university has different assets and capabilities, and our relationship with each varies accordingly. Through the support of quality work at selected institutions not currently participating in space research, the number of universities involved in space related problems is permitted to grow. By providing new opportunities to these institutions to work with us, many excellent research programs have emerged, new talents and skills have been developed, and new ideas have been brought to our attention. The net result is a broadening of our national base of research participation.

To the university already heavily involved in space-related research, this program provides an opportunity to make more efficient use of its assets by augmenting existing work, filling gaps in research programs, and consolidating related work. More importantly, however, it provides an opportunity for the development of multidisciplinary approaches to broad problems which require a focusing of talents from several different disciplines. Many of the scientific and technological problems facing NASA require an understanding of the behavior of large and complex systems that resist piece-meal attack, and their solution demands the concerted and cooperative effort that universities can provide by bringing together their many specialists from varied technical and scientific disciplines.

For the continuation and growth of these special purpose research programs in FY 1967, approximately 71 projects will be supported at a cost of $12 million. Sixty five of these grants will be for the continuation of projects supported in FY 1965, and the remainder will be to universities participating in this program for the first time.

OFFICE OF SPACE SCIENCE AND APPLICATIONS LAUNCH VEHICLE DEVELOPMENT PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The purpose of the Launch Vehicle Development Program is to ensure a timely and economical availability of launch vehicle capability to meet unmanned mission requirements. Continuing Advanced Studies of mission requirements defines needs in terms of improved vehicle performance. As the mission requirements exceed present vehicle capability, these performance increases are translated into required systems improvements, configuration changes, improved operating techniques, new stages, and new launch vehicles or combinations thereof. If major development is required to meet new mission needs, implementation of the development would be within the Launch Vehicle Development Program. The Scout and Delta programs, generated and implemented in this fashion, were completed in FY 1963. The Centaur development program is expected to be completed in a similar manner in FY 1967.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Supporting research and technology/Advanced studies.....	$7,100,000	$4,000,000	$4,000,000
Centaur development.....	89,400,000	51,300,000	29,700,000
Total.....	$96,500,000	$55,300,000	$33,700,000

Distribution of Program Amount by Installation:

John F. Kennedy Space Center, NASA.....	$1,321,000	$820,000	$700,000
Marshall Space Flight Center.	152,000	10,000,000	---
Goddard Space Flight Center..	1,557,000	250,000	---
Electronics Research Center..	100,000	200,000	250,000
Langley Research Center.....	735,000	570,000	600,000
Lewis Research Center.....	91,302,000	42,820,000	31,550,000
NASA Headquarters.....	1,333,000	640,000	600,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology/Advanced Studies

	1965	1966	1967
Advanced studies.....	$842,000	$500,000	$500,000

	1965	1966	1967
Supporting research and technology:			
Propulsion.....	$2,729,000	$1,245,000	$600,000
Guidance, control and navigation.....	285,000	200,000	500,000
Instrumentation and electronics.....	285,000	20,000	---
Structures and materials...	229,000	605,000	500,000
Vehicle engineering.....	130,000	1,430,000	1,900,000
FLOX.....	2,600,000	---	---
Total.....	$7,100,000	$4,000,000	$4,000,000

The purpose of Advanced Studies is to define vehicle requirements for future missions and to establish the methods by which needed performance, beyond current capabilities, can best be developed. These studies also provide indications of those areas of research and new technology development which may be most fruitful in terms of future mission benefits. The Supporting Research and Technology efforts are directed toward developing the new technology and techniques shown to be needed by the Advanced Studies. This facet of the program also provides for demonstration of new technology prior to full scale development efforts.

The FY 1966 and FY 1967 studies and technology efforts have been focusing on high-energy mission requirements for a small energetic (kick) stage as an addition to existing launch vehicles. The FY 1967 kick stage efforts will be directed at mission analyses, investigations of subsystem alternatives and vehicle adaptions, and program planning.

Studies are being conducted in the FY 1966 program on solid propellant performance prediction, operational hazards of electrostatic charges on vehicles, improved destruct systems, feasibility of adaptation of the Surveyor retromotor for use as launch vehicle stage propulsion, strapped down inertial guidance and radio guidance feasibility, fluorine hazards and comparison studies of high and low thrust for high velocity missions. Work will continue in FY 1967 on solid propellant prediction efforts, fluorine safety and, for the overall Launch Vehicle and Propulsion Programs, studies of advanced mission requirements, vehicle alternatives and program analysis.

The FLOX technology effort directed toward verifying the feasibility of adding liquid fluorine to the Atlas propellant system for performance improvement was completed with FY 1965 funds.

Centaur Development

	1965	1966	1967
Vehicle development.....	$77,206,000	$40,480,000	$17,000,000

	1965	1966	1967
Supporting services.....	$4,200,000	---	---
Instrumentation.....	100,000	---	---
Atlas boosters.....	4,250,000	---	---
RL-10-A3 engine improvements...	500,000	$10,000,000	$12,000,000
Propellants.....	3,144,000	820,000	700,000
Total.....	$89,400,000	$51,300,000	$29,700,000

The Atlas/Centaur is under development as a high-energy upper stage vehicle burning liquid hydrogen and liquid oxygen that will provide the required capability for NASA's unmanned lunar and planetary missions. The Centaur program has provided techniques for the handling, storage and use of liquid hydrogen in the space environment. Another feature of the Centaur vehicle is its utilization of an all-inertial guidance system through the complete mission profile.

This development program, initiated by the Advanced Research Projects Agency of the Department of Defense and transferred to NASA in 1959, consists of eight flight tests of the Centaur vehicle. Six of these flight tests have been completed.

After the failure of the first flight test, AC-1, on May 8, 1962, an extensive evaluation was made of the entire program by NASA and the various contractors. A basic reformation of the program was accomplished. With the exception of AC-5, which was destroyed when the Atlas booster failed shortly after launch, all subsequent flights have met all major development test objectives. The failure of AC-3 to achieve orbit occurred after all major test objectives had been met. The most recent success was AC-6, launched August 11, 1965, carrying a 2,084 pound dynamic model of the Surveyor into a simulated lunar intercept trajectory. AC-6 then successfully performed a retromaneuver so that the spacecraft stabilization system would not lock on the Centaur vehicle as a reference point. Flight data indicated that all planned flight events were nominal, and the injection was so accurate that a mid-course correction would not have been required to achieve lunar impact.

The last two development launches will demonstrate the parking orbit or two-burn capabilities of the Centaur vehicle. This is to be accomplished by first launching the vehicle into a 90 nautical mile parking orbit. The Centaur engines will be stopped for a 20 to 25 minute coast period, and then the engines will be restarted to burn until the required velocity is attained for a simulated lunar transfer trajectory.

General Dynamics/Convair is the prime contractor for the Centaur stage. This stage uses the RL-10-A3 engines developed under contract with Pratt and Whitney Aircraft Corporation, and a guidance system developed by Minneapolis-Honeywell as a subcontractor to General Dynamics. NASA has subsequently contracted directly with Minneapolis-Honeywell for the guidance system.

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The Lewis Research Center has been assigned management responsibility of the Centaur project. The RL-10-A3 development and improvement programs are under the direction of the Marshall Space Flight Center. Integration of the engines with the Centaur vehicle is under the management of Lewis Research Center.

Funding for FY 1967 is for completion of the developmental effort on the Centaur vehicle and improvement effort on the RL-10-A3 engines.

OFFICE OF SPACE SCIENCE AND APPLICATIONS LAUNCH VEHICLE PROCUREMENT PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objective of the Launch Vehicle Procurement program is to provide launch vehicles and launch support for unmanned space missions. In addition to the purchase of vehicle hardware, this program includes a broad spectrum of supporting activities required to meet each specific mission objective. The launch vehicles currently procured through this program are: Scout, Delta, Thor-Agena, Atlas-Agena, and Centaur.

Launch Vehicle Procurement is presented as a separate program, which is consistent with actual vehicle procurement practices, i. e., vehicles are ordered in specific quantities. However, in order to identify the amount of launch vehicle funding related to each of the various flight projects for the purpose of identifying total project requirements, such amounts are also shown with the applicable project presentation as a parenthetical notation.

To establish the quantity of vehicles to be ordered the following factors are considered: (1) the current and projected inventory; (2) vehicles ordered but not delivered; (3) current and projected launch schedules; and (4) procurement leadtimes required for vehicle delivery. Procurement of vehicles is adjusted to maintain minimum inventories; however, maintenance of some inventory level is necessary to provide the flexibility to meet changing requirements.

In addition to vehicle hardware procurement, the purchase of services associated with the launch of each mission is included in the Vehicle Procurement program. The costs of trajectory studies, mission modifications to the vehicle, launch crews, propellants, and other similar support are also included.

The Sustaining Engineering and Maintenance effort associated with each vehicle provides the means for keeping the operational vehicles and ground support equipment up-to-date to ensure high performance and reliability. This goal is achieved through product improvement programs, maintenance of ground support equipment, vehicle system engineering, and other supporting services. The cost of this part of the procurement program is not clearly identifiable with a specific mission and therefore these costs are not included in the parenthetical notations shown with each project.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Scout	$13,287,000	$11,700,000	$10,400,000
Delta	32,374,000	27,900,000	22,900,000
Agena	55,040,000	71,100,000	54,700,000
Centaur	44,814,000	64,000,000	64,000,000
Atlas	8,972,000	4,000,000	---
Total	$154,487,000	$178,700,000	$152,000,000

Distribution of Program Amount by Installation:

John F. Kennedy Space Center, NASA	$1,353,000	$2,507,000	$3,319,000
Goddard Space Flight Center	19,496,000	18,580,000	22,205,000
Pacific Launch Operations Office	99,000	---	---
Langley Research Center	13,737,000	11,600,000	10,400,000
Lewis Research Center	107,673,000	137,023,000	115,821,000
NASA Headquarters	12,129,000	5,625,000	---
Western Operations Office	---	3,365,000	255,000

The overall mission plan for launches during this period is:

Vehicle	Calendar Year 1965	Calendar Year 1966	Calendar Year 1967
Scout	4	3	8
Delta	6	6	9
Agena	4	7	11
Atlas	1	-	-
Centaur	2	4	4
Total	17	20	32

BASIS OF FUND REQUIREMENTS:

Scout Procurement

	1965	1966	1967
Vehicles	$1,962,000	$3,600,000	$3,600,000
Motors	3,279,000	1,928,000	2,500,000
Logistics and other	546,000	2,172,000	300,000
Sustaining engineering and maintenance	7,500,000	4,000,000	4,000,000
Total	$13,287,000	$11,700,000	$10,400,000

The purpose of the Scout Procurement program is to provide a reliable, relatively inexpensive vehicle for general space research. It is the smallest of the basic NASA family of launch vehicles and meets the requirements for a variety of small sized payloads for orbital, probe, and re-entry missions.

The Office of Space Science and Applications has assigned management of the Scout project to the Langley Research Center. Ling-Temco-Vought is the prime contractor for the production of Scout vehicles. There are two launch sites capable of launching the Scout vehicle: the Western Test Range in California, and Wallops Island, Virginia.

The logistic support of these launch sites has been integrated into a single effort within this program.

The first operational Scout vehicle was launched April 23, 1962. There have been 40 launches through the end of calendar year 1965 for a wide variety of NASA, Department of Defense, Atomic Energy Commission, and international missions.

The FY 1967 funds for Scout Procurement will be utilized to initiate new procurements of Scout vehicles and launch services. Funds will be applied to continued procurement of first, second, third, and fourth stage motors to meet CY 1967 launch requirements. Funding is also provided for other support requirements, such as adaptation of the Scout vehicles to satisfy spacecraft and other mission peculiar requirements.

To adequately provide Sustaining Engineering and Maintenance support for Scout missions, funds are required for continued effort in the areas of environmental testing, data reduction and analysis, engineering support, maintenance of ground support equipment at the two launch sites, publication of manuals, and other similar support.

Delta Procurement

	1965	1966	1967
Delta stages.....	$ 6,678,000	$10,300,000	$ 8,725,000
Thor boosters.....	10,200,000	9,144,000	9,000,000
Propellants.....	200,000	595,000	695,000
Third stages.....	554,000	861,000	480,000
Sustaining engineering and maintenance.....	14,742,000	7,000,000	4,000,000
Total.....	$32,374,000	$27,900,000	$22,900,000

The purpose of the Delta Procurement program is to provide a reliable launch vehicle for a wide variety of medium size satellites and small space probes.

The Office of Space Science and Applications has assigned management of the Delta project to the Goddard Space Flight Center. The prime contractor for the Delta launch vehicle is the Douglas Aircraft Corporation. Thor boosters are procured through the Air Force.

To date, the Delta vehicle has been launched only from the Eastern Test Range at Cape Kennedy. A second launch site capability is scheduled for completion in the Spring of 1966 at the Western Test Range in California, with an ensuing first Delta launch planned shortly thereafter. Launch services associated with the Delta vehicle are procured on an annual basis, and FY 1967 funds are planned to support requirements at both launch sites. Included in the FY 1967 request are funds to continue procurement of Thor boosters, Delta second stages and third stages to meet launch schedule requirements for the Delta vehicle.

Fiscal year 1966 Sustaining Engineering and Maintenance funds (along with the related funds for Construction of Facilities) will complete the establishment of the Western Test Range launch capability, and the improvement of the Delta vehicle to provide increased payload volume and weight.

Fiscal year 1967 Sustaining Engineering and Maintenance funds are planned to continue maintenance and updating of ground support equipment, mission analyses, performance studies, and miscellaneous minor improvement efforts.

Agena Procurement

	1965	1966	1967
Agena production.....	$15,756,000	$12,666,000	$11,339,000
Agena mission modifications....	12,949,000	31,049,000	14,613,000
Thor procurement.....	4,111,000	3,796,000	3,885,000
Atlas procurement.....	14,948,000	17,073,000	17,734,000
Propellants.....	577,000	516,000	1,129,000
Sustaining engineering and maintenance.....	6,699,000	6,000,000	6,000,000
Total.....	$55,040,000	$71,100,000	$54,700,000

In combination with Thor and Atlas boosters, the Agena second stage is employed extensively by NASA. The restartable Agena stage provides considerable latitude in mission capability among the various earth orbital and lunar or planetary missions.

The Agena was developed by the Air Force as a second stage for use in its programs. Early in 1960, NASA decided to use the Agena in combination with the Thor and Atlas boosters rather than develop a similar stage. However, each Agena stage must be modified to meet the specific mission requirements. NASA missions utilizing the Thor-Agena vehicle are presently planned to be launched into polar or near-polar orbits from the Western Test Range.

NASA uses the Atlas-Agena for its unmanned lunar and planetary exploration missions, such as Ranger, Mariner, and Lunar Orbiter; and to launch heavier scientific and applications satellites such as the Geophysical Observatories, the Astronomical Observatories, and the Applications Technology satellites. The Atlas-Agena is normally launched from the Eastern Test Range to support NASA missions, although capabilities for its launch exist at the Western Test Range.

The Office of Space Science and Applications has assigned project management to the Lewis Research Center. The prime contractor is the Lockheed Missiles and Space Corporation. Thor and Atlas boosters are procured through the Air Force.

Funds requested for FY 1967 will provide for continued procurement of the basic Agena stages, Atlas and Thor boosters, and the adaptation of the Agena stages for mission peculiar requirements. The necessary Atlas, Thor and Agena launch support, i.e., launch services, propellants, etc., will also be provided.

Fiscal year 1967 Sustaining Engineering and Maintenance funds are planned to continue efforts in shroud improvement, modifications and improvements to launch pad ground support equipment at both launch sites, and miscellaneous engineering support services.

Centaur Procurement

	1965	1966	1967
Vehicle production.....	$27,828,000	$39,100,000	$35,381,000
Atlas procurement.....	5,496,000	6,470,000	9,769,000
RL-10 engine procurement.....	4,700,000	3,200,000	3,100,000
Propellants.....	2,040,000	1,230,000	1,750,000
Sustaining engineering and maintenance.....	4,750,000	14,000,000	14,000,000
Total.....	$44,814,000	$64,000,000	$64,000,000

The Centaur vehicle is a high performance, general purpose launch vehicle for use on unmanned lunar, planetary, scientific, and applications missions which exceed the capability of the Atlas-Agena vehicle. The present procurement of operational Centaur vehicles is programmed to meet the requirements of the Surveyor unmanned lunar surface exploration project, and the Mariner unmanned planetary exploration project.

As with the Centaur development project, the Office of Space Science and Applications has assigned project management to the Lewis Research Center, and the prime contractor is General Dynamics/Convair, San Diego, California. Pratt and Whitney Aircraft Corporation of East Hartford, Connecticut and West Palm Beach, Florida is an associate contractor for the 15,000 pound thrust liquid hydrogen engines, and Minneapolis-Honeywell of St. Petersburg, Florida is an associate contractor for the Centaur guidance system.

OFFICE OF SPACE SCIENCE AND APPLICATIONS — BIOSCIENCE PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Bioscience program continues to have two primary objectives. The first is the search for extraterrestrial life, with the primary emphasis directed initially to the planet Mars. The specific aims of this objective include: (a) physical and chemical evaluation of the martian surface as a possible environment for life; (b) determination of whether or not life exists, or has existed, on Mars; (c) if life in some form exists, determination of its characteristics; and (d) if no life exists on Mars, investigation of the pattern of chemical evolution in order to evaluate the probability of its future occurrence either spontaneously or by contamination. The search for life on Mars is being implemented in two ways. Since a determination of the existence of martian life requires at least the landing of life-detection experiment packages, the feasibility of conducting such studies using an Automated Biological Laboratory is being studied. Such an integrated system will be capable of performing various experiments in a sequential fashion rather than having completely discrete experiments aboard. The concept of such a system includes the ability to reprogram its analyses, repeat various experiments; and perform necessary computations on the data it obtains. In addition, a program of planetary quarantine effort was established to minimize the possibility that terrestrial organisms could contaminate Mars and thus destroy its scientific value as a means of testing the various hypothesis regarding the existence of extraterrestrial life. The Voyager spacecraft will provide the first capability for landing a sterilized scientific package on the surface of Mars. Continuous effort will be made before initiation of the Voyager flights to assure an adequate understanding of and solution to the very complex problems associated with this effort before commitment to flight hardware procurement.

The second objective is directed towards attaining a thorough understanding of the effects of the space environment on terrestrial organisms. Its implementation includes ground-based experiments and the Biosatellite project. The Biosatellite will study the biological effects of weightlessness, the effects of an environment disassociated from the influence of the earth's rotation, and the combined effects of radiation and weightlessness. Nineteen experiments have been assigned to the respective payloads of the Biosatellite spacecraft. Each of the three principal payloads has a backup in the event of failure. If the flights are successful, the backup spacecraft can be utilized to repeat the experiments for confirmation of the results.

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A supporting program of basic and applied research is being conducted in conjunction with and support of the Bioscience program objectives. This effort includes such work as structural and chemical analysis of terrestrial fossils as a means of tracing the history of life on earth in order to improve our capability of looking for life or its precursor chemicals on the moon and planets, the development of automatic systems for conducting chemical urinary analyses during flight, analysis of perception in relation to continual transformations of the visual scene of the perceiver, and the development and miniaturization of a biological telemetry device which may be utilized for telemetry of biological activity aboard space vehicles.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Supporting research and technology	$12,501,000	$15,100,000	$14,700,000
Biosatellite	16,000,000	21,600,000	20,700,000
Total	$28,501,000	$36,700,000	$35,400,000

Distribution of Program Amount by Installation:

Goddard Space Flight Center	$385,000	$420,000	$420,000
Jet Propulsion Laboratory	1,519,000	2,337,000	2,500,000
Wallops Station	60,000	100,000	100,000
Ames Research Center	17,392,000	22,599,000	21,900,000
Langley Research Center	---	30,000	30,000
NASA Headquarters	9,145,000	11,214,000	10,450,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1965	1966	1967
Exobiology	$4,900,000	$5,000,000	$5,000,000
Environmental biology	2,800,000	2,800,000	2,800,000
Behavioral biology	2,100,000	2,100,000	2,100,000
Physical biology	1,900,000	1,900,000	1,900,000
Automated biological laboratory	---	1,000,000	1,000,000
Planetary quarantine	---	1,000,000	1,000,000
Bioscience investigations for manned missions	801,000	1,300,000	900,000
Total	$12,501,000	$15,100,000	$14,700,000

Exobiology

The Exobiology program supports the search for extraterrestrial life, including ground-based studies regarding the origin of life on earth, with particular emphasis on the possibility that some form of life may exist on the planet Mars. The ground-based studies are directly relevant to the search for extraterrestrial life since the data derived from these studies may lead to the formation of testable hypotheses regarding the origin and nature of long-evolved or incipient planetary life. In addition, the development of spacecraft experiment packages for biological exploration of the planets may be affected by these investigations as well as by studies of the planetary atmospheres and surfaces and fly-by missions by spacecraft such as Mariner IV.

An analysis of fossil remains in ancient terrestrial rocks has provided data of great interest in tracing the history of terrestrial life. One study employing high resolution mass spectrometry has provided quantitative indications that when molecules associated with life are analyzed in recent and ancient sediments, the quantities of these molecules decrease at a predictable rate as the age of the sediments increases. This technique is applicable to the geochemical analysis of Apollo lunar samples, the analysis of organic matter in meteorites, and the automated analysis of life-related compounds on Mars.

Proteins and their amino acids are universal components of all terrestrial organisms, and the most commonly abundant organic chemical components of living things. Although about 60 amino acids are known to exist, 18 are constituents of our contemporary biota. Of these, about half remain stable for millions of years. These facts suggest that gas chromatography, mass spectrometry, and the application of classical chemical techniques may be utilized in the biological exploration of Mars.

The development of a completely automatic soil processor capable of analyzing surface planetary substances such as soil, dust, and debris provides another way of seeking to detect and analyze extraterrestrial biological activity. This device is based on the property of organic chemicals generated by living matter to twist a beam of plane polarized light as the light passes through. All living species select, contain, and produce optically active substances. The property is retained in recent biological residues and in ancient organic deposits.

The moon is considered by many biochemists to represent a unique opportunity for study of prebiological chemistry and to provide an indication of organic chemistry that would probably have existed on the earth prior to the origin of life, maintained in "cold storage" for millions or billions of years. This is amenable to study by means of samples returned by Apollo missions or in-situ study by automated analytical equipment.

Environmental Biology

Research in the Environmental Biology area is concerned with the biological effects of the space environment on various living earth organisms, including man. Ground-based bedrest experiments with men were made for the primary purpose of determining the extent and cause of musculo-skeletal changes that occur with prolonged bedrest. Studies associated with these experiments indicated that definite cardiovascular deconditioning occurs after 30 days of bedrest and that almost complete recovery can be achieved by two weeks of ambulatory activity.

Research on the effects of stress on the cardiovascular system during simulated space flight has shown that cardiac rhythms (pulse and pressure) have been seriously altered by high noise levels and changes in light intensity.

The metabolic effects of prolonged weightlessness will be studied in the Biosatellite and other manned and unmanned space missions by a system under development by the Jet Propulsion Laboratory. This system will provide for in-flight analyses of physiologically significant urinary biochemical constituents. The system will be automated and will have a functioning capability of about 45 days. Once every six hours, samples of urine will be analyzed and the results telemetered to the experimenter providing him with information regarding the well-being of the subject relative to skeletal, muscular, and general nutritional status as these are affected by space flight.

Other studies have extended our knowledge of the environmental extremes which organisms can endure and still survive. Organisms obtained from such earth habitats as hot springs, deserts, and cold arctic tundra have been grown under circumstances usually considered lethal. The data resulting from these studies are of interest in considering the possibility of life in the reducing atmosphere of Jupiter.

Behavioral Biology

Recent research has emphasized ground-based studies preparatory to in-flight experiments on the effects of zero gravity and other conditions peculiar to the space environment on the behavior of organisms. Emphasis has been placed on the capacity of organisms to adjust to alterations in gravity, particularly the determination of responsiveness of gravity receptors to transient and prolonged stimulation. Additional studies have been conducted on the orientation of biological organisms in time and space in the absence of terrestrial cues.

Research has involved neurophysiological, biochemical, and behavioral analyses which have further elucidated brain-behavior relationships of importance to organisms in environmental adaptation. These studies have emphasized those neurobehavioral relationships which maintain activation and alertness. Other research has been concerned with problems of information storage and

retrieval in living systems, using biochemical biophysical, and electro-physiological approaches. Related studies on processes such as attention, discrimination, perception, and motivation, as well as complex sensori-motor functions have been productive of new insights into the mechanisms of behavior and their interactions with the space environment.

Physical Biology

The Physical Biology program supports research in comparative physiology, bio-instrumentation and molecular biology. Research in comparative physiology includes studies on living organisms which specifically lend themselves to investigations in orbiting biological vehicles, on the nutritional requirements of living organisms for prolonged space travel, and on physiological phenomena and dynamics of various systems. Nutritional studies have shown that men can live on chemically-defined liquid diets for at least six months without apparent ill effects. The dynamics of the body temperature regulatory system, the blood flow (cardiovascular system), and the hormonal system are being studied by physical modeling and analysis in an attempt to understand the mechanics of these systems under normal conditions as well as in stress situations.

Various types of biological instrumentation are being developed to measure and analyze various biological, biochemical, and biophysical phenomena. In biological telemetry, work is proceeding on the development of a multichannel sensing implantable device in order to measure, simultaneously, a number of biological and behavioral activities. In electron microscopy, the development of superconducting lenses may make it possible to observe microscopic material for longer periods of time.

In the area of molecular biology, research is being conducted on biological systems at the molecular and cellular levels. In work on the coding of amino acids during protein synthesis, it has been calculated that the numerical possibilities of amino acids sequence in DNA (deoxyribonucleic acid) are of such magnitude that they can account for the evolution of all living forms.

Automated Biological Laboratory

In order to conduct life detection studies on Mars, it will be necessary to develop an automatic, highly reliable, technically sophisticated biological experiment system. The concept of an Automated Biological Laboratory (ABL) is based upon the conviction of biologists that no single life detector will provide results capable of unambiguous interpretation. The concept approach being investigated through a feasibility study with the Aeronutronics Division of the Philco Corporation envisions a system which can look for many characteristics of life at one time, and which has the capability of reprogramming its analyses, repeating its experiments, performing the necessary computations on the resulting data, and transmitting this data to earth.

This integrated experiment system could perform scientific explorations designed to determine the physical and chemical characteristics of Mars, detect the existence of macromolecules, directly determine the existence and

characteristics of "life", and take pictures, both macroscopic and microscopic, through the light spectra from infrared through the visible and into the ultraviolet.

The aeronutronics' study established the feasibility of the concept of an integrated package of biological experiments, and presented a possible design for an ABL based chiefly on the current state of technology. The study also resulted in the suggestion that thirty five experiments could be included on the first ABL. These experiments would only require twenty seven instruments, however, since several of the instruments could perform multiple experiments.

Planetary Quarantine

The search for extraterrestrial life has the prerequisite that no terrestrial organisms must be conveyed to the planets prior to the time scientific payloads are landed. It is also highly important that life detection instruments are devoid of earth organisms when they land on the planet. Otherwise, they would detect the life they carried when operated on the planets. In order to achieve the goal of preventing the transmission of earth organisms to the planets, various methods have undergone rigorous and intensive study. Current evidence indicates that neither cold, vacuum, ultraviolet, nor solar radiation will reduce microbial life to acceptable levels.

Since the only two agents that kill microbial life, both on the surfaces and in the interiors of solids, are heat and ionizing radiations, and since radiation as a sterilizing agent is expensive, complex, and dangerous, the planetary quarantine program is seeking to utilize heat as the primary means of spacecraft sterilization. As a result, it is necessary to develop spacecraft parts that will withstand the heat required. A related requirement is that the quantity of biological loading on the spacecraft at the time it is ready for sterilization must be limited. Research indicates this may be accomplished most effectively by applying heat or a decontaminate to the spacecraft parts and then assembling them in ultraclean rooms. Subsequently, terminal sterilization will be accomplished by heating the spacecraft in dry nitrogen for a period of time proportional to the number of living organisms on board. Finally, it will be necessary to protect the sterile spacecraft from recontamination during launch from the earth by enclosing the sterile landing capsule in a hermetically sealed canister which would be removed when the spacecraft has reached outer space.

Bioscience Investigations for Manned Missions

For Gemini and Apollo earth-orbiting missions, experiments are in the development or flight stage; three of these have already flown, yielding significant results. The synergistic effects of radiation and weightlessness on human white blood cells were demonstrated during the GT-3 flight. Vision experiments conducted on GT-5 and GT-7 showed that the visual performance of the astronauts did not decline during the period of flight and that the ground observations made from orbital altitudes were within the predicted range of statistical probability. Two unique experiments being prepared for Apollo earth-orbital development flights deal with cell microscopy and stimulus-response relationships of the gravireceptors under conditions of acceleration and weightlessness.

Promising experiments have been identified, and preliminary mission parameters, and spacecraft requirements for a manned zero-gravity laboratory are in the process of definition for the post-Apollo time period. Other manned projects under study concern the use of spacecraft for the sterile collection and return of lunar samples for biological analyses on earth, and bioscience problems associated with manned interplanetary missions.

Biosatellite

	1965	1966	1967
Spacecraft	$10,980,000	$12,334,000	$12,900,000
Experiments	4,936,000	8,641,000	7,100,000
Ground operations	84,000	625,000	700,000
Total Spacecraft and Operations	$16,000,000	$21,600,000	$20,700,000
Thor Delta (Launch Vehicle Procurement Program)	(2,500,000)	(9,500,000)	(4,500,000)
Total (including Launch Vehicles)	($18,500,000)	($31,100,000)	($25,200,000)

The Biosatellite represents the first systematic effort to investigate the effects on biological systems of such unique aspects of the space environment as weightlessness, the effects of combined weightlessness and radiation, and the removal of living systems from the direct influence of the earth's periodicity. The experiments will study biologic functions at the cell, tissue, organ, and organism levels in a wide variety of plants and animals. In order to accommodate the various experiments, three missions are required.

The first flight will investigate the biological effects on seedlings, plants, and simple forms of life of weightlessness, and the effects on plants, animal cells, and insects of the combination of weightlessness and radiation. It will have a duration of three days. The second flight, scheduled for 30 days, will investigate the effects of weightlessness on a primate's general metabolic behavior and performance, and cardiovascular and nervous systems. The 21-day flight consists of general biology experiments to determine the effects of weightlessness on plant growth and development, growth of isolated human cells, gross body composition and function in mammals, and circadian (24-hour) rhythms indigenous to the organism.

The Biosatellite will be launched from Cape Kennedy by the two-stage, thrust-augmented Thor Delta launch vehicle. The experiments will be contained in the re-entry vehicle while other supporting equipment will be placed in the adapter section. The adapter will be separated from the re-entry vehicle prior to the retro maneuver. Recovery of the spacecraft will be by the United States Air Force using aerial recovery techniques. A backup recovery method will employ various water recovery techniques. The recovered capsule will be delivered to the laboratory at Hickam Air Force Base, Honolulu, within six hours for post-flight examination of the experiments.

It is anticipated that the Biosatellite flights will result in data which will have a wide range of applicability. The testing of biological hypotheses in the areas of genetics, developmental biology, environmental physiology, and general metabolism will be one result of these flights. The Biosatellite should also provide valuable data pertaining to biological requirements for prolonged manned space flight, and the possibility of delayed effects appearing in later life or subsequent generations of animal subjects, with possible applications to man. Also, these flights should result in the development and test of new instrumentation techniques, surgical preparations, and other procedures and devices which may have medical and other applications to human beings.

Fiscal year 1964 and prior years funding for this six flight program amounted to $10,412,000. Funding for FY 1965 provided for design, fabrication, and testing of the spacecraft, and continued funding for experiment development. Funding for FY 1966 provides for fabrication and testing of the spacecraft, subsystem and system acceptance and qualification tests of the prototype vehicle, assembly and functional testing of the 3-day and 30-day flight vehicles and continued funding for experiment development with primary emphasis on the 3-day flight. Funding for FY 1967 will emphasize fabrication, qualification, and systems testing of the 30-day and 21-day spacecraft, and continued funding on experiment development for these two spacecraft. Funding requirements for FY 1968 to completion including launch vehicles are estimated to be $15,628,000.

OFFICE OF SPACE SCIENCE AND APPLICATIONS METEOROLOGICAL SATELLITES PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objectives of the Meteorological Satellites Program are: (1) to develop a satellite capability for global and local readout of cloud cover day and night, global quantitative measurement of temperature, wind, moisture, and other meteorological factors as a function of height under continuous and variable time scales; (2) to develop and implement for the Department of Commerce, Environmental Science Services Administration (ESSA), the Tiros Operational Satellite (TOS) System; (3) to develop a meteorological soundings system to explore and study the atmosphere in the region 20 to 60 miles above the earth; (4) to develop the necessary meteorology-related spacecraft technology and supporting equipment; and (5) to explore the use of manned spacecraft for meteorology.

Objectives (1) and (2) are accomplished by the Tiros/TOS Improvement, Meteorological Flight Experiments and Nimbus projects; objective (3) is accomplished by Meteorological Sounding Rockets; and objectives (4) and (5) are accomplished by the Supporting Research and Technology/Advanced Studies.

Ten Tiros spacecraft, including Tiros X funded by ESSA, have been successfully launched since April 1960 providing cloud cover and meteorological data for research and operational use. Tiros IX and X were launched in 1965. Tiros IX, a research and development satellite in a "wheel" configuration, was essentially the prototype spacecraft for the TOS System to be operated by ESSA starting in 1966. Tiros X was launched into polar orbit instead of a sharply inclined orbit to provide more global coverage.

Nimbus I, successfully launched in August 1964, had an active life of about one month due to failure of the solar array drive mechanism. Three additional flights are planned, one each in 1966, 1967 and 1969. These flights will test: (1) improved power supply and data acquisition systems; (2) initial sensors for obtaining vertical measurements of meteorological data; and (3) sensors and systems to provide full global daytime and nighttime cloud cover data for operational use by utilizing both direct readout capability and stored data for release to data acquisition stations. Research and application of meteorological sensors on non-meteorological satellites is conducted in the Meteorological Flight Experiments project with present effort directed to tests on the Applications Technology Satellites (ATS). Approximately 50 large research rockets and 100 small developmental sounding rockets are launched per year at the current level of effort to explore the region 20 to 60 miles above the earth and to obtain meteorological data from this region. In addition, the project includes field experiment support to acquire atmospheric data in the 20 to 60 mile region with cooperating foreign countries. The investigation of scientific techniques; design and development

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of advanced components for general application; improved component reliability and lifetime; study of data acquisition techniques; and feasibility studies on future spacecraft design and capabilities are conducted under Supporting Research and Technology/Advanced Studies.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Supporting research and technology/advanced studies.....	$7,311,000	$8,300,000	$9,100,000
Tiros/TOS improvements.....	4,100,000	3,700,000	2,600,000
Meteorological flight experiments.....	1,200,000	3,900,000	5,500,000
Nimbus.....	16,000,000	20,000,000	23,400,000
Meteorological soundings.....	2,380,000	3,000,000	3,000,000
Total.....	$30,991,000	$38,900,000	$43,600,000

Distribution of Program Amount by Installation:

Marshall Space Flight Center.	$120,000	$170,000	$170,000
Goddard Space Flight Center..	29,505,000	35,400,000	39,300,000
Wallops Station.....	---	180,000	140,000
Electronics Research Center..	175,000	450,000	500,000
Langley Research Center.....	425,000	630,000	630,000
NASA Headquarters.....	766,000	2,070,000	2,860,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology/Advanced Studies

	1965	1966	1967
Synchronous meteorological satellite.....	---	$145,000	---
Sensor requirements and evaluation.....	$2,554,000	2,635,000	$2,335,000
Meteorological component development.....	2,215,000	2,044,000	1,795,000
Meteorological sensor development.....	1,276,000	496,000	690,000
Advanced systems and components	975,000	1,680,000	2,080,000
Advanced studies.....	---	100,000	100,000
Applications for manned space missions.....	291,000	1,200,000	2,100,000
Total.....	$7,311,000	$8,300,000	$9,100,000

The objectives of the Supporting Research and Technology/Advanced Studies are: (1) to develop and evaluate components for potential meteorological satellite system application; (2) to design and develop satellite sensors for the detection and controlled acquisition of meteorological data directly from the atmosphere and from other sources; (3) to investigate scientific techniques and tools for the systematic observation, analysis and subsequent interpretation of meteorological atmospheric phenomena; (4) to optimize satellite performance and information retrieval techniques through advanced system analyses; and (5) to conduct advanced studies on future meteorological satellite systems and components. The results obtained from this endeavor contribute both to achieving the research and development goals of NASA and to the development of the operational meteorological system for ESSA.

Project direction is assigned to the Office of Space Science and Applications at NASA Headquarters, with implementation by Headquarters, Goddard Space Flight Center, Electronics Research Center, and Marshall Space Flight Center.

Funds were expended in FY 1965 and prior years for the design and evaluation of electronic and mechanical instrumentation packages to convert, amplify and process data that will be acquired by advanced optical and infrared sensors. Significant advances were achieved in developing engineering prototypes of separate satellite cameras to achieve automatic day-night coverage; to obtain panoramic high resolution data; and to provide real-time readout by continuous image dissection. New strides were made in satellite data storage techniques; data compaction studies were initiated to gain greater data capacity. Advanced satellite control and stabilization methods were investigated, leading the way to vastly improved meteorological instrument platforms. Funds were also utilized for new developments in rocket wind measurements, on initial efforts to measure stratospheric temperatures and the thermal structure of the atmosphere, and in the study of microwave sensing techniques and sferics measuring techniques. A feasibility study of a synchronous meteorological satellite and studies of necessary camera resolutions for highly eccentric and synchronous orbits were also conducted.

In FY 1966 efforts are continuing in many of the above areas, such as an improved automatic picture transmission (APT) camera and storage system, and improved elements for the interrogation, recording and location subsystem (IRLS) for processing meteorological data from remote instrumented platforms. Research has been continued into the relationship between the heat energy budget of the earth and large scale atmospheric phenomena, and into continued development of an interferometer, spectrometer and other instruments to measure the structure and radiation of the atmosphere. Techniques are being developed to measure the intensity and location of sferics signals, and the atmospheric density by measurement of the refraction of starlight. The flight model of a rocketborne ozonesonde is being completed. Advanced simulated and scaled down systems are being completed for the optimization of satellite control and power components with emphasis on long life and reliable operation. Studies are also being performed in the area of meteorological experiments for manned earth orbiting satellites. An advanced mission study will be undertaken to determine the system parameters of future operational missions for meteorological satellites.

In FY 1967, funds are required for design and development work on remote microwave radiation sensors to take advantage of recent break-throughs in frequency-multiplier components at experimental millimeter wavelengths in the electromagnetic spectrum. Prototypes of advanced new cameras on which work was initiated in prior years will be qualified for space flight. Advanced satellite control techniques, to replace present reaction wheels and associated gas-fed nozzles with passive gravity reacting masses and improved momentum damping techniques, will proceed beyond initial study stages. The design of a flexible automatic computerized telemetry system will begin a two-year development period, providing an extremely versatile method of collecting several types and rates of environmental data aboard the satellite for transmittal to the ground. Microminiaturized transmitters and receivers will be produced for various satellite needs, and will significantly advance the present capabilities for very low power, high reliability, and compactness in physical size. Solid state devices will be investigated as a possible replacement for some of the pick-up tubes presently used, and will result in improvements in life and reliability. Advanced mission studies will be continued on future operational meteorological systems, leading towards a second generation operational satellite system.

Applications for manned space missions include the study and development of scientific investigations and advanced remote sensing equipment for manned orbital spacecraft. These experiments will be utilized for the observation of atmospheric phenomena and its effects on the terrestrial environment. Several investigations of this type have taken place on manned Gemini flights. Studies of experiments for Apollo manned orbital missions were initiated in FY 1965 and FY 1966 to select experiments to take full advantage of manned space flight missions and capabilities. Fiscal Year 1967 funds will be used to continue this effort.

Tiros/TOS Improvements

	1965	1966	1967
Spacecraft	$1,400,000	---	---
Ground support	1,250,000	$400,000	---
TOS improvements	1,450,000	3,300,000	$2,600,000
Total Spacecraft and Support	$4,100,000	$3,700,000	$2,600,000
Delta (Launch Vehicle Procurement Program)	(400,000)	(---)	(---)
Total (including Launch Vehicles)	($4,500,000)	($3,700,000)	($2,600,000)

The successful launch and operation of Tiros IX has demonstrated the feasibility of obtaining nearly global cloud coverage of the sunlit portion of the earth on a daily basis. The objectives of the continuing Tiros research and development project are to provide developmental support for the TOS system.

During 1965, the ninth and tenth Tiros satellites were successfully launched. Tiros IX demonstrated the capability of a cartwheel configured spacecraft to provide global daylight cloud cover pictures on a daily basis. Tiros IX has definitely established the feasibility of the cartwheel concept for the Tiros Operational Satellite (TOS) system. With Tiros IX data, ESSA routinely prepared daily global cloud maps for use in operational weather forecasting. Tiros X, which was the first Tiros spacecraft funded by ESSA, was launched in July 1965 to insure that there would be satellite coverage during the 1965 hurricane season. These satellites, together with Tiros VII and VIII which continue to operate in orbit, have made possible world-wide cloud coverage since February 1965.

The Tiros Operational Satellite (TOS) improvements effort initiated in FY 1965 provides for the research and development of components and subsystems towards meeting the stated evolutionary requirements of the TOS system. The requirements include the following objectives: (1) increased reliability, (2) extended life, (3) expanded sensor capability, and (4) improved operational capability. Attainment of these objectives will result in less frequent satellite replacement and a more economical operational system. Presently, two separate TOS spacecraft are required, one to provide global cloud cover data and another to provide local cloud cover data. The major objective of our TOS improvements effort has been directed towards the incorporation of both of these capabilities into a single spacecraft by combining a tape recorder with automatic picture transmission (APT). The next step beyond this is the effort to replace the camera systems with the High Resolution Infrared Radiometer (HRIR) to give TOS a nighttime global cloud cover capability. A feasibility study has already been completed covering the synchronization of the radiometer scan with spacecraft rotation to produce good quality cloud pictures. A further effort to extend the HRIR capability to both day and night (only the latter was demonstrated by Nimbus I) is already underway. This is the program to attain the desirable objective of a single operational spacecraft with both day and night global cloud cover capability.

The Office of Space Science and Applications is responsible for the overall management of this project. Responsibility for project management is assigned to Goddard Space Flight Center. The major spacecraft contractor is Radio Corporation of America.

The FY 1964 and prior year funding for the currently approved 10 flight program, including launch vehicles, amounted to $43.5 million. The 1965 funds were utilized to complete funding for the development and launch of Tiros IX, ground operations to support Tiros VII, VIII, and IX in orbit, and improvements to the TOS system. The FY 1966 funds are being used to incrementally fund for the APT with recorder developments, ground operations to support Tiros VII, VIII, IX, and X, and improvements to the TOS system. The FY 1967 request will continue funding of TOS improvement subsystems.

Meteorological Flight Experiments

	1965	1966	1967
Meteorological flight experiments.....	$1,200,000	$3,900,000	$5,500,000

The objective of the Meteorological Flight Experiments effort is to conduct meteorological research and development on non-meteorological satellites and space vehicles. Meteorological experiments will be conducted on Applications Technology Satellites to: (1) evaluate feasibility of the operation of meteorological sensors and components aboard gravity gradient stabilized spacecraft at medium and synchronous altitudes; (2) test new camera systems and techniques aboard both spin stabilized and gravity gradient stabilized spacecraft; (3) demonstrate new concepts in weather data collection via synchronous satellites; and (4) evaluate the utility of weather data dissemination via synchronous altitude satellites. The spin scan camera experiment planned for the first ATS, ATS-B, will investigate the meteorological utility of cloud photographs taken from synchronous altitude to detect and track storms, particularly short-lived phenomena such as thunderstorms, waterspouts and tornadoes. Experience derived from this initial experiment will be used to develop new sensors and techniques for obtaining cloud data from synchronous altitude on ATS-C, D, and E.

The Office of Space Science and Applications is responsible for the overall management of this project. Responsibility for project management is assigned to Goddard Space Flight Center.

This project was initiated in FY 1965. Fiscal Year 1965 funding was utilized to procure and modify high and low resolution cameras and provide for ground equipment and integration support for the experiments for ATS-A. Fiscal Year 1966 funds are being used to procure vidicon cameras for ATS-A, to procure image dissector cameras for ATS-C, flight hardware for the weather data dissemination (WEFAX) experiment, and to provide ground support of the spin scan camera experiment on ATS-B. The FY 1967 funds are required to complete procurement of the high and low resolution cameras for ATS-A, the image dissector or equivalent spin scan camera, and Omega Position Location Experiment (OPLE) spacecraft hardware for ATS-C; to initiate the camera and WEFAX hardware development for ATS-D and E; and to incrementally fund the unique ground equipment, plus operations and data evaluation for the ATS meteorological experiments. It is anticipated that these experiments will help to define the configuration of a synchronous meteorological satellite.

Nimbus

	1965	1966	1967
Spacecraft.....	$9,032,000	$11,795,000	$9,500,000
Experiments.....	3,891,000	4,825,000	9,900,000
Ground operations and support..	3,077,000	3,380,000	4,000,000
Total Spacecraft and Support.	$16,000,000	$20,000,000	$23,400,000
Thorad-Agena (Launch Vehicle Procurement Program).....	(3,898,000)	(3,742,000)	(5,331,000)
Total (including Launch Vehicles).....	($19,898,000)	($23,742,000)	($28,731,000)

The objectives of the Nimbus project are: (1) to develop a spacecraft with adequate power supply and stabilization to test a number of meteorological sensors; (2) to develop a variety of meteorological sensors to obtain day and night cloud cover and to obtain atmospheric data such as pressure, temperature, wind, and water vapor at various altitudes over the globe; and (3) to test these sensors and associated data acquisition and handling techniques prior to recommending their use on the operational systems funded by ESSA. The data obtained are made available for meteorological research and operational use to the ESSA and other domestic and foreign weather services. The Nimbus spacecraft is larger than the TIROS or TOS and is oriented to view the earth at all times; thus, it provides a basic satellite system for testing a variety of subsystems sensors and meteorological experiments.

The successful launch of Nimbus I on August 28, 1964, proved the basic spacecraft configuration and the usefulness of the meteorological sensors tested which included three vidicon cameras for global daytime cloud cover data, a high resolution infrared radiometer (HRIR) for global nightime cloud cover and the automatic picture transmission (APT) system for direct transmission of realtime daylight cloud cover pictures to small local weather stations. A failure in the solar array drive reduced power which caused the termination of useful data after approximately one month of successful operation. A new experiment, a Medium Resolution Infrared Radiometer (MRIR) will be flown, in addition to improved versions of the sensors tested on Nimbus I. The MRIR experiment will permit a full global study of the earth's heat balance, and represents one of the most significant meteorological experiments so far undertaken. In addition to the MRIR, the Nimbus C spacecraft will test vidicon cameras and a High Resolution Infrared Radiometer (HRIR) for global and local cloud cover data, both day and night. Nimbus C will provide ESSA in nearly realtime HRIR data for operational purposes and initiate experimentation with nighttime direct local readout of HRIR data through local APT ground stations. Modifications have been made to the solar array drive mechanisms in the spacecraft.

The current Nimbus program includes the development of two additional spacecraft (Nimbus B and D) scheduled for launch in 1967 and 1969 respectively. Significant spacecraft and meteorological sensor advances are being developed for testing on these flights such as: (1) a 50-watt radioisotope thermoelectric generator (RTG) which will demonstrate the feasibility of RTG long life power supplies for meteorological satellites; (2) new experiments for determining the temperature profile and the water vapor content of the atmosphere such as spectrometers developed by NASA and ESSA; (3) a sensor to measure the solar flux in the ultraviolet spectral region to determine its influence on the upper layers of the atmosphere; and (4) initial experimentation in collecting, recording, and relaying data from a number of sensors placed on and above the earth's surface to record atmospheric and meteorological data. These Nimbus flights will test the initial sensors for obtaining vertical measurements of meteorological data such as temperature and water vapor content, and test sensors and systems to provide full global daytime and nighttime cloud cover data for operational use by direct readout and also by stored data for release to data acquisition stations.

The Office of Space Science and Applications, NASA Headquarters is responsible for the overall management of the Nimbus project. Responsibility for project management is assigned to the Goddard Space Flight Center. The major contractors are General Electric for integration and test of the spacecraft and for the controls subsystems and the Radio Corporation of America for camera subsystems.

Fiscal Year 1964 and prior years funding including launch vehicles amounted to $107.3 million. Fiscal Year 1965 funds were utilized to complete the Nimbus C spacecraft, incremental funding of the Nimbus B spacecraft, experiments, and related ground operations and support. Fiscal Year 1966 funds are being utilized for final preparation, launch and ground operations for Nimbus C, incremental funding to continue the Nimbus B spacecraft, experiments, ground operations, and support efforts, and to initiate definition and design studies of the Nimbus D spacecraft and experiments. Fiscal Year 1967 funds are required for ground operations and support of the Nimbus C spacecraft to be launched in 1966; to continue the development of the Nimbus B spacecraft; and more advanced experiments and initial hardware development for the Nimbus D spacecraft. Funding requirements including launch vehicle procurement for FY 1968 to completion of this four spacecraft flight program are estimated to be $56.2 million.

Meteorological Soundings

	1965	1966	1967
Large research sounding rockets.	$1,920,000	$1,920,000	$1,920,000
Sounding rocket system development.....	425,000	630,000	630,000
Field experiment support.....	35,000	450,000	450,000
Total.....	$2,380,000	$3,000,000	$3,000,000

The objectives of Meteorological Soundings Program are to: (1) develop the systems and techniques for exploration of the region 20 to 60 miles above the earth; (2) investigate the structure and characteristics of the upper atmosphere; and (3) provide for the exchange of data obtained from this region among cooperating countries. Research indicates that this region may act as an important link between the sun's energy and the dynamics of the weather of the lower atmosphere.

The objective of the large research sounding rockets effort is to develop and improve sensors and techniques for obtaining meteorological data on the composition, structure and behavior of the atmosphere in the region 40 to 60 miles above the earth. The objective of the small sounding rocket system development effort is to develop a reliable, inexpensive, simplified system, including the rocket, sensors, and data acquisition techniques, for obtaining similar data in the region 20 to 40 miles above the earth. The field experiment support effort provides for the sounding rocket experiments in cooperation with other countries. NASA is cooperating with several foreign countries in assisting them to establish meteorological rocketsonde facilities. Through this support, useful data are obtained over the territories of cooperating foreign countries on a cost-sharing basis, involving no exchange of funds.

Fiscal Year 1964 and prior year funding amounted to $4.1 million of which $3.5 million was utilized for large research rockets and $600,000 for small rocket development.

During FY 1965, 49 large research rockets were launched consisting of 26 grenade experiments, 13 sodium vapor trail and 10 pitot-static tube experiments. In January 1965, Point Barrow, Alaska was established as a launch site and provided measurements of the atmospheric structure during the Arctic night for comparison with measurements at other sites with which they were coordinated. Eight of the pitot-static tube experiments were launched from shipboard in the South Pacific off the coast of South America spaced from the equator to 60°S latitude to provide for the first meteorological measurements above 30 miles in this area. In the small meteorological sounding project, 100 small developmental sounding rockets were launched to provide upper atmosphere data and to test several developments, such as a new parachute configuration, a ruggedized transmitting tube and an improved temperature sensor. In addition, studies were conducted on the design and performance of rocket motors and on the development of consumable rocket motor casings.

In FY 1966, approximately 50 large research rocket launches are planned. These launches will continue the study of the relation of the Arctic atmospheric structure to that in the sub-Arctic, mid-latitudes, and the tropics during various seasons including the time of greatest frequency of noctilucent clouds. Flight tests will be conducted with a new payload to measure the amount of ozone in the upper atmosphere. Also, the funds will be utilized to continue the development of the small sounding rocket system involving the launch of about 100 small developmental sounding rockets, flight test of various payload components and research to improve rocket performance and reduce falling mass hazard. An international cooperative field experiment

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project was initiated with Argentina and Brazil for the establishment of two launch sites in South America and the coordination of meteorological launches from these sites with launches in North America.

In FY 1967, funds are required to provide for the launch of approximately 50 large research rockets and 100 small developmental sounding rockets, development and improvement of sounding rocket systems and initiation of design and development efforts on an advanced system. Also, funds are required for the continuation, extension and development of field experiment projects jointly with countries in South America, Europe and Asia to study and observe the upper atmosphere through the coordinated launches of small developmental sounding rockets.

OFFICE OF SPACE SCIENCE AND APPLICATIONS

COMMUNICATION AND APPLICATIONS TECHNOLOGY SATELLITES PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The previously separate Communication Satellite Program and the Applications Technology Satellites Program are combined into one program entitled Communication and Applications Technology Satellites. The objectives of the combined program are to; (1) assure that technology required for establishment of future communication, navigation, and other applications satellite systems is developed, (2) study requirements for, and technically assess the applicability of satellites to the future needs of communication, navigation, and other promising applications systems, and (3) fulfill NASA's responsibilities under the Communications Satellite Act of 1962.

Serving as relay stations at altitudes that are within line-of-sight of distant points on the earth's surface, communications satellites offer microwave communication over long distances, not presently attained by high frequency radio. They therefore offer the potential for providing all types of telecommunications services on a world-wide basis. Studies are underway to determine the need for an improved world-wide navigation system, traffic control, search and rescue, and communication systems for aircraft and ships. Satellites offer great potential in this area. Applications Technology Satellites offer the potential of testing and evaluating advanced subsystems applicable to communications, meteorology, navigation and other purposes; testing and evaluating satellite structures and stabilization systems peculiar to communications, navigation, and other satellite endeavors; and offer the potential for determining the radiation levels and the long term effects of this environment on spacecraft components at different altitudes, particularly the synchronous altitude where very little environmental data exists.

The Echo, Relay, and Syncom projects are completed except for continued data reduction and analysis activity. Five Applications Technology Satellites launches are planned for the 1967-69 period, one at 6,500 mile altitude and four at synchronous altitude.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Supporting research and technology/Advanced studies.....	$2,124,000	$4,500,000	$4,600,000
Echo II.....	325,000	---	---
Relay.....	462,000	200,000	---

	1965	1966	1967
Syncom.....	$168,000	$100,000	---
Early gravity gradient test satellite.....	5,000,000	---	---
Applications technology satellites.....	22,695,000	28,000,000	$21,800,000
Total.....	$30,774,000	$32,800,000	$26,400,000

Distribution of Program Amount by Installation:

	1965	1966	1967
Goddard Space Flight Center...	$24,414,000	$31,092,000	$25,107,000
Jet Propulsion Laboratory.....	396,000	648,000	193,000
Langley Research Center.....	215,000	---	---
NASA Headquarters.....	5,749,000	1,060,000	1,100,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology/Advanced Studies

	1965	1966	1967
Communication and navigation....	$874,000	$1,700,000	$1,900,000
Applications technology.....	700,000	2,000,000	2,100,000
Advanced mission studies.....	550,000	800,000	500,000
Data analysis.....	---	---	100,000
Total.....	$2,124,000	$4,500,000	$4,600,000

The supporting research and technology effort is being conducted in four areas namely, (1) communication and navigation, (2) applications technology, (3) advanced mission studies, and (4) data analysis.

There are no additional passive communication satellite launches planned, however, a modest effort will continue in FY 1967 as in past years, on materials, structures, and erection system development for advanced passive satellites. Passive satellite technology is being continued because such satellites have unlimited multiple access and frequency response capabilities, inherent long life, and high reliability. Investigation effort will continue in FY 1967 on active satellite systems capable of linking terminals of greatly reduced size and cost, making possible communications with over-ocean aircraft, ships at sea, and small land stations. Investigations will continue on the effect of scattering of electromagnetic waves by earth's atmosphere and space environment; results have and will make important contributions to the International Telecommunications Union Conference on Space Communications. Measurement techniques have been developed for measuring radio reflectivity

characteristics of large inflatable structures on the ground so that their potential usefulness in space can be predicted. In FY 1967 these techniques will be used to measure small segments of new and improved passive satellite materials and structures, and on advanced antenna designs to determine their characteristics.

Navigation traffic coordination satellite system conceptual studies funded in prior years indicated that satellites could assist over-ocean aircraft and ships at sea to obtain more precise position information under all weather conditions, and could aid air-sea traffic control, and coordination of emergency rescue operations. As a result interagency review of existing and future agency needs is continuing. We will analyze and compare various navigation traffic coordination systems (including those involving satellites) to determine the course of our future research and development efforts in this area. In FY 1967, studies will be conducted in the navigation-traffic control area to determine the feasibility of incorporating position-fixing experiments on future NASA satellites to establish the operational capabilities of the more promising techniques.

Past investigations of multiple beam forming, electronically steerable spacecraft antenna array techniques have yielded promising results. Laboratory models of promising arrays are now being developed for experimental purposes to determine their potential for space applications such as multiple access communications with small mobile terminals, and possibly direct broadcast satellites. Efforts in FY 1967 will be continued in the area of attitude measurement and control devices. Attitude measurement devices such as starfield readers, RF sensors, and non-RF sensors and control devices such as gravity gradient components, momentum wheels and small thrusters will be investigated. Effort will be continued on the design and preliminary development of a spaceborne millimeter propogation experiment for Applications Technology Satellites. The frequency range 10 to 100 gigacycles per second is of great interest because the lower frequency bands are crowded.

Studies on long-lived, fully stabilized spacecraft having a large space erectable antenna which can be pointed precisely to selected geographic areas on earth will be continued. Active and hybrid gravity gradient stabilization control systems will be considered. Feasibility studies on voice broadcast and TV broadcast satellites will be continued in FY 1967. A feasibility study will also be conducted in 1967 to determine satellite system concepts and approaches to provide wide band communications between interplanetary probes and earth terminals via satellite relays; provide aids to interplanetary navigation and tracking; and provide spacecraft-to-spacecraft communications and global navigation aids.

There is a new SR&T item in FY 1967 to cover data analysis in three projects otherwise completed by FY 1967, namely Echo II, Relay, and Syncom. In order to completely ascertain spacecraft performance and economic factors, there must be available spacecraft reliability, degradation, and lifetime data.

Therefore, it is desired to delineate this phase of the effort in FY 1967, and close out the research and development spacecraft phase of the projects at the end of FY 1966. Funding requirements beyond FY 1967 will depend on the lifetime of the spacecraft.

Echo II

	1965	1966	1967
Ground operations and support....	$325,000	---	---

The Echo II project consisted of design, development, launch, and evaluation of a 135 foot large inflatable passive communication satellite. Other than a low level effort in experiments on Echo II, the project was completed in FY 1964. Fiscal year 1965 and prior year funding, including launch vehicles, amounted to $20.1 million. No funds are required for FY 1966. A minimal amount of funds are required in FY 1967 for continued data analysis. This requirement is included in the SR&T line item.

Relay

	1965	1966	1967
Ground operations and support....	$462,000	$200,000	---

Project Relay consisted of the design, development, launch, and evaluation of two intermediate altitude active communication satellites. This project demonstrated the capability to reliably and economically perform narrowband and wideband communications, including telephone, digital data and TV demonstrations, between widely separated ground stations for long periods of time. In addition, Relay satellites are equipped to measure levels of radiation in the space environment and the effects of radiation on certain critical components.

Relay I was successfully launched in December 1962, as was Relay II in January 1964. The FY 1965 and prior years funding for the two launches including launch vehicles amounted to $40.2 million. Fiscal year 1966 funds are being used for continued data reduction and analysis. A minimal amount of funds are required for FY 1967 for continued data analysis. This requirement is included in the SR&T line item.

Syncom

	1965	1966	1967
Ground operations and support....	$168,000	$100,000	---

Project Syncom consisted of the design, development, launch, and evaluation of synchronous altitude active communication satellites. This project demonstrated the capability of reliably and economically performing communications experiments from synchronous orbits including telegraph, digital data, and TV demonstrations.

Three Syncom spacecraft have been launched: Syncom I in February 1963 was unsuccessful; Syncom II in July 1963 was successful in achieving the desired inclined synchronous orbit; and Syncom III was successfully launched into an equatorial synchronous (stationary) orbit. Syncoms II and III continue to function satisfactorily. Syncoms II and III were turned over to the Department of Defense on April 1, 1965. The FY 1965 and prior years funding for this three flight program including launch vehicles amounted to $30.8 million. Fiscal year 1966 funds are being used for continued data reduction and analysis. A minimal amount of funds are required for FY 1967 for continued data analysis. This requirement is included in the SR&T line item.

Early Gravity Gradient Test Satellite

	1965	1966	1967
Spacecraft.....	$5,000,000	---	---

The Early Gravity Gradient project consists of the design, development, and flight testing of a gravity gradient stabilization system. The primary objective of this effort is to demonstrate a gravity gradient stabilization subsystem in support of the advanced Defense Communication Satellite Program in the near synchronous altitude region, provide data to support the selection of design parameters, and assess the feasibility of gravity gradient stabilization for advanced space systems. NASA and DOD entered into an agreement whereby the Air Force Space Systems Command will be responsible for the procurement of flight hardware, and will flight test the gravity gradient system as an integral part of the initial Defense Communications Satellite flights. NASA will continue to monitor this effort and provide technical assistance to the Air Force. Fiscal year 1965 funds of $5.0 million are available to the Air Force to cover the costs of the spacecraft. No FY 1966 or subsequent year funds are required for this project by NASA. A flight test is scheduled for 1966 by DOD.

Applications Technology Satellites

	1965	1966	1967
Spacecraft.....	$20,695,000	$24,850,000	$17,800,000
Operational support.....	2,000,000	3,150,000	4,000,000
Total Spacecraft and Support...	$22,695,000	$28,000,000	$21,800,000
Atlas-Agena (Launch Vehicle Procurement Program).....	(4,404,000)	(8,240,000)	(12,803,000)
Total (including Launch Vehicle).....	($27,099,000)	($36,240,000)	($34,603,000)

The objectives of the Applications Technology Satellite project are (1) to design, develop, flight test, and evaluate a spacecraft capable of performing communications, meteorological, gravity gradient stabilization, scientific and other technological experiments in a 6,500 mile circular orbit, (2) to perform communications, meteorological, scientific and other technological experiments utilizing a spin stabilized spacecraft in synchronous orbit, and (3) to perform communications, meteorological, scientific and other technological experiments utilizing gravity gradient stabilized satellites in synchronous orbit. The basic spacecraft will weigh about 650 pounds. Five launches are scheduled--one in 1966 and one in 1968 in synchronous orbits utilizing spin stabilized satellites; one flight planned for 1967 in the 6,500 mile circular orbit primarily to evaluate the gravity gradient stabilization system; and two flights in synchronous orbit using gravity gradient stabilized spacecraft scheduled for 1968 and 1969.

The Office of Space Science and Applications, NASA Headquarters, is responsible for over-all management. Responsibility for project management is assigned to Goddard Space Flight Center. The major contractors are Hughes Aircraft Company for spacecraft development, and General Electric Corporation for gravity gradient stabilization system development.

Funding for this project commenced in FY 1964 with $16.8 million. Funding through FY 1966 has provided for continuation of development including assembly of the first spin stabilized synchronous spacecraft, its experiments and their integration; parts fabrication and prototype model assembly of the second spacecraft and its experiments; and procurement of common components for the remaining spacecraft. Funding in FY 1967 will provide for the first launch, completion of the second spacecraft and its experiments, and preparation for its launch. This funding will also provide for fabrication of the third spacecraft and its experiments and for continuation of development on the fourth and fifth spacecraft. Operational and data analysis efforts on the first launch will be initiated. Funding requirements, including launch vehicles, for FY 1968 to completion of this five flight program are estimated to be $35.1 million.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — BASIC RESEARCH PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The purpose of the Basic Research Program is to initiate and administer fundamental research in the physical and mathematical sciences. This research will provide an understanding of phenomena which is necessary for other NASA programs for the development of current and future aircraft and spacecraft. This basic research is carried out in NASA's Research Centers with some contract assistance by universities, industrial laboratories and other Government laboratories. Fundamental knowledge in many fields is essential for NASA's programs to advance in an orderly manner and on a scientific basis. Basic research in NASA has, therefore, to cover a wide range of disciplines, and varies from very fundamental studies into the nature of the atomic nucleus and its internal energies to more applied research in materials for applications such as the supersonic transport or entry vehicles. Much of the Basic Research Program cannot be specifically identified with current NASA projects. Its broad objective is to increase man's knowledge and understanding of the physical laws of nature and of their mathematical expression, definition, and interpretation.

The Basic Research Program is concentrated in four disciplinary areas: Fluid Physics, Electrophysics, Materials, and Applied Mathematics.

The understanding and prediction of the tremendous heating loads experienced by space vehicles during reentry into the earth's atmosphere from missions to the moon and beyond has been an important part of the research program in fluid physics. This research, which had been extended to studies involving entry into the atmospheres of other planets, has succeeded in the past year in unifying predictions of frictional heating so that any gas, characteristic of any atmosphere, can be handled by the same simplified analysis. Similar research is being pursued on other gas dynamic aspects of atmosphere entry and will lead to the design of efficient heat protection and atmosphere braking systems for interplanetary spacecraft. Fluid physics research also encompasses fluids having properties very much different from the atmospheric gases, as for example, magnetic liquids. Liquids reacting to magnetic fields may lead to unique space power systems, and provide a means for studying and controlling fluids in "zero gravity" situations.

Electrophysics encompasses theoretical and experimental physics research devoted to exploring and explaining the bulk and atomic behavior of solids, liquids, and gases subjected to gravitational, electric, magnetic, and

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nuclear force fields. It is designed to increase our understanding of physical phenomena, information which is essential for advances in technology areas such as electronics, space power, and propulsion. For example, an experimental investigation using the nuclear magnetic resonance technique has been under way to determine the presence of hydrogen nuclei in various atoms. The equipment sensitivity has been so improved that extremely small quantities of hydrogen may be recognized. Since hydrogen is a constituent of water, this now becomes a means of determining whether trace amounts of water may be present in rock and soil samples from the moon and planets. The presence of water may indicate the existence of some form of life.

The demands of the manned and unmanned space programs are putting unprecedented requirements on all classes of materials. Designers are calling for lightweight structural materials, chemically stable and radiation resistant coatings, high temperature and high strength materials for propulsion systems, high temperature ablatives for thermal protection, versatile electronic materials, and high temperature bearings and lubricants. New approaches and concepts are required to meet these requirements. The goal of basic materials research is to understand how and why materials can be strengthened by alloying additions and fibrous reinforcements and made resistant to all the components of the space environment. The behavior of well characterized materials in electrical fields is also being studied so that better electronic devices may be developed for space communication and circuitry.

Applied mathematics is concerned with research in mathematical techniques relevant or necessary for application to scientific or technological problems which arise in carrying out any part of the NASA functions. Such mathematical research performed preliminary to the physical operation of which it is an abstract model can usually result in considerable economies of total operation, and often is the only feasible approach to the problem. Recent examples of this have been the successful Ranger and Mariner flights which attained their objectives as scheduled. These results could never have been achieved through non-mathematical experimentation, but had to follow procedures dictated by previous extensive mathematical research.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Supporting research and technology.....	$21,231,000	$22,000,000	$23,000,000
Total.....	$21,231,000	$22,000,000	$23,000,000

Distribution of Program Amount by Installation:

	1965	1966	1967
Marshall Space Flight Center..	$916,000	$815,000	$850,000
Goddard Space Flight Center...	257,000	117,000	120,000
Jet Propulsion Laboratory.....	5,792,000	5,056,000	5,400,000
Ames Research Center.....	1,966,000	1,910,000	2,100,000
Electronics Research Center...	95,000	595,000	1,000,000
Flight Research Center.....	3,000	30,000	30,000
Langley Research Center.....	1,901,000	2,119,000	2,200,000
Lewis Research Center.....	2,234,000	2,731,000	2,800,000
NASA Headquarters.....	7,503,000	8,627,000	8,500,000
Western Operations Office.....	564,000	---	---

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1965	1966	1967
Fluid physics.....	$7,803,000	$8,043,000	$8,200,000
Electrophysics.....	4,039,000	4,404,000	4,800,000
Materials.....	8,034,000	8,193,000	8,500,000
Applied mathematics.....	1,355,000	1,360,000	1,500,000
Total.....	$21,231,000	$22,000,000	$23,000,000

Fluid Physics

The efficient design of spacecraft configurations and heat protection systems, of nozzles for air-breathing and rocket fueled propulsion systems, and the ability to solve the communications blackout reentry problem, all depend on a knowledge of non-equilibrium flow processes, i.e., on flows in which the time for temperature-induced chemical reactions occurring in the gas is of the same order as the time for the gas to flow along the body. Thus, an important part of the FY 1967 research program in fluid physics is concerned with the determination of chemical reaction rates in flow situations of interest. These rates will be determined primarily in chemical shock tubes at temperatures up to 15,000° F, as well as in "in situ" nozzle flows.

Non-equilibrium flows occur in regions of reduced pressure and density or at moderate altitudes. However, at very high altitudes, e.g., at 100 miles and above, the density of air is so low that inter-particle collisions which cause chemical reactions and normal gas-dynamic effects are almost non-existent. This so called "free-molecule" flight regime is of great importance in predicting such phenomena as the drag and heating of satellites,

orbital lifetimes of satellites, the heating and thrust loss from control rockets in space, and the contamination of the lunar surface by rocket exhausts. All of these phenomena are directly influenced by the energy and momentum transferred by a particle to a surface during impact, by adhesion to the surface, and by the surface material and surface condition. By means of a laboratory research program, gas-surface interactions will be studied intensively in FY 1967 both theoretically and in molecular-beam devices designed to duplicate the density and energy of space conditions. These studies will lay the foundation and provide the interpretive data for possible future flight experiments to investigate the phenomena with actual satellites.

Another research area that will receive increased attention during the next fiscal year is the flow of "strange fluids", i.e., fluids having viscous, elastic and magnetic properties that differ greatly from those of conventional liquids and gases. These fluids are more than scientific curiosities and are being studied with aerospace applications in mind. Visco-elastic studies include, for example, the flow of blood in parts of the circulatory system, and the fascinating phenomenon of greatly reduced drag of liquid and polymer mixtures when flowing through a channel. Additionally, the physical properties of magneto-fluids are being investigated in order that such fluids can be considered as a base for new space power generating systems.

Considerable progress has been achieved during recent years in developing electromagnetic gas accelerators, demonstrating that electromagnetic interaction on ionized gases may become a powerful investigative technique in future high temperature gas technology. More fundamental research in plasma physics is needed, however, because the properties of plasmas depend sensitively on interactions with electric and magnetic fields, in addition to their dependence on temperature and pressure as in real gas dynamics.

In FY 1967 increased emphasis will be placed on the investigation of plasma properties in their functional relation with system parameters. Chemical phenomena under the extreme (high and low) environments of temperature and pressure will be expanded, as will chemical kinetics as applied to propulsion systems and aerodynamic braking in planetary atmospheres. The classical principles of fluid physics will be utilized to explain fundamental biological and physiological processes to generate new concepts in organic physics.

Electrophysics

The electrophysics program consists of in-house and external experimental and theoretical investigations into the interactions of particles and force fields. The program includes tasks in classical and quantum physics in areas of nuclear, atomic and molecular physics, solid state physics, and theoretical physics.

Research is being conducted on the determination of the behavior of the positron in the earth's gravitational field. A positron, a form of antimatter, can combine with an electron whereby the pair is annihilated and energy in the form of a gamma ray, that is an electromagnetic wave, is released. Using a preliminary experimental arrangement the lifetime of negative helium ions could be measured. After this feasibility study, a larger experimental apparatus was constructed. This newer equipment is being checked first by measuring well known electrons; then the positrons' gravitational characteristics will be determined. If the experiment is successful, information on possible antigravity in nature will be obtained.

A comprehensive analysis has been made of the scattering of alpha particles (helium) from the nuclei of tin atoms containing even numbers of protons. Such experiments yield information on the excitation of the nucleus and in particular on interactions with individual particles in the nucleus. The results demonstrate that presently known theory adequately describes these experiments. This work is part of a comprehensive program aimed at understanding nuclear interactions and structure.

A much more accurate measurement has been made of the lifetime of the positive pi meson or pion -- a fumdamental particle of nature. The pion is believed to be responsible for binding particles together to form the nuclei of atoms. The lifetime of the free pion is one of its characteristics which determines its ability to perform this function.

In FY 1967 increased effort will be made in nuclear physics research. Experimental and theoretical investigations will be conducted to obtain more detailed information on nucleon-nucleon reactions. The data from this work will contribute to our understanding of collisions between solar protons and materials of the spacecraft structure. The information is needed to improve the design of the shielding material thus preventing radiation damage to equipment on the spacecraft. Furthermore, at the Electronics Research Center, a research program concerned with a better understanding of the fundamental energy exchange processes in crystalline solids will be pursued; and the emission, absorption, and scattering of electromagnetic waves will be studied. Such information provides the base of knowledge required by the Electronics and Control Program to improve reliability and useful life of critical components. It will also lead to better signal sources for space communications.

Materials

Understanding why materials behave as they do in mechanical, chemical, radiation, and thermal environments is the goal of the materials research program. The scope ranges from solid state physics - the nature of solid matter - to the application of such fundamental knowledge to advanced materials for NASA's future missions as well as defining corrective actions for current material problems. For example, the premature failure of titanium oxidizer tanks and titanium structural members may well be avoided as a result

of the recently initiated research effort on stress-corrosion cracking. When chosen for use in these applications, it was believed that titanium was immune to stress-corrosion cracking, a kind of unheralded and often catastrophic fracture at normal stresses in certain corrosive environments. Recent failures, however, show that some titanium alloys will crack in nitrogen tetroxide and even in water. Research will be conducted both in-house and by contract to establish the extent and gravity of the problem and to find solutions, both short range and long range.

Another example of basic research motivated by current deficiencies in materials is the research on polymers for use at low temperatures. Glass reinforced propellant tanks require the use of a liner to minimize the loss of hydrogen through the walls of the tank by permeation. Polymeric materials are being studied for such applications; however, they are subject to cracking at low temperatures. Basic studies to understand the relationship between the structure of polymers and their properties at cryogenic temperatures are under way. This understanding should provide the necessary information for synthesizing and processing polymers for use at very low temperatures.

Considerable progress is now being made in obtaining simple and trouble-free lubrication systems for advanced space vehicles. The ideal system would be one in which the bare metals slide upon one another without binding or wearing. It now appears that this is possible if the distribution and arrangement of the metal and impurity atoms is controlled by alloying, mechanical working, and heat treatment. Current research should establish the guidelines to be followed in performing these operations.

Advanced aircraft engines on the other hand can continue to use liquid lubricants provided they are protected from oxidation and thermal decomposition at temperatures several hundred degrees higher than those used in current commercial power plants. Current research at NASA Research Centers and in several research contracts is emphasizing several alternate techniques for preventing degradation. One technique is to use inert gases to protect the lubricant. Another involves the "once through" concept which consists of continuously feeding fresh lubricant into the bearings in a very low but adequate flow rate.

Fundamental research in electronic properties of materials for circuitry in communications devices will be continued. The creation of new electrical devices based upon current understanding of materials behavior is facing diminishing returns. There is, therefore, an urgent need to accelerate the fundamental studies of all material phenomena. Research is being increased both at the Centers as well as on contract to obtain more knowledge of the mechanisms of such phenomena as diffusion, sputtering and electron and ion emission from solids and electron-lattice, and electron-defect interactions in crystals. The role of impurities and alloying additions on semiconductors, electrical insulators and ferroelectric materials is also being pursued.

In FY 1967 the general field of solid state physics will be expanded with particular emphasis on electronic properties. This is a vital area and one in which the Electronics Research Center will contribute heavily.

Applied Mathematics

Research in applied mathematics is concerned with the development of improved mathematical techniques for the solution of physical problems. The problems which may arise in aerospace science or engineering usually require the solution of non-linear differential equations. Fast and simple solutions are desired for planning experiments and predictive evaluation of results.

Research will continue in aerodynamic mathematics for predicting gas flow around or within a body moving at hypersonic speeds, and for determining optimum aerodynamic shapes of aircraft wings and bodies in supersonic and hypersonic air-flows. Gravitational and orbital mathematics will be used to determine more accurately what trajectories could produce a successful lunar orbiting vehicle, as well as to make progress in the continuing problem of more accurate and economical predictions of orbits and positions of earth satellites and other space vehicles. Grants and contracts in mathematical research are also planned for investigation of methods for solving equations of heat-flow in reentering spacecraft, supersonic aircraft, and turbine blades, and for studying programs for optimum performance of aircraft using the calculus of variations. Studies will also continue in the theory of plates and shells of various shapes at various temperatures as a mathematical basis for safe and efficient design of advanced or proposed aeronautical and spacecraft structures.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1967 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY SPACE VEHICLE SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The basic objectives of the Space Vehicle Systems program, namely to identify and solve critical design problems associated with space flight and advance the state-of-the-art, require that there be a continual shift in emphasis dictated first by the progress and direction of the overall NASA space program, secondly by the revelation and investigation of new findings and concepts, and also by the necessity for developing immediate solutions to pressing technical problems on current NASA and military space vehicles. Conversely, the program is planned and implemented to provide much of the research that establishes the feasibility and influences the course of the overall NASA space program.

To cope with the technical problems associated with space vehicle launch, ascent through the atmosphere, flight in space, entry, and landing, the program encompasses the technical areas of Aerothermodynamics, Structures, Space Environmental Factors, Design Criteria, and Flight Experiments. The first three, coupled with related Flight Experiments, comprise the backbone of the research and technology effort. The area of Design Criteria represents the effort required to digest the vast quantities of technical information flowing from the research effort and from operational experience and present it in compact, simplified, and authoritative form that can be used by the designer.

In the area of spacecraft aerothermodynamics a highly significant accomplishment was realized during FY 1966 in the second successful Project Fire flight. That experiment determined very accurately the peak heating environment due to both convective and radiative heating processes for a blunt ballistic type of vehicle entering the earth's atmosphere at lunar return speeds of about 37,000 feet per second. The two Project Fire flights have now effectively defined the earth entry heating environment for Apollo. Emphasis will be placed during the coming year on consolidating and building on the new findings of Project Fire to develop improved knowledge of the extreme heating environment associated with entry from planetary flight, involving speeds of 50,000 feet per second and greater. In closely associated research on structures, attention will be directed to advanced ablative thermal protection systems that will be required for such an environment, and work will proceed toward the development of techniques for anchor-point experiments in flight at these extreme speeds which are beyond the reach of laboratory facilities.

Research emphasis in aerothermodynamics and structures will also be directed toward advanced manned space flight in near-earth regions, as exemplified by the lifting-body class of maneuverable entry vehicles. Attention will be focused especially on the flight problems in the critical terminal approach and landing phase using the M-2 and HL-10 test vehicles and on the technology of efficient, readily refurbishable ablatively protected structures. Increased attention will also be given to new concepts of maneuverable entry vehicles that incorporate propulsive lift for terminal descent and landing.

Considerably greater emphasis will be given in FY 1967 to parachute and decelerator technology for several important applications. New developments in steerable parachutes and paragliders with non-rigid structural elements may provide reliable, controlled descent and touchdown capabilities on land for current manned spacecraft types such as Apollo. The thin atmosphere of Mars has placed new demands on parachute technology for lowering instrument payloads to the surface at impact velocities low enough for them to survive and operate. In this application principal needs are for reliable deployment, structural integrity with light weight, and stable descent at the low atmospheric densities anticipated. Flight experiments will be needed to verify ground-based research.

In the areas of space environmental factors and in space structures, several notable accomplishments were made during FY 1966. Major strides were made toward determining the penetrating meteoroid environment in near-earth space through the successful launching of three Pegasus spacecraft by Saturn I launch vehicles. These three large-area spacecraft together with the earlier smaller Explorer XVI and XXIII satellites are providing quantities of statistical meteoroid penetration rate data in structural specimens up to 16 mils in thickness. These data have already been of great value in the Apollo program and will help define the design environment for the Manned Orbiting Laboratory. An essential and closely related part of the meteoroid technology research effort involves the tying together of flight measurements, laboratory impact and penetration measurements, and ground-based observations of natural meteors. A substantially augmented ground-based program is needed and is planned for FY 1967. Additional flight experiments are also needed to extend the thickness range of structural specimens subjected to meteoroid penetration in near-earth orbits and to extend the penetration measurements to the vicinity of Mars and into the asteroid belt where the population of penetrating meteoroids may be much greater than near the earth.

Toward this end research has already produced a notable advance in technology toward the development of the very high quality penetration and impact sensors that will be required.

Research will be continued on the effects of high-energy space radiation on spacecraft materials and components, solar radiation effects and temperature control, the storage of cryogenic liquids such as liquid hydrogen for long periods of time in space, and the behavior and control of fluids in the weightless state.

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In launch vehicle aerothermodynamics and structures, technology research will be continued on a wide variety of problems of importance to current types of launch vehicles such as base heating associated with large multiple rocket installations, intense acoustic noise, structural loads, more advanced and efficient structural designs, and dynamics of large space vehicle structures. Special attention will be given to the exceedingly difficult technical problems involved in the recovery and reuse of launch vehicle stages, both from the standpoint of devising techniques for the recovery of existing types of vehicles and from the standpoint of completely different types of advanced vehicles designed from the outset for reuse.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Supporting research and technology	$25,707,000	$26,000,000	$28,700,000
Project Fire	1,811,000	500,000	---
Lifting body flight and landing tests	1,400,000	1,000,000	1,000,000
Scout reentry project	400,000	3,000,000	4,800,000
Project Pegasus (Saturn-launched meteoroid experiment)	13,690,000	2,500,000	---
Small space vehicle flight experiments	1,010,000	2,000,000	1,500,000
Scout launched meteoroid experiments	175,000	---	---
Total	$44,193,000	$35,000,000	$36,000,000

Distribution of Program Amount by Installation:

	1965	1966	1967
Manned Spacecraft Center	$629,000	$435,000	$670,000
Marshall Space Flight Center	16,444,000	4,201,000	3,096,000
Goddard Space Flight Center	1,231,000	1,751,000	2,081,000
Jet Propulsion Laboratory	3,599,400	3,718,000	4,200,000
Ames Research Center	3,354,000	3,076,000	3,475,000
Electronics Research Center	---	250,000	250,000
Flight Research Center	1,825,000	1,010,000	1,010,000
Langley Research Center	10,593,800	11,466,000	14,282,000
Lewis Research Center	2,407,831	3,087,000	3,223,000
NASA Headquarters	3,473,969	6,006,000	3,713,000
Western Operations Office	635,000	---	---

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1965	1966	1967
Spacecraft aerothermodynamics....	$5,723,000	$6,191,000	$5,346,000
Spacecraft structures.....	5,819,000	6,201,000	6,710,000
Launch vehicle aerothermodynamics	1,488,000	855,000	1,300,000
Launch vehicle structures.....	3,398,000	2,554,000	3,264,000
Space vehicle environment factors.....	8,039,000	7,974,000	10,805,000
Advanced space vehicle concepts..	606,000	500,000	---
Space vehicle design criteria....	634,000	1,725,000	1,275,000
Total.....	$25,707,000	$26,000,000	$28,700,000

Spacecraft Aerothermodynamics

Research in spacecraft aerothermodynamics is concerned with atmospheric heating, flight performance, stability, and aerodynamic control associated with hypervelocity entry of vehicles into the atmospheres of the earth and other planets. The program also seeks to devise new concepts of vehicles and flight techniques to enhance our space flight capabilities by sophisticated use of planetary atmospheres for maneuvering and braking. A closely related objective is that of advancing the technology relating to the terminal descent and landing of both manned and unmanned spacecraft.

In addition, the program provides technological support in the solution of specific problems encountered in vehicle development projects of NASA and the military services. The program also provides the institutional support for the Jet Propulsion Laboratory wind tunnels.

A major accomplishment of the past year was the successful flight of Fire II and the analysis of reentry heating data from both flights of Project Fire at speeds of about 37,000 feet per second. The data indicate that at speeds of this magnitude most radiative component of the aerodynamic heating is associated with radiation in the very short wave length ultraviolet part of the energy spectrum. This new finding has already had a significant impact on theoretical and ground-based experimental research. New efforts will be made to understand the exact nature of the physical and chemical processes governing the production and absorption of the radiant energy. Such an understanding is essential to the extension of our knowledge of aerodynamic heating to higher speed regimes of 50,000 feet per second and greater associated with atmospheric entry from planetary flight. Such high speeds are beyond our capacity for direct simulation in the laboratory, hence ground-based research will need support and confirmation by flight experiments which will be directed toward determination of both the heating environment and the performance of thermal protection systems. Since recovery of the experiment payload appears essential, work will be carried out on developing both the flight and recovery techniques for such applications.

An important area to which substantial effort will be directed in FY 1967 is the technology of advanced manned spacecraft having substantial maneuvering capability in the atmosphere. The ability to produce appreciable aerodynamic lift, and the ability to control the amount of lift and drag, promises large benefits, which include: greatly reduced peak g-loads on crew and passengers; widened, less critical entry corridors; greater lateral flight range which provides a larger number of potential landing sites, and thus improved overall operational flexibility; and precision in returning from orbit. With these end objectives in mind, emphasis was placed during the past year on (1) development and construction of the M2-F2 and HL-10 manned low-speed flight research vehicles now entering the flight test phase, (2) laboratory research on the hypersonic performance and heating of the lifting-body vehicles of the M-2/HL-10 class configured to have good flight characteristics at low speeds, (3) generalized mission and preliminary design studies involving lifting-body types of vehicle for guidance of research planning, and (4) preliminary investigation of lifting entry configurations radically different from the M-2 or HL-10. This research will be continued at the Langley and Ames Research Centers in FY 1967. Some of the advanced configurations to be investigated may possess better hypersonic performance than the M-2 or HL-10 class of vehicles, while others may have potentially better airplane type landing capability. Some concepts will incorporate parachute and propulsive lift for soft vertical landing. The Flight Research Center will be heavily involved with the flight test program on the M2-F2 and HL-10 vehicles during FY 1967.

In the area of terminal descent and landing increased emphasis will be given to parachute and decelerator technology with special reference to (1) the soft landing of instrument packages on Mars, (2) terminal descent over land areas with control of the flight path for manned ballistic or semi-ballistic entry vehicles, and (3) recovery of launch vehicle stages. In the Mars landing application, the very thin atmosphere of Mars compared to that of the earth requires the deployment of large lightweight parachutes at relatively high speeds at very low atmospheric densities. Research information is required to assure high reliability of deployment, provide accurate information on aerodynamic forces, and provide for stable descent with the proper terminal or impact velocity. Because of the dynamics involved scaling from small models is difficult and a program of flight tests at relatively large scale is needed to verify and extend ground-based research. Attention will also be given to the aerodynamic problems and performance of high-speed auxiliary deceleration devices, including towed ballutes and inflatable or otherwise extendable skirts, for increasing the frontal area and hence the drag of the basic planetary entry vehicle to increase the transit time through the thin atmosphere and reduce the speed for terminal parachute deployment.

In the applications to manned spacecraft and to booster recovery technology requirements are generally similar, and will involve the study of advanced controllable gliding types of parachute configurations such as the so-called limp paraglider which uses no rigid structural members, and investigation of the deployment of large parachutes beyond the present state-of-the-art for heavy payloads.

Spacecraft Structures

The objective of this program is to identify and solve critical spacecraft structural problems through analytical and experimental research. Major elements of the program include: advanced structural concepts and materials applications, protection against entry heating and space environmental hazards, determination of critical loads and structural response, protection against vibration environments and landing impact, and prolonged storage of cryogenic liquids in space.

In the realm of advanced concepts, requirements for future systems are anticipated, and pertinent advances in structures and materials technology which may have been developed independently are combined to evaluate their feasibility and usefulness in practical applications. A current example is a contract and in-house study of inflatable lunar shelters at the Langley Research Center. Preliminary work has indicated a promising potential that such shelters may provide a shirt-sleeve environment, complete life support and communication facilities, internal temperature control, and meteoroid protection.

Another advanced concept being studied under contract concerns large orbiting antennas for unmanned scientific missions. In this case, requirements from other disciplines associated with radio astronomy are blended with advances in space structures to provide the technology necessary for lightweight, large area antenna systems.

Expanded effort will be directed in FY 1967 to the problems involved with improved structures to withstand atmospheric entry. One area is associated with refurbishable earth entry vehicle structures. As the frequency and magnitude of earth orbital operations increase, economic advantages may be gained by reuse of spacecraft if the critical areas of the structure could be readily restored. Current spacecraft and their heat shields are normally integral structures which do not facilitate repair or replacement of damaged components. Various concepts for providing refurbishment without sacrificing structural efficiency will be investigated.

Another area of emphasis concerns planetary entry structures for use in conjunction with the exploration of Mars. As mentioned previously, current estimates of the Martian atmosphere indicate that the atmospheric pressure is so low compared with that of earth that satisfactory terminal conditions cannot be achieved with conventional vehicles. Consequently, it is necessary to rely on very lightweight vehicles with large frontal areas in order to minimize impact velocity and enhance capsule survival. Research at the Jet Propulsion Laboratory and the Langley Research Center is endeavoring to isolate and resolve the structural problems of such vehicles in order to permit them to be designed with confidence.

Among other important problems, increased emphasis is required during FY 1967 in the area of high frequency vibrations to provide more adequate analytical and experimental techniques for coping with the extremely complex problems encountered in the wide variety of vibration environments encountered by spacecraft. In another area, storage of cryogenic propellants, the technology for tank structures and insulation, is well advanced for short-time storage in launch vehicles. Increased research is required for prolonged storage of cryogenic liquids, such as liquid hydrogen, in spacecraft. Planetary missions will involve storage periods of years rather than hours or days. The significant advantages of liquid hydrogen as a propellant cannot be fully realized unless further advances are made in cryogenic tank structures and thermal protection systems. These investigations at the Lewis Research Center and the Marshall Space Flight Center will be extended in FY 1967.

Launch Vehicle Aerothermodynamics

This program is concerned primarily with heating, acoustic, aerodynamic and recovery problems associated with present and future launch vehicles.

Considerable research has been accomplished on the measurement of temperatures in the base area of both model and full scale clustered rockets to determine the heating caused by the jet exhaust and the burning of entrained gases in the base area of the vehicle. However, a sound understanding of the problem and adequate prediction and control of launch vehicle base heating have been severely hampered by the lack of basic information on the nature of the complex flows in the base region. The situation has been aggravated by inadequate techniques for measuring the flow fields with the accuracies required. An electron gun technique recently developed under the auspices of the Marshall Space Flight Center appears to offer considerable promise for mapping the flow density and temperature in the base region for high altitude flight regimes. In FY 1967 this technique will be employed in several experimental investigations using scaled models of clustered rocket nozzle arrangements. Hopefully, this will lead to improved means of predicting the base temperatures on actual launch vehicles and in controlling the flow to reduce base temperatures in critical hot spots. Also in FY 1967 efforts will be continued to develop techniques applicable to inflight flow measurement on launch vehicles early in the launch trajectory after lift off.

A better understanding of the base flows will likewise generate improved understanding of factors affecting noise pressures in the base region. In FY 1967 research will be augmented at the Marshall Space Flight Center on sound pressures experienced on the vehicle and on the surrounding terrain during operation of large scale clustered rocket motors. Through this research to better understand the noise source, and continued research on atmospheric factors influencing sound propagation, greatly improved accuracy should be possible in predicting sound levels at all distances and azimuths surrounding launch vehicle rocket engine firings for both static tests and actual launches. This will be of considerable value in planning and scheduling engine firings to avoid or reduce disturbances to adjacent communities and nearby buildings, or to alert certain areas where noise levels are expected to be high. Also

in FY 1967 research will be emphasized on the substantially magnified sound pressures on launch vehicles in regions of separated flow behind vents and protuberances of various kinds.

The research effort on launch vehicle aerodynamics in FY 1967 will continue to be largely concerned with investigation of specialized problems with existing launch vehicles or those under active development, and with investigation of future launch vehicle concepts, many of which involve recovery. Recovery injects a completely new dimension to the aerodynamics, flight control and heating of launch vehicles, irrespective of whether the recovery mode ranges from that of a first stage landed in the ocean by parachutes, or of a second stage from orbit to a landing on land by lifting surfaces. There are a large number and variety of advanced launch vehicle concepts and recovery modes, many of which have commonality in technology with manned spacecraft as well as hypersonic cruise and supersonic transport aircraft. A modest effort has been expended in FY 1966 to exploit the latter technologies as applied to launch vehicles, while at the same time emphasizing studies to evaluate the many possible concepts, sizes and configurations of future launch vehicles to identify those of greatest interest for concentrated research investigations. This effort will be expanded in FY 1967.

Launch Vehicle Structures

The primary objectives of this program are to explore and evaluate advanced structures and materials concepts for launch vehicles, to provide improved methods for determining the loading and response of vehicle structures, and to develop more reliable means of predicting and confirming the strength of launch vehicles.

Primary structural design conditions for most launch vehicles are associated with atmospheric wind loadings, i.e., ground winds prior to launch and flight winds after launch at altitudes up to about 50,000 feet. Progress is being made at the Ames and Langley Research Centers in experimental studies of ground wind loadings on full scale vehicles for comparison with wind tunnel data, and techniques for simulating atmospheric turbulence in wind tunnel tests are being evaluated. These efforts will continue in FY 1967 with the objective of providing more precise methods which are needed for predicting ground wind loads. The efforts to develop an accurate system for measurement of flight wind conditions have resulted in radar/spherical balloon system now in routine use at the Kennedy and Pacific launch sites. The roughened, two-meter, spherical balloon wind sensor developed at the Marshall Space Flight Center has demonstrated stable ascent through the atmosphere and rapid response characteristics previously unattainable with other techniques.

Without comprehensive detailed design studies, it is often difficult to evaluate the merits of existing or potential advances in structural concepts and materials applications as applied to launch vehicles. Techniques for rapid evaluation of these merits are being investigated under contract. The techniques under study show significant promise for defining the relative payoffs, e.g., weight and cost savings, to be expected from a wide range of

advanced structures technology. Such definition will provide guidance for future research which would be applicable either for modification of existing vehicles or for the development of new launch vehicles. Recovery and reuse of launch vehicles create a number of formidable structural/material problems. Although the technology being developed for reusable manned spacecraft will be applicable, certain problems unique to the reuse of the larger and less dense structures of launch vehicles must be studied. Particular attention will be focused during FY 1967 upon substantially different configurations for future generations of launch vehicles.

A general purpose computer program is being developed for the analysis of complex space vehicle structures. This program will be standardized such that it can be used by all of the NASA Centers. It will be available to industry so that the result may improve the structural analysis capability of industry on the whole. It may eliminate also to a large extent the need for special purpose programs that are now constantly under development, and serve as an effective means of communicating structural information between NASA contractors and NASA Centers. Since the program will provide substantial improvement in structural systems analysis, it might be used also by other industries involving structural design. It should be completed and put into general use by the end of FY 1967.

Space Vehicle Environmental Factors

This research program is concerned with the vehicle design problems incurred by the environment of space. The objective of the program is to determine in detail the nature of the space environment from the vehicle design standpoint, to investigate the effects of the environment on spacecraft, and to find solutions for related technical problems. The scope of the research effort includes high energy radiation effects and shielding, the meteoroid environment and impact hazard, thermal radiation and temperature control, high vacuum technology, and the behavior and control of fluids under zero gravity conditions.

Research is being performed to determine radiation effects on engineering properties of sensitive spacecraft materials, devices, and components and to increase the understanding of the basic mechanisms for radiation damage to permit development of improved radiation resistant materials and spacecraft components. Completion of new radiation facilities at the Langley Research Center and the Goddard Space Flight Center will result in increased emphasis on in-house research during FY 1967. The new Space Radiation Effects Laboratory at Langley, operated by the Virginia Associated Research Center under contract to NASA, will become the principal center for NASA experimental research on high energy proton and electron radiation effects. Increased funds are required in FY 1967 for the operational support of the laboratory, as well as for support of increased applied radiation research at Langley. Radiation environmental testing and simulation techniques, and correlation of damage by the various types of radiation will receive increased emphasis at the new Goddard Space Flight Center radiation facility.

In connection with the protection of man and equipment from the effects of high energy radiation in space, theoretical and experimental studies are being performed to provide data on the shielding effectiveness of materials with special emphasis on the secondary radiation produced within the shielding material. A continuing effort in shielding research will be required, with a general increase in research devoted to advanced shielding concepts. Research in an advanced and promising shielding concept which uses a combination of both magnetic and electrostatic forces to deflect charged particles, such as protons and electrons, offers promise of very large savings in shield weight for extended missions.

A broad research program including both laboratory and flight experiments is under way to obtain definitive data on the characteristics of meteoroids and their hazards to spacecraft. A major milestone has been accomplished in the launching of three large area Pegasus meteoroid detection satellites. These spacecraft are providing definitive data in near earth regions on meteoroid penetration of much thicker structural material specimens than any previously flown. However, it is now clear that data on still thicker materials are needed for support of future long duration manned missions where the probability of encountering larger meteoroids is much greater than in short-duration flights. Such measurements must be made with high statistical reliability, and emphasis will be given to the continued development of improved meteoroid flight sensors. In addition to flight experiments, the Harvard College Observatory and Smithsonian Astrophysical Observatory under NASA contract are studying natural meteors entering the earth's atmosphere using radio reflection and optical techniques. Such observational measurements yield data on the near earth meteoroid population for the larger meteoroids. Increased emphasis will be placed in this area of research since an urgent need exists to develop means of correlating these data with the flight measurements of actual meteoroid penetrations to provide design data for the widest possible range of meteoroid sizes. Laboratory research on hypervelocity impact will also be continued and expanded since this phenomenon must be better understood before the desired correlation can be accomplished with confidence. One of the important and currently uncertain factors involved in impact theory and in correlation of ground observations and flight data is particle density. At the Ames Research Center preliminary laboratory simulations of meteoroid entry into the atmosphere have shown that meteoritic rock undergoes foaming and a radical change of shape at high heating rates. This new finding, which has been injected into the meteor observational program, indicates that present deductions of meteoroid density based on measured meteor velocities and decelerations in the earth's atmosphere may be in error.

Laboratory hypervelocity impact research is still limited by the inability to simulate meteoroid sizes and velocities simultaneously. Continued emphasis will be given to the development of promising techniques for achieving better simulation, along with improvement of present in-house equipment to keep pace with new developments in this area.

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The zero gravity fluid behavior program will continue to be concerned primarily with research on fluid dynamics as in fuel tanks under near zero-gravity conditions with particular emphasis on effects of attitude control maneuvers on behavior of the liquid vapor interface, response to outflow disturbances and fluid collection and interface formation times. The results of such research is important to any on-board fluid system. Much of the research in this area will be performed in the new 400-foot drop tower facility at the Lewis Research Center. While similar studies with very small models in the 100-foot Lewis drop tower facility have led to good qualitative understanding of the phenomena involved, the experiments in the new facility will result in data for larger size models giving much greater confidence to extrapolations to full size flight systems.

The exchange of heat to and from vehicles in space is solely by thermal radiation. Since the radiative characteristics of spacecraft surfaces are known to be altered by solar ultraviolet and other space radiations in combination with space vacuum conditions, accurate quantitative temperature predictions for long duration flights are difficult. Present design techniques include iterative or multiple trial processes involving tests in large facilities where adequate simulation of the solar spectrum is difficult. Testing of spacecraft thermal control coatings in space and in the laboratory will continue along with the development of new more stable coatings. Methods will be developed to measure the spectral reflectance of materials over a wide range of conditions, along with the development of new computer programs to apply such data to extensive inter-reflection between surfaces of complex spacecraft shapes. Research on new thermal radiation sources will continue, as will research in the area of thermal scale modeling. The Mariner IV spacecraft configuration was selected for an experimental evaluation of scale modeling techniques. Results obtained in testing of a half-scale thermal model of the Mariner IV have been most encouraging with respect to the application of these techniques which could reduce significantly the future requirements for large solar simulation facilities.

In the testing of spacecraft and materials under simulated combined thermal and vacuum environmental conditions of space, a series of new problems has developed due to an unpredicted contamination of surfaces in vacuum chambers. This contamination produces unwanted changes in the thermal balance of spacecraft under test and adds to the difficulty in analyzing effects due to ultraviolet and other radiations. This and other problems associated with the creation, maintenance and measurement of simulated space vacuum will be under continued study in FY 1967.

Space Vehicle Design Criteria

Space vehicle failures have occurred because of the application of inadequate or inappropriate design conditions or procedures. Moreover, the problem of retrieval of information applicable to the design of future space vehicles continues to grow more complex as the mass of new technical information resulting from research studies, vehicle project development and operating experience increases. The objective of this program is to assist project managers and designers by providing them with technical information suitably

filtered from the total mass of data available and arranged in useful forms for uniform application to design. Attainment of this objective entails identification of design problems that must be considered to ensure the flight worthiness of space vehicles, formulation of existing technical information bearing on these problems into authoritative guides to design, dissemination of these guides in an orderly and usable set of design criteria documents to NASA and industry users, and updating as required.

This effort encompasses the preparation of design criteria in the technical areas of environment; structures; propulsion; and stability, guidance and control. The work effort is being carried out at seven of the NASA Centers, at the Jet Propulsion Laboratory, and by contract with several aerospace companies and consulting firms. To provide focal points for detailed control and guidance of the program effort, three of the NASA Centers function as lead Centers: Langley Research Center - Structures Criteria; Lewis Research Center - Propulsion Criteria; and Electronics Research Center - Guidance and Control. Fiscal year 1967 funds will provide for continuing contract effort by the lead Centers and other Centers necessary for the timely formulation of design criteria in each technical area where criteria are to be established.

In calendar year 1965 criteria monographs pertaining to solar electromagnetic radiation, buckling of thin-walled cylinders and aerodynamic and ground wind loads were issued to industry and interested government agencies. In addition to the monographs issued, work was continued or initiated on approximately forty-five drafts of planned monographs.

The continuation of this program in FY 1967 should reduce the chances of failure in the future, and ensure an optimum balance between reliability and performance as permitted by the latest available knowledge and experience.

Lifting Body Flight and Landing Tests

	1965	1966	1967
Flight vehicle and support services..	$1,400,000	$1,000,000	$1,000,000

The lifting body class of reentry vehicle configuration has received considerable research attention because of the improved atmospheric maneuvering performance over that of ballistic and semi-ballistic vehicles of the Gemini and Apollo type. This research leads to widened reentry corridors, reduced g-loads on crew and passengers, and greater lateral ranging ability with consequently improved operational flexibility and precision in return from orbit. The lifting body types of vehicle also offer the capability of horizontal landing at prepared land sites.

One of the most important questions with such vehicles is that of terminal approach and landing, investigation of which is the objective of the current flight research project being carried out at the Flight Research Center on the Ames M-2 and Langley HL-10 configurations. These test vehicles were constructed by the Northrop Corporation to NASA specifications. They are built of aluminum using conventional airplane-type construction and adapting off-the-shelf components such as landing gear, control systems, hydraulic systems, ejection seats, etc., and incorporate a ballast feature by which large changes in weight can be made covering a wide range of platform loadings. The M-2 has reached the flight test stage after being thoroughly tested in the Ames 40- x 80- foot wind tunnel. The HL-10, delivered in January 1966, will reach flight readiness in the spring of 1966 after undergoing similar 40- x 80- foot tunnel tests. They will be carried by a B-52 (the same aircraft used for launch of the X-15) to an altitude of 40,000 feet and a speed of about Mach number 0.8 and released to glide back to earth.

The funds in FY 1967 will provide for the continuing aggressive and extensive flight test program, in which both NASA and USAF test pilots will participate, covering a wide range of vehicle loading and operational conditions.

Scout Reentry Project

	1965	1966	1967
Spacecraft and support.....	$400,000	$3,000,000	$4,800,000
Scout (Launch Vehicle Procurement Program).....	(2,260,000)	(---)	(1,800,000)
Total (including launch vehicles).	($2,660,000)	($3,000,000)	($6,600,000)

The objective of this project is to support the advancement of atmosphere entry technology by performing critical anchor point experiments in hypervelocity reentry flight. Emphasis is on the technologies of aerothermodynamics and high temperature structures and thermal protection systems with the aim of correlating, verifying, and extending research results obtained in laboratory facilities.

In heat shield technology an experiment will be flown to a reentry speed of about 27,000 feet per second to determine the performance of an advanced low-density phenolic nylon heat shield material of particular interest to ballistic and semi-ballistic entry vehicle application. The flight will subject the test heat shield to a high intensity, short duration heat pulse with the objective of verifying the prediction of the performance of the material based on a very thorough laboratory determination of its physical and chemical properties and its performance in arc jet tests.

Further heat shield material experiments are being devised to determine in a similar way the behavior of several promising ablation materials of especial interest for lifting entry vehicle applications. These materials, of which silicone elastomers are one example, have characteristics suited to long duration, relatively low level heating, with short duration high heating rates superimposed during maneuvers. Problems associated with ease of refurbishment are an important consideration, and spacecraft recovery is an essential feature of these flight experiments to study at first hand heat shield damage and its repair.

In the area of aerothermodynamics, two flight experiments will be conducted to provide basic data on the heating rates associated with turbulent boundary layers at high Mach numbers and Reynolds numbers, and to investigate factors which affect transition from laminar to turbulent flow under these conditions. The data are important in predicting heating rates and skin friction on a variety of advanced vehicles, including lifting reentry vehicles, ballistic missiles, hypersonic cruise aircraft and certain classes of reusable launch vehicles. The data cannot be obtained in ground test facilities and anchor point data from flight experiments are needed to resolve disagreements among various theories used to predict turbulent heating rates.

At speeds associated with entry into the atmosphere of Venus and reentry into the earth's atmosphere on return from planetary flight, characteristically 45,000 to 50,000 feet per second and higher, critical flight experiments will be needed to provide anchor point data on both the heating environment and the behavior of thermal protection systems in this extreme heating environment. Such experiments, for which spacecraft recovery is essential, are difficult to devise and will require long lead time for their development. Intermediate steps will be necessary. To this end, configuration and instrumentation concepts will be developed, along with a velocity package, for launch to intermediate reentry speeds of around 36,000 feet per second by Scout launch vehicles.

Small Space Vehicle Flight Experiments

	1965	1966	1967
Spacecraft and support.....	$1,010,000	$2,000,000	$1,500,000

Planetary Entry Technology - One of the most critical problems associated with the exploration of Mars by unmanned spacecraft is that of terminal descent and noncatastrophic landing on the surface. The very low density of the Martian atmosphere will require the use of large, lightweight parachutes that can be deployed with high aerodynamic and structural reliability at relatively high speeds and low dynamic pressures. While several promising parachute concepts have been identified, their opening and structural loading characteristics under the expected conditions have not been established and cannot be established by ground tests alone. The problems will therefore be studied by means of high altitude flight tests under conditions that closely simulate planetary atmospheric conditions. A series of scaled-model tests will be carried out using Nike rocket launch vehicle, coupled closely with larger scale experiments, lofted by balloons and rockets launched at high altitudes.

Heat Shield Materials Technology - As discussed under Scout Reentry Heating Experiments flight measurements of the performance of ablative heat shield materials constitute a continuing program to provide critical anchor point data and to improve understanding of the complex ablative process. The Scout-launched experiments provide data at speeds corresponding to actual spacecraft reentry speeds. A vital link between the Scout experiments and ground-based research is provided by flight tests using the smaller low-cost Pacemaker rocket system to provide flight data at conditions that can be closely approximated in laboratory facilities and therefore afford direct comparison.

An important aspect of the heat shield materials technology program is recovery and examination and analysis of specimens after flight test. Research into recovery concepts and instrumentation aids will be conducted in this program during FY 1967.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1967 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — ELECTRONICS SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The purpose of the Electronics Systems Program is to insure the availability of electronic technology capable of satisfying the stringent reliability and performance requirements of future space and aeronautical systems and related support functions. The scope of the program extends from conceptual systems research, including performance predictions derived from studies of control and information theory, through the development and evaluation of advanced electronic techniques and components, the elements common to all operating electronic systems. The efforts of this program are motivated by the performance demands of future missions and the operational limitations of today's equipment. Typical general objectives are: (1) attainment of the extended operating lifetimes and reliability requirements of future space missions, and (2) performance and adaptability of instrumentation, communications, data processing, control and guidance subsystems. The program utilizes both analytical and experimental research approaches prosecuted in industrial, university, and government laboratories. Flight experiments are performed, when necessary and prudent, to circumvent the limitations of the earth-bound laboratory research programs.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Supporting research and technology.....	$23,222,000	$30,000,000	$34,000,000
Flight projects.....	2,400,000	2,300,000	2,800,000
Total.....	$25,622,000	$32,300,000	$36,800,000

Distribution of Program Amount by Installation:

	1965	1966	1967
Manned Spacecraft Center.....	$465,000	$525,000	$450,000
Marshall Space Flight Center..	3,685,000	4,003,000	4,200,000
Goddard Space Flight Center...	2,967,000	2,975,000	2,960,000
Jet Propulsion Laboratory.....	2,727,000	3,566,000	3,290,000
Ames Research Center.....	3,480,000	3,718,000	4,100,000
Electronics Research Center...	2,178,000	5,110,000	10,000,000
Flight Research Center.....	1,038,000	698,000	660,000
Langley Research Center.....	6,660,000	7,260,000	7,420,000
Lewis Research Center.....	400,000	539,000	540,000
NASA Headquarters.....	2,022,000	3,906,000	3,180,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1965	1966	1967
Guidance systems.....	$4,523,000	$6,050,000	$6,250,000
Control systems.....	5,351,000	6,000,000	6,150,000
Communications.....	4,190,000	4,800,000	5,600,000
Tracking and data acquisition..	2,860,000	3,550,000	3,700,000
Data handling and processing...	3,172,000	3,650,000	4,150,000
Instrumentation.....	3,126,000	3,950,000	4,150,000
Electronic techniques and components.....	---	2,000,000	4,000,000
Total.....	$23,222,000	$30,000,000	$34,000,000

Guidance Systems

Guidance System research and technology efforts are directed toward identifying requirements and characteristics of future space guidance and navigation systems, and developing sensors, components and subsystems capable of attaining advanced performance goals. Systems and trajectory analyses provide the framework for examining sensor, instrumentation and data processing trade-off assessments for future space missions and for the development of guidance equations, navigation logic and advanced systems concepts. From these analyses, the research objectives leading to advanced sensors, reference elements and associated instrumentation components are derived. The program emphasizes research in inertial, optical and electromagnetic phenomena to develop the sensors and techniques directly related to space guidance and navigation.

In the area of inertial guidance components, new activities, designed to improve component performance and reliability, will be concentrated in the Guidance Laboratory at the Electronics Research Center. A typical example of this work is the laser gyro. This device makes use of laser beams to sense inertial quantities; additional research is necessary to realize its operational potential. Proper mixing of gases to control the laser modes of oscillation and the ultimate means for replacing gas lasers with solid state lasers are the areas of endeavor to be explored during the next phase of its development.

In view of the fact that the sun, celestial and planetary bodies provide the primary targets for space navigation and attitude reference, expansion of research on passive electromagnetic sensors, particularly that related to improved detectors, no-moving-part and lightweight tracking devices is planned for this fiscal year, primarily at the Electronics Research Center.

Increased efforts in active radar and laser devices are required to effect future rendezvous and planetary letdown portions of manned and unmanned

missions. This area of technology has not heretofore received proper emphasis due to limitations of available personnel and facilities at the Centers. The major increase in this effort will be in the Guidance Laboratory at the Electronics Research Center.

Current and continuing efforts in this program will provide the components and technology necessary to support the development of future guidance and navigation systems. Planned efforts will derive the requirements for advanced research and specify characteristics and components to meet the demands of long term space missions for interplanetary exploration and travel.

Control Systems

The research efforts sponsored by the Control and Stabilization program provide the technological base for future aerospace vehicle control systems. Areas of study include manned and automatic flight control systems, spacecraft attitude stabilization and control, and the development of mathematical tools for system analysis and synthesis. Specific objectives include: more precise mathematical descriptions of manual and automatic control performance, the development and application of modern control theory to future system problems, and the advancement of the state-of-the-art of control and display system components.

During the coming year, intensive efforts will continue in the area of mathematical modeling of both automatic and manual control performance. Past efforts have provided quasilinear descriptions of a pilot's control performance and the techniques capable of limited application. These models have been shown to be valuable in both the analysis and design of vehicle control systems. They have been used in system designs for the supersonic transport, for manually controlled launch vehicles, and for lifting body research vehicles. The efforts in FY 1967 at the Ames Research Center will extend and refine the applications of these techniques, and in addition will concentrate heavily on describing, mathematically, the control function in terms that include decision making, time varying, and adaptive characteristics of the human's control performance.

The effort in the area of system synthesis is illustrated by a problem in optical technology, the pointing of extremely narrow beam laser telescopes. System studies indicate requirements to point these beams with accuracies of up to 0.01 arcseconds of angle, a requirement far exceeding existing control capability. System studies have generated potential means of accomplishing this goal. In the coming year effort will be directed by the Langley Research Center toward the component development necessary to demonstrate the concept feasibility.

During the past year, the component development program efforts have been devoted to advancing the state of the art of display media through the development of X-Y, vertical scale, and alphanumeric electroluminescent displays, and development of electromechanical components such as brushless DC motors, and momentum exchange devices. Other components under development

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include a display for aircraft zero-zero landing research, an optical system for pilot remote visibility, satellite attitude control hardware, both active and passive, such as nutation dampers and a dual redundant attitude control valve, and television simulation displays. A significant FY 1967 expansion in control components will provide an important payoff in realizing analytical concepts developed over the last few years. The primary expansion is at the Electronics Research Center; other Centers will maintain essentially the same level of effort as in the past.

Communications

The communications subprogram provides a firm technology base upon which to refine present systems and to build future generations of deep space communications systems. Research efforts contributing to this firm technological base are in the microwave, submillimeter and optical frequency domains.

Microwaves

Extremely high data rates (10^7 to 10^{12} bits/sec) are required for real time transmission of high resolution photography and telemetry for scientific purposes from the outer planets. Deep space communication data rate is directly related to the power of the spacecraft transmitter tube, and consequently, our research in microwave tubes for spacecraft is oriented towards higher powered tubes. Mariner IV, using a ten-watt tube, transmitted at 8-1/3 bits/sec from Mars. A 20-watt tube has been developed by Watkins-Johnson for the Langley Research Center. A 1,000-watt tube would improve our communication data rate by 100 times over the Mariner 10-watt tube.

Efforts to be undertaken in FY 1967 at the Electronics Research Center include studies and laboratory experiments to develop the technology required for space-qualified 500-to 1,000-watt tubes for future missions.

Reentry communications is the subject of an intensive research effort. Upon reentering the earth's atmosphere, a spacecraft is enveloped in a plasma sheath which causes a blackout in communications. The Langley Research Center is conducting a Reentry Attenuation Measurements (RAM) flight project to provide basic data concerning the plasma sheath and to test the water injection method of alleviating the effects of the plasma. A further discussion on RAM appears in the Flight Projects section. A major break-through in both understanding and eliminating the effects on communications of plasma is necessary in order to provide reliable communications and tracking for lunar and interplanetary mission reentry velocities of 36,000 to 70,000 feet/sec. Research will continue in this area during FY 1967 at the Langley Research Center with major emphasis on evaluating results of flight data.

Advanced electronics devices which utilize the plasma engulfing the spacecraft are being investigated by the Electronics Research Center for communicating through the blackout period of reentry. Techniques to maintain communications while entering the atmospheres of other planets will also be studied during FY 1967.

Millimeter/Submillimeter

Advances in technology are handicapped by the lack of stable, efficient sources. At the present time deep space communication using these frequencies is not possible. Successful development of suitable sources in this frequency region will make the millimeter-submillimeter region useful for future deep space communications. Research being initiated by the Electronics Research Center should yield this capability in the future. Preliminary studies have shown that atmospheric attenuation in this region may be serious enough to require the use of orbiting relay stations to convert from submillimeter to microwave frequencies for retransmission to the earth station. Results of studies by the Mission Analysis Division concerning efficient, long life orbiting communication relay stations will be used to guide the research effort in FY 1967.

Optical

Electro-optical systems show promise of improving data rate capability from deep space by as much as three orders of magnitude over that possible at microwave frequencies. To realize these high data rates requires considerable improvement in both laser and optical technology. For example, 30 to 60 inch, diffraction-limited, lightweight, space telescopes with surface tolerances of .000002 cm are required for optical communications, but are not in existence today. Studies are under way to select and develop optimum detection techniques for the ground terminal. The Electronics Research Center, for which a Space Optics Laboratory is included in this year's facility request, will be the major research facility for the implementation of the total optical program.

Techniques to remotely monitor and control surface characteristics and the alignment of large primary segmented mirrors in space are under study at the Langley Research Center. The segmented approach to achieving large lightweight diffraction-limited optical telescopes will be applicable to both optical communications and astronomy. This effort will continue in FY 1967.

Tracking and Data Acquisition

Tracking and data acquisition systems capabilities are generally constrained by the physical characteristics of the system components. To provide means of circumventing these limits, research in this program includes: investigations of multiple ground antenna arrays, large lightweight spacecraft antenna development, and optical tracking.

Increased data rates can be achieved by increasing the effective area of ground antennas. Antennas larger than 210 feet are confronted with severe structural, mechanical and cost problems. The alternative of arraying many smaller antennas effectively increases the area while simultaneously reducing structural design and fabrication problems. However, the electronic problem of phase locking low level signals is introduced and must be solved.

Stanford Research Institute, Research Triangle Institute, and Electronic Communications Inc. have completed antenna array studies for the Langley Research Center and for the Goddard Space Flight Center. Experiments are being formulated during this fiscal year for arraying of two 15-foot antennas at the Goddard Space Flight Center to further identify scientific and operational problems peculiar to arrays of this type. These experiments will be undertaken in FY 1967 with major emphasis on the phase locking of the individual signals and the identification of operational problems.

Increasing the size of spacecraft antennas is another approach used for improving data rates, but prelaunch antennas sizes larger than 15 feet are impractical. Therefore, means to erect large antennas in space are being investigated. A nine-foot, deployable antenna developed by Goodyear for the Jet Propulsion Laboratory has been successfully tested and will be used in FY 1967 as a laboratory instrument to further refine deployment techniques. In FY 1967 the Jet Propulsion Laboratory plans to complete a computer program which will allow theoretical evaluation of perturbations and modifications to the antenna reflecting surface. These investigations, augmented by additional studies at the Electronics Research Center, will seek the capability to erect 20 to 30 foot antennas on unmanned spacecraft providing potential data rate improvements of two orders of magnitude over present capabilities.

Additional efforts will be directed towards achieving large apertures at optical frequencies. Tracking and pointing accuracy techniques are problems associated with large ground and airborne optical systems. The Goddard Space Flight Center and the Langley Research Center will continue studying this problem. Tests will be initiated by the Langley Research Center and the Electronics Research Center this fiscal year to determine the atmospheric and space environment effects on coherent optical transmission. These efforts will be continued in FY 1967.

Data Handling and Processing

The rapid evolution of spacecraft technology and the accompanying increase in data gathering capacity of on-board systems continue to tax the data processing capability. Even though significant advances have been made in the technology of both spacecraft and ground data handling techniques and systems, additional research in advanced components and software is required to keep pace with our data sensing ability.

In FY 1967, work at the Goddard Space Flight Center will continue to develop techniques and systems for computer checking of vehicle readiness in the prelaunch phase and to program and monitor launchings from earth, other celestial bodies, or from orbit, including margin testing and prediction of incipient failures; adaptive control of trajectory selection based on predicted partial failure; and continuous assessment of system status. Work in this area has resulted in development of a command and control link which allows more completely automated sequencing and programming of spacecraft checkout, and calibration of scientific experiments. As an example of the growth in the complexity of spacecraft systems and experiments, the

Explorer XVII launched in 1963 had approximately fifteen functions commandable from the ground, while the Radio Astronomy Explorer (RAE) to be launched in 1967 will have over ten thousand.

Advances in ground computer processing of TV pictures from Mars have resulted from past research in this subprogram. Similar efforts have been started in on-board picture storage and compression, and will continue and expand in the next several years.

Investigation of coherent optical phenomena for improvement of data storage and manipulation will be expanded in FY 1967 at the Electronics Research Center.

High capacity on-board data storage devices are required to serve as temporary repositories for the large amounts of data gathered by TV systems. A single high quality TV system may generate several million bits of information each second. Since this far exceeds the capability of present and near future data transmission links at planetary distances, methods are required to store the data until it can be transmitted. The Jet Propulsion Laboratory has demonstrated the feasibility of a small magnetic tape data storage unit which will store one hundred million data bits in several cubic inches. In FY 1967 research will continue to develop a working device as well as to investigate other methods for data storage in devices having no moving parts.

Compression of data aboard a spacecraft is a continuing goal of data processing research required to match the amount of scientific data collected with the current and projected data transmission capability. One such system, developed by the Goddard Space Flight Center for the Interplanetary Monitoring Platform satellite, makes use of the mathematical properties of histograms or bar graphs. Data gathered by particle sensors is coded in a form which can be represented by such a graph. Special on-board computing circuits calculate the pertinent mathematical properties and transmit only these properties to earth. From these properties ground-based computers may then reconstruct the graph. By this process, only one-tenth of the data has to be transmitted.

During FY 1967, emphasis will be placed on perfecting such concepts and extending them to a broader spectrum of experiments.

Instrumentation

The expansion of aerospace scientific knowledge is strongly dependent upon the advancement of instrument technology and the development of new measurement methods. Scientific instruments are essential to sense and measure fundamental astrophysical, engineering and bio-medical parameters.

The principal goals in instrumentation research are to increase accuracy, to extend the measurement range, to improve energy and signal conversion, to reduce size and power consumption, and to eliminate synergistic effects.

Solid-state electronic components have permitted the development of novel circuit designs and new instrument transducers of improved sensitivity. One

example is the design of a miniature accelerometer based on semiconductor piezo resistive properties. A theoretical and experimental study of the stress sensitivity and the effect of mechanical strain on semiconductor diodes and transistors, performed by the Research Triangle Institute under the direction of the Langley Research Center, has resulted in the development of a miniature accelerometer with high frequency response and using a unique stress sensitive transistor in the form of a silicon needle. This transducer will find a wide variety of aerospace applications and the principle lends itself to other applications for measuring pressure, stress, and vibration. Further work is required to refine the design of the accelerometer and to eliminate side effects of temperature.

An important feature of aerospace investigations is the acquisition and transmission of pictures. In this process, optical signals are usually converted into electronic signals by means of imaging devices. In an effort to overcome some of the deficiencies of presently used vidicon tubes, micro-miniature techniques are being explored and have made possible the development of a phototransistor sensor. Progress made since last year has led to the design of a small solid-state TV camera using a 50 x 50 matrix of phototransistors in an area ½" x ½" which operates at low voltage without the complexity of beam scanning. This camera has been developed and demonstrated by Westinghouse, under the direction of the Marshall Space Flight Center. Refinements of the camera to provide more densely spaced sensing elements and permit non-mechanical, opto-electronic coupling into readout electronics require further investigation during FY 1967.

The higher measurement accuracies required for aerospace exploration are limited by the error introduced by the necessary conversion of original analog signals for long distance transmission by digital telemetry. Digital transducers have received increased attention to minimize such errors, to simplify circuitry, and achieve better compatability with digital telemetry.

As an example of current efforts, the Dynamics Research Corporation, under the direction of the Marshall Space Flight Center, has done some preliminary work based on the birefringent behavior of optical media under stress. Polarized light channeled through various optical paths will produce digital outputs which reflect the applied stress in digital form. Such digital sensing devices with no mechanical moving parts, promise to provide considerable system simplification and measurement reliability and are planned to be supported at the Marshall Space Flight Center and expanded at the Electronics Research Center in FY 1967.

Force, pressure, acceleration, and vibration are frequently measured with strain gages made of metal foil strips which change their electrical resistance when their lengths change due to applied stress. Solid-state strain gages have been developed which are many times more sensitive than metal foil gages, but heretofore have been temperature limited. Experiments performed at the Langley Research Center have recently shown that exposure to controlled radiation reduces the temperature sensitivity of certain semiconductor strain gages to a level comparable with metallic foil type gages.

Since their high sensitivity is not affected, strain measurements many times smaller can now be performed under environmental conditions where temperature changes are experienced. Work in FY 1967 is required to increase the range of measurement and to investigate additional materials.

Electronic Techniques and Components

The Electronic Techniques and Components subprogram, first established in FY 1966, is directed to perform the research necessary to determine future requirements to extend the state-of-the-art; and to provide the necessary supporting research and technology for electronic and electromechanical components and their materials. The subprogram supports in-house and contractual research in electronic components, including high temperature and radiation tolerant devices; electromechanical components such as solid-state relay and interconnection concepts; and methods and techniques for qualification and standardization of components designed to explore means for improving and assessing the reliability and quality of materials, parts and devices.

A particularly critical problem in the microelectronics area today is the interconnection and assembly problem. A contracted study has resulted in recommendations for research in this area. The Electronics Research Center will evaluate the results of this study and orient its investigations to those recommendations offering the greatest potential for increased reliability and performance as part of their FY 1967 activities.

Strong emphasis was placed in electronic component research in FY 1966; efforts were centered around high temperature component development and materials technology. These efforts were concentrated at the Electronics Research Center and will be expanded in FY 1967.

The problem of assembling electronic components is of great concern to spacecraft systems and is one of the most important in terms of potential reliability improvement. The Jet Propulsion Laboratory has developed an outstanding capability in new assembly methods for integrated circuits in space applications. In FY 1966, a technique developed at the Jet Propulsion Laboratory was committed for use on the plasma experiment of the Orbiting Geophysical Observatory (OGO-E). As we probe deeper into space with more complex experiments and spacecraft, this problem will be of even greater concern. Additional support in advanced assembly concepts will be required in FY 1967.

Since the near earth radiation environment is now fairly well known, it is important to determine what effects this environment has on electronic circuit devices. A Goddard Space Flight Center sponsored study indicates that state-of-the-art integrated circuits withstand the radiation environment with little degradation. These efforts will be continued in FY 1967 with emphasis on determining the performance capabilities of the newer class of microelectronic devices in the radiation environment.

Since power in spacecraft is at a premium, minimization of power consumption is an important objective. The Langley Research Center has initiated efforts to develop low power logic functions and a differential amplifier in microelectronic form. This effort will continue in FY 1967. The development of computer techniques for use by engineers in analyzing the design and performance of electronic circuits for spacecraft applications will be continued as a means for achieving improved performance and efficiency as well as increased reliability in space systems.

Flight Projects

	1965	1966	1967
Radio Attenuation Measurements (RAM-C)	$900,000	$1,300,000	$1,300,000
Small Flight Projects:			
(SCANNER)	1,500,000	1,000,000	---
(Sextant Experiment)	---	---	500,000
Earth Coverage Horizon Measurement	---	---	1,000,000
Total Flight Projects	$2,400,000	$2,300,000	$2,800,000
Scout (Launch Vehicle Procurement Program)	(---)	(1,400,000)	(800,000)
Total (including Launch Vehicles)	($2,400,000)	($3,700,000)	($3,600,000)

These projects provide the verification of experimental results obtained in laboratory investigations and acquire data essential to the development of advanced sensors and systems of improved performance and reliability. Brief descriptions of these projects are provided in the following paragraphs.

Radio Attenuation Measurements (RAM)

Project RAM was designed to acquire an understanding of the plasma generated by a spacecraft reentering the earth's atmosphere and to determine means of eliminating a communications blackout caused by this plasma.

RAM A and B thus far have shown the relative merits of material addition, magnetic fields, aerodynamic shaping, and higher radio frequencies as methods of overcoming the blackout problem in the velocity range up to 18,000 feet per second.

The major objective of Project RAM C is to obtain reentry communications measurements in the velocity range of 25,000 to 27,000 feet per second. At these velocities the dominant ionization and recombination processes include not only those experienced in the low velocity range of RAM A and B flights, but also processes observable only in the medium and high velocity regimes.

Two flights will be made by the Langley Research Center from Wallops Station. The first, RAM C-A, will test the material addition and X-band telemetry concepts as methods of overcoming the blackout problem. The second, RAM C-B, will be a plasma diagnostic experiment designed to yield measurements of free-electron and ion concentrations at various positions along the spacecraft.

Launches are scheduled in the third quarter of calendar year 1966 for RAM C-A and the first quarter of calendar year 1967 for RAM C-B. Provisions are made for an additional launch for calendar year 1967 in the event the results from the first or second launch make it advisable.

Horizon Definition Research (SCANNER)

The SCANNER project has the objective of making detailed measurements, from high altitudes, of the natural radiation gradients which define the earth's horizon. These data are essential to the development of accurate horizon sensors. The project is an extension of current laboratory research on horizon characteristics. Two experiments will be performed by the Langley Research Center from suborbital ballistic trajectories using the Trailblazer II launch vehicle. Flight #1 is scheduled for August 1966 and Flight #2 is scheduled for November 1966.

Sextant Experiment

Simulation studies at the Ames Research Center, which have included participation by Astronauts, have demonstrated the feasibility of making manual sextant sightings for spacecraft navigation. These studies will be extended to experimental manual navigation measurements by Astronauts in manned spacecraft. These experiments will provide knowledge of the effects of the spacecraft environment, including window optical distortion and actual celestial targets, on sighting accuracy capability. The performance will also be directly compared with that of the more sophisticated primary navigation equipment to determine the potential of manual navigation techniques and instruments for primary as well as backup navigation use.

Earth Coverage Horizon Measurement

This project will extend limited measurements attained through Project SCANNER and supporting X-15 flights to a comprehensive measurement of the earth's horizon radiance profile over a broad range of seasonal and climatic variations. Advanced studies have been initiated in FY 1966 to identify suitable flight experiments and techniques. In FY 1967, these studies will be broadened and completed, and the operational requirements for the planned project defined. The Langley Research Center is directing the initial phases of the effort.

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RESEARCH AND DEVELOPMENT

FISCAL YEAR 1967 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — HUMAN FACTOR SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

This program has four major objectives: (1) to determine man's reactions to the unique environments of space and aeronautical flight; (2) to define the essential requirements for sustaining and protecting man in these environments; (3) to develop the technology necessary to provide suitable life support and protective systems; and (4) to integrate man's capabilities with those of machines to obtain composite systems of superior performance.

The scope, as well as the success, of future manned space missions will depend upon the support and effective utilization of man for extended periods of time. Equally important are man requirements and proper utilization in future aeronautical systems. The understanding of man's performance capability and psychophysiological limitations directly affect design considerations and are essential to insure the effective integration of man as a functional part of the total system. Continuity of effort and timely progress in this program are essential. The increasing priority of certain lagging investigations and technological developments is reflected by the requested funding increases in the various sub-programs.

This program is accomplished through a multi-disciplined approach including researchers in nearly every field of medicine, biology, psychology, engineering, physics and electronics located in NASA centers, Department of Defense aerospace medical facilities, universities and industry generally located throughout the country.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Supporting research and technology.....	$12,160,000	$13,000,000	$15,500,000
Small biotechnology flight projects.....	1,160,000	1,900,000	1,500,000
Total.....	$13,320,000	$14,900,000	$17,000,000

Distribution of Program Amount by Installation:

Manned Spacecraft Center.....	$365,000	$795,000	$1,100,000
Marshall Space Flight Center.	355,000	310,000	300,000
Goddard Space Flight Center..	---	25,000	---
Jet Propulsion Laboratory....	100,000	100,000	---

	1965	1966	1967
Ames Research Center.....	$4,233,000	$5,224,000	$5,830,000
Electronics Research Center..	60,000	359,000	700,000
Flight Research Center.....	1,750,000	1,500,000	1,250,000
Langley Research Center.....	4,053,000	4,246,000	5,000,000
Lewis Research Center.....	232,000	125,000	---
NASA Headquarters.....	2,172,000	2,216,000	2,820,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1965	1966	1967
Human research and performance.	$3,879,000	$5,102,000	$6,080,000
Life support and protective systems.....	5,503,000	4,496,000	5,800,000
Man-systems integration.....	2,121,000	2,902,000	3,120,000
Advanced concepts.....	657,000	500,000	500,000
Total.....	$12,160,000	$13,000,000	$15,500,000

Human Research and Performance

Long term manned space flight will expose man to environmental conditions quite different from those on earth. The objective of this research is to understand the physiological and psychological reactions of man to these conditions and to predict their effects on his performance and well being. The environmental phenomena considered range from zero gravity to solitary confinement and include electromagnetic and particle radiation, magnetic fields, acceleration forces, artificially produced atmospheres, temperature, humidity, and vibration.

During the past year, continuing progress has been made in radiobiology research. The predominating ionizing radiation particles of interest to us in space are protons. Preliminary experiments indicated that at the lethal-dose level, the biological damage mechanism of proton radiation for small animals is somewhat similar to that of gamma radiation. However, additional experiments over many energy levels are required for validation, along with interaction with other parameters such as heat, varied oxygen levels, and vibration. Measurements of dose distribution from the skin inward to a depth of 25 cm with 730 Mev protons shows approximately a 40 percent increase in dose at about 5 cm inside the body. This increase is due to the production of secondary radiation in tissue.

In the area of vestibular research, NASA has a substantial program to investigate the functioning of the primary balance mechanisms, the vestibular organs within the inner ear, and to determine what changes will occur in their functioning under zero-G conditions. The perception of orientation

and coordination of body movements occur within the general framework of man's relationship to the force of gravity. Since the interactions between the balance mechanisms and the normal one-G environment are so important, there is a need to know in detail what the results will be when this gravity framework is removed for long periods of time. If it is found that man cannot adapt to long term weightlessness, one engineering solution will be the rotation of the spacecraft. If this is necessary, the effects of different levels of rotation must be known. This is being studied at the Naval Aerospace Medical Institute by exposing both animal and human subjects to various rotating environments and studying the relationships between functional disturbances produced by the varying force fields and vestibular integrity.

A more fundamental approach to this problem is being studied at the Ames Research Center. There NASA is studying the output of a portion of the inner ear in various accelerations. Flight hardware for this experiment to measure this output in an animal in zero-G is nearing completion; it is scheduled for flight on Apollo 205.

Cardiovascular Research

There is concern that in long term space flight, man may suffer a deconditioning of the cardiovascular system. The Ames Research Center is carrying on various research projects in the cardiovascular field in order to determine if deconditioning will occur in stressed conditions. One of the research tasks in this area is concerned with evaluating the changes in the part of the work resulting from changes in gaseous, chemical, and thermal environments. The essence of this work indicates that changes in cardiac performance measured on the isolated heart are small in response to a range of temperatures and changes in oxygen tension which cause serious disturbances to the central nervous system.

Metabolism and Nutrition

Recent manned space flights have indicated that metabolic changes especially dehydration, or possibly alteration of water balance have occurred. The Ames Research Center is carrying on research to determine the basic mechanism of dehydration and at what levels functional deterioration begins. In addition to the above work, Ames is also looking into alteration of the metabolism of fats, carbohydrates and proteins under stressed conditions.

Microbiology

There is a possibility that changes in susceptibility or resistance to infectious agents may occur under those environmental conditions to be found in space travel. A contract was recently granted to the Naval Medical Research Institute in order to conduct work in this area. Animals will be maintained in hypobaric chambers with selected artificial atmospheres, and they will be compared to control groups under normal conditions.

Life Support and Protective Systems

Life Support and Protective Systems are those systems necessary to maintain man in an unstressed condition, sustain human life, and prevent physical injury in the hostile environment of space.

Present spacecraft utilize relatively short duration life support systems in which the food, water and gases for the atmospheres are stored, and the waste is chemically treated and stored. Significant reduction in systems weights, which is essential to the economic feasibility of long duration manned space flight (e.g., to the planets), is possible by developing regenerative systems. Regenerative life support systems will supply man's requirements (food, water, oxygen) by regeneration from his own metabolic and waste products.

The Langley Research Center has developed and has begun testing loosely coupled components of a partially regenerative system in a life support test bed. Oxygen is removed from carbon dioxide, and fresh water from cabin condensation, urine, and wash water. Components will be studied individually as to efficiency, problem areas, and reliability, as well as collectively while sustaining four men for 100 days. Several new approaches to handling the different elements of the regenerative process are being investigated and will be developed into broad based form for study in the test bed.

Two separate contractors are studying, for the Ames Research Center, techniques available for a closed regenerative life support system recycling all elements including food. A breadboard of this system of choice will be contracted for study in FY 1967.

One promising development in advanced space suits is the metal extravehicular suit being developed for the Manned Spacecraft Center under a contract with Litton Industries. The concept uses constant volume joints to increase mobility and eliminate "spring back" effects.

By FY 1967, this metal suit will have reached such a state that additional effort will be needed for the further development and integration of the ancillary equipment with the protective shell, such as thermal control, life support, etc.; with additional effort, these items can be incorporated in suits for test.

Man-Systems Integration

In manned flight systems, mathematical modelling of man and analytical and experimental data on human performance in aircraft and space vehicles are developed, collated and evaluated to provide a basic library of man-machine information for advanced system technology. For manned and unmanned flight systems, the role of man as a major sub-system is studied in the ground support activities as well. Simulation studies are performed to provide design data and to validate design concepts under realistic conditions to further the understanding of the integration of man into aerospace systems.

A typical study involves the use of an advanced design multi-man capsule which will be mounted on the motion generator at Ames. The internal atmospheric environment, rates of acceleration and vibration, seating and working space layouts, and displays and controls will be modifiable to simulate various internal vehicle configurations. This capsule will be used to study the effects of these factors on pilot performance and to define human factors design criteria for aircraft flight control characteristics such as those involved in V/STOL, conventional jet, supersonic and hypersonic transport and private planes. Similar factors will be studied in manned boosters and space vehicles to define the optimal role of man in launch, orbit insertion, rendezvous and docking, mid-course flight, lunar and other extraterrestrial de-orbit and landing.

Another typical study is concerned with astronaut extravehicular activities to determine appropriate tasks for man outside of the space vehicle. His effectiveness in maintenance and repair of vehicles and satellites, transfer of personnel and cargo between vehicles, and assembly and support of large vehicles in space are pacing items for reduced costs and increased reliability of these vehicles. The interaction of space suits, astronaut maneuvering units, and life support systems must be studied to determine design needs.

Substantial reductions in cost and human error can result from studies of optimum crew sizes and task requirements for earth and lunar ground support activities, and orbital launch. Minimum crew skills needed to achieve checkout, launch, and mission control must be determined as soon as possible in order to be available in time to influence planning and design of future systems. The analysis of performance and shelter of astronauts and astronaut scientists on the moon is a continuing effort.

Advanced Concepts

Research on advanced concepts in any field is essential to solving the next generation of problems in a particular field. In human factors research, many of these problems are likely to involve ways of further integrating man into the operational systems of future aircraft and spacecraft. Several interesting possibilities have arisen in recent years, some showing enough promise to warrant serious study. The following example is representative:

> An investigation is being made through the Applied Physics Laboratory of Johns Hopkins University which is exploring advanced non-anthropometric space suit technology utilizing prosthetic type provisions along with the usual space suit arm and glove provisions. Non-conventional propulsion might be feasible as opposed to walking. Conceptual designs which appear feasible and practical will be subjected to further evaluation through components mock-up and testing.

Small Biotechnology Flight Projects

	1965	1966	1967
Small biotechnology flight projects.....	$1,160,000	$1,900,000	$1,500,000

In many fields of aerospace technology, there are problems that cannot be solved in the laboratory at all but must be solved in flight. Apparent solutions to many other problems can be found on the ground but must then be evaluated in flight before they can be accepted. This small-flight projects program serves these essential purposes for the Human Factors Systems research program.

One example of our current flight experiments is the aircraft pilot's stress study at the Flight Research Center. The aviators are outfitted with the bioinstrumentation for various physiological parameters. The actual collection of the biomedical data to determine baselines of various physiological functions under stress is funded as a flight project.

An example of a flight experiment which requires the space environment and is the outgrowth of laboratory benchwork is an experiment at Ames on the behavior of the otolith organ, the organ of balance located in the inner ear. For this flight experiment, the nerve impulse signals from individual nerve fibers of frog's otolith are tapped. The frog's otolith is similar to man's. The action of the otolith under weightlessness will be measured by recording its nerve impulses to give an indication of the adaptiveness of this organ to weightlessness. This experiment is scheduled for Apollo 205.

An experiment currently being built for the Electronics Research Center for flight on Apollo is a nephelometer to measure the concentrations and size of dust particles in the spacecraft atmosphere under weightlessness.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1967 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY

SPACE POWER AND ELECTRIC PROPULSION SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The space power and electric propulsion systems program provides research and technology to evolve new and improved methods of power generation and electric propulsion for space applications. The program includes work aimed at more efficient and practical use of nuclear, solar and chemical energy for the generation and utilization of electric power in space; as well as the development of the technology of electric thrustors powered by either solar or nuclear power systems.

All space vehicles require electric power for operation of such equipment as communications, telemetry, guidance, stabilization and scientific instruments. The power level and duration varies widely (watts to megawatts and hours to years) depending on the purpose of the vehicle, but the trend is toward the higher power levels and longer mission durations. This trend results from the availability of larger launch vehicles such as the Saturn and from the desire to undertake more ambitious programs. All power system experience to date has been at relatively low power levels, less than 1 kilowatt, and the vast majority of applications have involved solar cell and battery systems. This experience has shown that current solar cell and battery systems will require major improvements in performance, particularly at the higher power levels and that advanced systems that are more compact and independent of the sun will be required.

Electric thrustor systems offer promise of significant savings in spacecraft weight, trip time or increased payload. The power required ranges from watts for attitude control systems to megawatts for manned interplanetary propulsion systems. Solar cells appear to be satisfactory power sources for the lower power thrustors. Work is needed on the system aspects of electric thrustors in anticipation of several early applications.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Supporting research and technology.....	$36,770,000	$38,200,000	$37,000,000
Space electric rocket test (SERT)	2,300,000	3,000,000	---
SNAP-8 development.....	19,150,000	4,000,000	5,500,000
Total.....	$58,220,000	$45,200,000	$42,500,000

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1967 ESTIMATES

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Total.....	$58,220,000	$45,200,000	$42,500,000

Distribution of Program Amount by Installation:

	1965	1966	1967
Manned Spacecraft Center.....	$53,000	$100,000	$650,000
Marshall Space Flight Center...	2,415,000	2,010,000	1,650,000
Goddard Space Flight Center....	3,512,000	4,260,000	3,990,000
Jet Propulsion Laboratory.....	5,607,000	4,491,000	6,050,000
Ames Research Center.....	191,000	110,000	50,000
Electronics Research Center....	---	50,000	300,000
Langley Research Center.....	1,324,086	846,000	700,000
Lewis Research Center.....	43,516,700	28,768,000	26,065,000
NASA Headquarters.....	1,351,214	4,565,000	3,045,000
Western Operations Office.....	250,000	---	---

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1965	1966	1967
Nuclear-electric power.....	$13,106,000	$14,000,000	$13,180,000
Electric propulsion.....	9,919,000	10,000,000	9,850,000
Solar power generation.....	7,911,000	9,050,000	9,000,000
Chemical power generation.....	5,834,000	5,150,000	4,970,000
Total.....	$36,770,000	$38,200,000	$37,000,000

Nuclear-Electric Power

The primary objective of the Nuclear Electric Power Generation Technology program is to provide a broad design basis for the energy conversion equipment to be used in the advanced nuclear electric power generating systems needed for future space missions. Close coordination and cooperation is maintained with the reactor technology program of the AEC.

The contractor and in-house effort in the program are concerned with the technology associated with (1) the Rankine cycle alkali metal turbogenerator, (2) thermionic direct conversion, (3) the Brayton gas turbogenerator, and (4) magnetohydrodynamic (MHD) systems. The Rankine cycle and thermionic conversion systems offer the most promise of attaining the light weights needed for electric propulsion systems. The nuclear thermionic concept which is in an early stage of research has few moving parts, and with its inherent redundancy and small radiator area, may ultimately prove to be the better system for many applications. The Brayton cycle conversion system potential advantages and applications are discussed as a part of the solar power section since the same equipment is being investigated for both the solar and nuclear energy sources. MHD conversion systems are of interest as a possible longer range alternate to the high temperature turbine-generator and thermionic approaches.

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The Rankine turbogenerator program in FY 1966 obtained much useful information on heat transfer, working fluid properties, cavitation phenomena and high temperature refractory materials. In addition, performance and operating evaluations of such components as the turbine, condenser radiator, pumps, etc., are currently underway and progressing toward the design and fabrication of prototype high temperature components for ground testing. The present component testing is concerned exclusively with lower temperature non-refractory alloy test components. The component test programs will be continued in FY 1967. "Dry" vapor performance testing of the two stage potassium turbine at General Electric will be completed by the end of FY 1966. Facility and test unit construction materials limit operating temperature to a maximum of about 1600°F. A 2000 hour endurance run to evaluate erosion damage is also scheduled to be completed in FY 1966. It is planned to extend endurance testing in FY 1967 to 5000 hours if the test data continue to be favorable. This turbine program will also begin design and fabrication of a three stage turbine unit. Single tube boiling and condensing heat transfer programs are scheduled to be completed in FY 1966. In FY 1967, refractory metal and boiler and flight-type condenser studies will begin.

After extensive studies, an advanced tantalum base alloy, T-111, was selected to be the construction material for a two-phase potassium corrosion loop which will operate at a boiling temperature of 2100°F. The loop components (pump, boiler, condenser, instrumentation) were successfully endurance tested during FY 1966 at rated temperature for 2500 hours as part of a component development and evaluation program. The T-111 loop is scheduled to begin operation in FY 1967 and will be directed toward a 10,000 hour test objective.

During FY 1966, considerable progress was made on determining the suitability for high temperature operation of various electrical insulators, magnetic materials, electrical conductors and bore seal materials. During FY 1967 tests of promising materials will be extended to longer times and higher temperatures, and geometries representative of prototype electrical hardware will be fabricated.

The present phase of the advanced Rankine turbogenerator program has been conducted with stainless steel or superalloy components. Although these alloys simplify test operations considerably, they are useful only to about 1600°F. In FY 1966, a design study of a versatile test rig capable of testing refractory alloy components such as turbines, boilers, condensers, etc., is being performed. Fabrication of the test rig is planned to begin in mid FY 1967. This will enable component tests to be performed at about the 2000°F temperature expected to be required for suitably lightweight systems.

The major technological obstacle associated with the nuclear thermionic conversion approach is the attainment of fuel materials that will be dimensionally stable at the very high temperature ($> 3000^{o}F$) and uranium fuel burnup conditions required for efficient, long life operation. The AEC and NASA are conducting coordinated nuclear fuel research programs aimed at investigating two broad classes of materials: the uranium oxides at General Electric, Vallecitos, and the uranium carbides at General Atomic. Fuels testing will continue during FY 1967 at the NASA-Plum Brook Test Reactor.

In addition to the fuels research effort, tests of electrically-heated thermionic diodes assembled with fueled or unfueled emitters will continue in FY 1967. During FY 1966, significant improvements in converter operating life continued to be made. However, performance degradation with time remains a problem. Other thermionic research includes investigations of electrical insulator and metal ceramic joining alloys aimed at developing materials and weldments which will maintain satisfactory electrical and structural properties in a nuclear reactor at the high temperatures and for the long periods required. FY 1967 programs will be conducted to further improve diode performance and simplify diode design configurations.

During FY 1965, cold gas tests of radial-flow turbomachinery intended for use at low power levels achieved the high efficiencies that were predicted by design studies. Similar development and test programs on low power axial flow gas cycle turbomachinery are being conducted in FY 1966. The testing of "hot" gas bearing-supported radial and axial flow turbomachinery units will begin in FY 1966 and will be continued in FY 1967. Particular emphasis in this program continues to be on component efficiency and reliability.

The Jet Propulsion Laboratory (JPL) is continuing an analytical and experimental program on a liquid metal magnetohydrodynamic (MHD) conversion system. Basic feasibility of the direct current (DC) generator component of such a system was demonstrated with room temperature test components.

In FY 1967, JPL will investigate alternating current MHD generators. The AC units are theoretically more efficient than the direct current devices and will also reduce the power conditioning requirements to satisfy predicted electrical load requirements. Test programs will continue in FY 1967 which deal with methods of minimizing hydrodynamic losses in other system components such as mixers, two-phase nozzles, separators, diffusers, etc.

Electric Propulsion

The objective of this program is to provide the advanced technology leading to the development of electric thrustor systems for space propulsion. Such thrustor systems when used in conjunction with lightweight solar or nuclear power generation systems for prime propulsion, offer the potential of substantial increases in payload reductions in vehicle weight, or reductions in travel time generally in proportion to the energy requirements of the contemplated missions. Electric thrustor stationkeeping and attitude control systems offer a primary advantage of reduced system weight when compared with conventional chemical thrust systems for long duration applications. These performance improvements result from the high specific impulses developed by electric thrustors which convert electrical energy into kinetic energy of a propellant. However, a major requirement that must be attained for effective application is a capability for thousands of hours of reliable operation. In addition, attainment of high overall thrustor system efficiency is of major importance for prime propulsion applications because the total power required for operation of the thrustor system, and thus the power plant weight and the mission payload capability, is dependent on thrustor system efficiency.

Electrostatic thrustor systems in which the propellant atoms (or heavy particles) are electrically charged and then accelerated by an electrostatic field, will continue to receive the major emphasis in FY 1967. Two types, the electron-bombardment and contact ion engines which differ basically in the propellant charging or ionization technique, have made the most progress. In the electron-bombardment thrustor the propellant atom is ionized by electron-collisions. The life of the cathode which produces the necessary electrons is the major factor controlling the life of the thrustor. The cathode life improvement program discussed last year has resulted in a successful 2600 hours test of a cesium thrustor. Further life tests with goals of 3500 and 8000 hours are being conducted in FY 1966. In FY 1967, emphasis will be placed on full system testing including thrustor, feed system and power conditioning. In addition, system interaction problems which become important as thrustor applications increase, such as ion beam impingment on spacecraft structures and radio-frequency interference will also be studied in FY 1967. Since studies of solar-powered mid-course propulsion for planetary missions show potential, these efforts will continue. In addition, scaling of thrustors to the 300 KW size required for future applications will be continued at the Lewis Research Center.

In the contact ion engine, propellant atoms are charged or ionized by coming in contact with a hot material, usually porous tungsten. In order to meet engine life requirements, over 99% of the propellant atoms must be ionized. Previous difficulties in achieving the required ionization at reasonable efficiencies and lifetimes led to a decision to deemphasize contact engine development and concentrate on the ionization problem in FY 1966.

However, techniques of coating porous tungsten with iridium and rhenium were evolved which, on a laboratory scale, show promise of permitting the desired ionization and life expectancy. The performance of these improved ionizers will be evaluated in FY 1967. Progress in thrustor technology has led to an important decision to flight test a small (~15) contact ion thrustor system on the initial Applications Technology Satellites (ATS) in anticipation of using similar systems on the later synchronous gravity-gradient stabilized ATS flights. This first NASA utilization represents an initial and important step in the transition of the status of electric propulsion from an advanced idea to useful applications. Thrust vector control through electrostatic ion beam deflection will be incorporated on similar engines in FY 1967 for evaluation.

A resistojet will also be considered for the ATS. This is one version of an electrothermal engine which accelerates propellant by heating and subsequently expanding the propellant through a conventional converging-diverging nozzle system. System studies have shown the resistojet to be of interest for cancelling aerodynamic drag of large spacecraft such as orbiting laboratories. Research in FY 1967 on this class of device will concentrate on establishing long life and in investigating utilization of waste material (i.e. excess water, etc.) from manned space station life support systems as the propellant. Efforts to evaluate the replacement of the resistojet's electric heater with radioisotope heat sources will also be carried out in FY 1967.

The electromagnetic thrustors, which employ magnetic forces in the development of thrust, offer the promise of superior performance and reduced complexity over the entire range of specific impulse and consequently will receive research emphasis in FY 1967. Efforts will in particular be made to verify the performance of the promising MPD arc jet. Preliminary data of 70% efficiency at a specific impulse of 4000 seconds has been reported. However, the inadequacy of ground facilities to simulate the true space environment causes an uncertainty in these data. A comprehensive effort will be conducted in FY 1967 to eliminate these uncertainties.

Solar Power Generation

Solar photovoltaic cells are relatively low in weight and have proven to be a practical and reliable source of spacecraft electric power at levels up to several hundred watts. However, the availability of the Saturn class of launch vehicles is making possible much larger spacecraft requiring substantially more onboard electric power. During the past year an in-house program was started at the Jet Propulsion Laboratory and the Marshall Space Flight Center, supported by contracted programs at the Boeing Company, the

Ryan Aeronautical Company, and Electro-Optical Systems on the research and technology problems related to very lightweight, kilowatt size solar cell arrays. The investigation of such key problem areas as more economical solar cell fabrication and assembly methods, array packaging and deployment and lightweight structures and folding and unfolding mechanisms will require an increased effort in FY 1967. Although improvements have been achieved, significant weight penalties can still be attributed to the need to protect solar cells from damage by the energetic particle radiation, micrometeoroid and high temperature environments to be encountered by spacecraft operating in space. A continuing effort is needed in these areas, as well as efforts to improve cell efficiency and reduce cell weight.

The output of the array is a direct current (DC) voltage which must be changed (inverted) to alternating current (AC), transformed to higher or lower voltages, regulated, filtered to suppress surges and distributed to the various spacecraft loads. It is essential for the higher power systems that the efficiency of the many electronic components and circuits used for these purposes be improved while maintaining satisfactory reliability.

New work on power transistors to lower saturation resistance and increase current and voltage capabilities is to be undertaken at the Electronics Research Center. Work on integrated circuits at the Marshall Space Flight Center and at the Jet Propulsion Laboratory will be continued with emphasis on higher power handling capability, larger area devices and improved interconnections.

The thermionic conversion of solar thermal energy appears particularly promising as a source of electric power for spacecraft operating near to the Sun. These systems make use of solar concentrators and high temperature thermionic generators which should be relatively unaffected by operation in the high temperature and particle radiation environment near the Sun. Work during the past year has resulted in improvements in thermionic diode operating lifetime, power density, and conversion efficiency. For example, one thermionic converter recently passed 10,000 hours operation and is continuing on test. This is significant in that it is the first such device to demonstrate the possibility of such operating lifetimes. Further improvements are needed in uniformity of converter characteristics and in efficiency and power density, and based on current experience appear possible with additional work. The output voltage per converter ranges between 0.6 and 0.8 volt for operation at 1730°C but by reducing the internal voltage losses could be increased to about 1.2 volts with resulting improvements in conversion efficiency. Further research is planned on the use of surface and plasma additives to reduce the internal losses.

Work is continuing on the Brayton cycle power conversion system technology program initiated in FY 1963, using solar and nuclear power program funds. The use of Brayton cycle conversion systems with solar power sources will minimize solar concentrator size due to the cycle's inherent high efficiency. In a like manner, the use of Brayton equipment with isotope power sources will minimize the amount of scarce and expensive isotope, e.g. Plutonium 238, required. Other significant advantages of importance to both solar and

isotope power systems, such as reduced material compatibility problems, and no zero-g problems are derived from the fact that the Brayton cycle uses an inert gas, e.g. argon or neon as the working fluid. The first experimental turbomachinery and heat exchangers have been fabricated, delivered, and are under test at the Lewis Research Center. Cold flow tests have verified design performance. Hot flow tests have not yet been conducted.

Both of the above solar thermal systems (Brayton and thermionic) require focusing concentrators (mirrors) to develop the high temperatures required. The difficulties involved in fabricating large, lightweight mirrors (concentrators) possessing high surface contour accuracies require a continuing effort leading to full size mirrors of 20 to 30 feet diameter weighing less than one pound per square foot (1 lb/ft^2) and having an efficiency of greater than 85% with a concentration ability of over one thousand to one.

Chemical Power Generation

The fuel cell power systems now under development for Gemini and Apollo can be expected to satisfy the need for on-board space electric power for the two-week earth and lunar orbital missions for which they have been designed. With technology improvements the usefullness of these fuel cells can be extended to mission durations of 30 to 45 days. In addition, the first really long duration missions may make use of fuel cells for a total life of 90 days and longer. Thus, there exists a need to extend the present technology objectives from the 400 hour endurance characteristic of Gemini and Apollo to 1000, 2000, and eventually, 3000 hours while maintaining the high reliabilities required for manned missions. Of equal importance is the need to extend standby life, to improve on orbital start and restart capability, and to obtain lightweight, compact systems.

Work on the above problems is continuing using an Allis-Chalmers fuel cell as an experimental system. Experimental modules have been tested at the Manned Spacecraft Center. These breadboard units have been run for more than 1500 hours and have operated well under continuous as well as start-stop conditions.

A reliability test program is needed to obtain parametric design data for operating durations in excess of 3000 hours. Work to further improve efficiency and complete the technology for low-temperature, in-orbit startup is needed. In addition, there is a need to acquire the technology necessary to support the development of larger fuel cell modules in the 3 to 5 kilowatt size.

Primary and secondary (rechargeable) batteries are used for relatively short duration applications, i.e. 34 hour Gemini mission, or in conjunction with solar power systems when the spacecraft is periodically in the dark. To date, spacecraft batteries have been relatively low power devices, which will not be able to satisfy the fast recharge, high power and broad operating

temperature range requirements of anticipated missions. Laboratory experiments and ground based system experience indicate that it should be possible to develop satisfactory units. However, such work is not being conducted as part of specific battery development programs in support of approved missions. Therefore, NASA has initiated a research and technology program aimed at improving energy density, cycle life, capacity retention and resistance to high temperature degradation. It is important that this program be strengthened in FY 1967 in order to meet the anticipated needs in the 1970's for larger batteries for orbital, lunar surface and planetary mission applications.

SNAP-8 Development

	1965	1966	1967
Development.....	$19,150,000	$4,000,000	$5,500,000

The objective of this technology project is to conduct the ground development of a 10,000 hour, 35 electrical kilowatt nuclear electric generating system suitable for space applications in the 1970's and beyond. Principal applications for SNAP-8 are large earth orbiting space stations, lunar exploration, direct TV broadcast satellites, and manned Mars missions.

SNAP-8 is a joint NASA-AEC project with the AEC responsible for the reactor and shield and NASA responsible for the power conversion system and full power system integration. It utilizes a boiling mercury turbogenerator to convert thermal power developed by a compact space reactor into electrical power. The design approach places priority on reliability and ease of development (maximum use of current state-of-the-art) and provides flexibility to adapt to a range of potential missions with a minimum change.

During calendar year 1965, NASA completed testing to determine performance data of the first generation of major power conversion system components -- the system pumps, heat exchange components, and the turbine alternator. The performance was demonstrated to be satisfactory except for the boiler which although performing as required once it reached full thermal power, has been giving erratic superheat performance during initial startup. A boiler redesigned to investigate solutions to this problem is now in test. Endurance development of the components has been started. Single unit endurance times demonstrated to date range from 670 to 2600 hours. As part of the endurance test program, a complete mercury loop was operated for 670 hours, producing electrical power within SNAP-8 specifications. This test was terminated by failure of the first turbine after 830 hours of operation, but mechanical design modifications have now been completed and turbine testing will be resumed shortly. The SNAP-8 reactor completed 12,000 hours of operation, 8,800 of which were at system power and temperature. The reactor is undergoing post-test examination.

During FY 1966, NASA will continue with component performance and endurance development testing and will complete preparations for the test of a first breadboarded power conversion system utilizing FY 1966 funds authorized and appropriated by the Congress.

During FY 1967, development testing of components will be continued and tests of the first power conversion system will be initiated. Supporting technology programs in heat transfer, materials, system dynamics and endurance instrumentation which were delayed by the phase-out operations will be initiated to provide the necessary basis for understanding system behavior and to improve performance as required.

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OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY NUCLEAR ROCKETS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The mission of the nuclear rockets program is to provide the necessary research, design, and engineering data, test hardware, and general technology required to develop nuclear rocket systems with power levels, operating times, restart conditions, and specific impulse values suitable for advanced space exploration missions. A program directed to meet these objectives will assure availability of these advanced propulsion systems when they are needed.

Through the use of nuclear rocket propulsion, significant performance advantages accrue to many advanced space missions such as lunar base logistics operations, deep space probing with heavy complex spacecraft, and manned exploration of the planets. A number of studies have been conducted to evaluate the potential of the nuclear rocket in its major applications. For the manned Mars mission, the studies indicated that spacecraft departure weight in earth orbit is substantially less with nuclear rocket propulsion than with chemical propulsion, the weight differences ranging from 1 or 2 million pounds for favorable missions modes and times (low energy requirements) to many millions of pounds for less favorable mission opportunities.

The major areas of effort are the research and engineering of the nuclear reactor, the development of certain non-nuclear components, and the integration of the reactor and non-reactor components into a complete experimental engine system.

The experimental ground test engine system is being investigated to provide an essential understanding of the interaction of components in nuclear rocket engines and of the system performance characteristics. Progress in the technology phase warrants the initiation of specific engine development in FY 1967.

The nuclear rockets program is a joint AEC-NASA undertaking. To ensure an integrated program, the Space Nuclear Propulsion Office, established by interagency agreement between AEC and NASA, manages all aspects of nuclear rocket propulsion work for the two agencies. Research and technology work is conducted both in AEC Laboratories (e.g., the Los Alamos Scientic Laboratory) and NASA Centers (e.g., the Lewis Research Center and the Marshall Space Flight Center), although the major portion of the work is conducted by industry.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Supporting research and technology	$20,891,000	$21,000,000	$16,900,000
NERVA	35,370,000	36,000,000	33,100,000
NRDS operations	739,000	1,000,000	3,000,000
Total	$57,000,000	$58,000,000	$53,000,000

Distribution of Program Amount by Installation:

Marshall Space Flight Center	$1,375,000	$1,125,000	$900,000
Jet Propulsion Laboratory	6,000	---	---
Lewis Research Center	9,846,000	6,599,000	3,550,000
Space Nuclear Propulsion Office	45,760,000	50,218,000	48,500,000
NASA Headquarters	13,000	58,000	50,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1965	1966	1967
Rocket reactor research	$13,069,000	$14,250,000	$11,700,000
Nuclear rocket engine systems	6,269,000	5,150,000	3,950,000
Safety	500,000	500,000	250,000
Vehicle technology	1,053,000	1,100,000	1,000,000
Total	$20,891,000	$21,000,000	$16,900,000

The supporting research and technology (SR&T) effort supplies four basic needs: (1) general supporting research and technological data for current projects; (2) necessary basic technology for the development of future generations of nuclear rocket engines and vehicles; (3) feasibility analyses of advanced nuclear propulsion concepts; and, (4) studies of the special safety problems of nuclear rockets.

Rocket Reactor Research

This activity supports work in two general areas: first in the area of advanced concepts and in the design studies of reactor concepts of interest for future applications; secondly, these funds provide for nozzle and propellant feed systems for use in the ground test of Phoebus 2.

Advanced concept work is concentrated on various types of cavity reactors, in which the fissionable materials are in gaseous, liquid or dust form. Primary in-house capability and research is centered at the Lewis Research Center. Additionally, the capabilities of industry and universities are applied through contracts and research grants. The emphasis is on laboratory research because propulsion systems and large scale experiments cannot yet be defined due to a lack of basic information on feasibility and, in some cases, a lack of basic research data.

NASA funds the development of a liquid hydrogen turbopump feed system to be used in the testing of high-power (Phoebus 2) reactors at the Nuclear Rocket Development Station. This system is based on the liquid hydrogen pumps and turbines developed for the KIWI test series.

Liquid hydrogen regeneratively cooled exhaust nozzles are also required for the Phoebus 2 reactor program conducted by the Los Alamos Scientific Laboratory. Development of such nozzles is underway in a contract let during FY 1965.

Nuclear Rocket Engine Systems

This research provides information for specifying characteristics of future generations of nuclear rocket engines as well as establishing a general base of information on the design and operation of components and engines. Engine component technology is the responsibility of NASA; the in-house effort is conducted by the Lewis Research Center with other work being accomplished under industrial and university contracts principally under Lewis' direction.

Turbomachinery research is directed at the unique problems posed by application to a nuclear rocket engine, and is coordinated with turbomachinery research conducted for advancement of chemical rocket technology.

Another important supporting effort in the nuclear rocket program is provided by the nuclear cold flow rocket engine systems tests conducted by Lewis in the Nuclear Rocket Dynamics and Control Facility. These tests have included the first bootstrap starts of the nuclear rocket engines, and start-up tests in which the turbopump was deliberately run into stall to determine the start-up performance of a nuclear rocket engine under such conditions.

Radiation effects work is conducted at Plum Brook as part of the engine component research work to define the behavior of materials in combined radiation, cryogenic, and vacuum environments. Such information supports all phases of the nuclear rocket program and is essential for the design effort.

The combined environments of radiation, vacuum, extreme temperatures and very high bearing speeds create difficult development problems in regard to bearings, seals and lubrication. An inpile bearing test loop is in operation for research on bearing configurations in a combined radiation and cryogenic environment.

Research continuing through FY 1967 will include work on nozzles for nuclear rocket engines. Analyses and research have been undertaken in areas of refractory metals and coatings, fluid mechanics and heat transfer, stress analysis and thermal fatigue.

In FY 1967 NASA will continue to support, although at a reduced level, the National Bureau of Standards Cryogenic Engineering Laboratory in research and engineering related to the use of liquid hydrogen. While this support has come from the nuclear rocket program, the research has benefited all programs that use liquid hydrogen (e.g., Centaur, Saturn, the J-2 engine, etc.) by supplying basic property data and cryogenic engineering support.

Propellants and pressurants in support of the research and development activities on turbopumps and nozzles for Phoebus reactor tests as well as the Phoebus reactor tests themselves are provided by SR&T funds.

Safety

Safety work is an integral part of the overall nuclear rocket program. It includes effort on hydrogen safety by the Bureau of Mines aimed at unique safety problems associated with handling large quantities of liquid hydrogen in the nuclear radiation environment. Also included is work on evaluation of countermeasure systems to assure safe disposal of nuclear engines and operational safety analyses of nuclear rocket engines.

Vehicle Technology

This program provides information on new concepts relating to vehicle staging and configuration for future applications of nuclear rocket engines to spaceflight missions.

Modular vehicle concepts in which each module includes a nuclear rocket engine and propellant tank has particular attraction since our basic tank/engine design conceivably could satisfy a variety of missions from lunar to planetary stop-over, merely by clustering as necessary the requisite number of essentially identical modules. The modular studies initiated in FY 1965 have defined a configuration in sufficient detail to point out areas requiring advanced technology effort.

In FY 1966 the feasibility of designing and constructing a reasonably close ground test version of a modular tank, which could be used for advanced technology development by means of cold-flow testing is being investigated in depth.

Examples of problem areas requiring advanced technology development include long term storage of liquid hydrogen in space for periods exceeding a half a year, and structural design of tanks for applications requiring assembly into clusters, while in Earth orbit. Investigations in these areas are coordinated with and complement other elements engaged in space vehicle research. In addition, nuclear rocket engine-vehicle interactions, and coupling requirements are also important and will receive continued attention.

NERVA

	1965	1966	1967
Engine systems development.....	$5,426,000	$5,600,000	$6,000,000
Component and subsystem development.....	12,444,000	11,800,000	9,600,000
Ground test and operations support.....	14,572,000	15,100,000	15,000,000
Propellants.....	2,928,000	3,500,000	2,500,000
Total.....	$35,370,000	$36,000,000	$33,100,000

The objective of the NERVA technology effort is to develop the technology of nuclear rocket engine systems utilizing graphite solid-core reactors. Progress in the graphite reactor program has been very good. The NERVA technology work is conducted principally under a joint AEC-NASA contract by the Aerojet-General Corporation and Westinghouse Electric Corporation. Altitude equivalent performance levels in excess of 750 seconds specific impulse at 55,000 pounds of thrust have been achieved for extended durations.

In view of the reactor progress, increased emphasis is being devoted to the engine system phase. This effort includes the development of critical non-nuclear components, such as the nozzle, turbopump and control system, and the integration of these components with the reactor into meaningful nuclear rocket engine systems tests. It is important to gain a thorough understanding of the interactions of the various components during start-up, full power operation, operation at off-design conditions, and during cool-down periods. With this knowledge we can develop components and systems leading to the development of operational flight engine systems with a high assurance of success.

Engine system work includes investigations of engine system transient start-up characteristics, steady state operating cycles, system dynamics of engine throttling and shutdown, and investigation of engine restart characteristics.

The development of test facility technology is necessary to provide confidence in undertaking a future nuclear rocket engine development program. The facility technology objectives include proof of the techniques for remote testing of downward firing engines and the feasibility of remote handling operations for engine system maintenance and disassembly.

Selected engine components are being developed in connection with the engine systems evaluation program, but component development is limited to those major components which strongly influence system performance. Valves and lines are facility or "boiler plate" types wherever possible. For the ground test program, most components will not be qualified to the high degree of reliability necessary for flight operation. However, major components such as turbopumps, nozzles with hot-bleed ports, and actuators for engine reactor control will be of flight design and will be adaptable to "flight" operating conditions.

Significant accomplishments to date in the KIWI and NERVA projects include: reactor start-up and stable operation using liquid hydrogen as a coolant; demonstration of a satisfactory reactor design that avoids the flow-induced vibration previously encountered; successful operation of a single reactor for 16.5 minutes at design conditions; restarting a reactor and achieving design power after a prior run at design power; automatic start-up of a reactor from sub-critical conditions, thereby demonstrating the capability to start the nuclear rocket automatically as would be required in a flight system; completion of studies confirming the ability to cluster engines; and the conduct of a Transient-Nuclear-Test with favorable results. Other progress includes improvement in fuel element quality, and advances in nozzle and turbopump technology.

The program calls for the initiation of the NERVA engine development phase in FY 1967. It has been determined that an engine designed for a power level of 4,000 to 5,000 thermal megawatts giving a thrust of about 200,000 to 250,000 pounds could efficiently perform all these missions in which nuclear rockets offer significant advantages. Such an engine system will be based upon the high-power Phoebus 2 reactors technology being developed by the AEC's Los Alamos Scientific Laboratory.

The preceding discussion of NERVA has presented the project from an overall, integrated point of view. The following paragraphs discuss the project from a different viewpoint, that of its major areas of work effort and fund allocation.

Engine Systems Development

The objective of this phase of the NERVA project is to perform the engineering, fabrication, and testing of experimental engine systems. The program includes cold flow tests conducted in a non-nuclear engine simulator as well as hot flow tests conducted with operating reactors. Characteristics

evaluated in the cold flow simulator tests include the initial portion of engine start-up with liquid hydrogen, flow stability, flow leakage, system pressure losses, and control response times. During FY 1967, the Cold Flow Development Test System (CFDTS) will be modified to the ground experimental engine (XE) cold flow configuration. The preliminary design and systems analysis of the 200,000 to 250,000 thrust engine will be continued in FY 1967. In addition, effort will be spent on studying concepts for remote removal and installation of the engine from and into the test stand and for remote disassembly and reassembly of components about the engine external shield.

Component and Subsystem Development

Development of components and subsystems include those required for the experimental engine systems and some required for the conduct of reactor experiments. Principal objectives are the development of the liquid hydrogen turbopumps, thrust chamber assembly, and engine controls. During FY 1967, final assembly and shipment of XE-1 components will be accomplished and fabrication and acceptance testing of the thrust chamber assembly of the second experimental engine (XE-2) will be completed. A pressure vessel and a thrust chamber assembly will be fabricated for the engine and the experimental reactor program. In addition, a chamber gas temperature probe will be fabricated and submitted for testing.

Ground Test and Operations Support

Overall, this phase of the project provides remote handling equipment, checkout and test equipment, and maintenance equipment for all test operations, including special test equipment for components associated with the large engine. It also provides certain instrumentation for diagnostic and control purposes, for reliability and quality assurance testing, and for operational safety monitoring. During FY 1967, the design criteria and the design and fabrication of the required transport, handling, hot disassembly and post-operative equipments for the experimental engines will be completed.

The operation and maintenance instructions and acceptance test specification for the experimental engine cold flow support equipment will be formulated. In addition, design and procurement of storage equipment for the various engine and reactor test articles will have been completed during FY 1967. Safety evaluation reports for the experimental engines (XE-1 and XE-2) will be issued and the program comprehensive safety evaluations and reviews and operational safety at the testing station will be continued.

Propellants

Funds provided under this heading will be used for procurement of propellants, primarily liquid hydrogen, required in various NERVA testing programs.

Nuclear Rocket Development Station Operations

	1965	1966	1967
General site support.....	$739,000	$1,000,000	$3,000,000

The mission of the Nuclear Rocket Development Station (NRDS) is to provide a site for ground static testing of the reactors, engines, and eventually, vehicles associated with nuclear rocket development. Management of the Nuclear Rocket Development Station is assigned to the Space Nuclear Propulsion Office. The major users of the Station are Aerojet-General Corporation, Westinghouse Astronuclear Laboratory, and the AEC Los Alamos Scientific Laboratory.

Maintenance, housekeeping services, and management functions must be provided at this site. These funds provide for NASA's share of the general site operations, the major part of which is now funded by the AEC. Technical support is not included under this category but is funded from the appropriate project category such as NERVA.

NASA's share of the NRDS Operations costs will increase by an amount of $2,000,000 in FY 1967 over FY 1966. The major reason for this increase is the additional maintenance support required for E-MAD and ETS-1 facilities which will become operational in early 1967. Another element contributing to the increase is the raised level of housekeeping support associated with experimental engine systems testing at NRDS which will be initiated in FY 1967. The first test will be an XE cold flow test scheduled for November 1966 followed by the first XE-1 power test in the summer of 1967.

General site support includes routine maintenance and operation of the facilities; for example, custodial services, maintenance of roads, grounds, and utility systems, furnishing of utilities, building operating supplies, fire protection, and cafeteria services. Included also are the services of a support contractor to maintain and operate plumbing, electrical, carpenter, welding, and machine shops. Funds in this category also cover costs of maintaining and operating support facilities and equipment.

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OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — CHEMICAL PROPULSION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objective of the chemical propulsion program is to provide a sound base of technology on which to develop propulsion equipment for the National space program missions. This base must cover research examination of fundamental concepts, of engineering data, design, fabrication, and experimental testing to prove that the basic technologies can be integrated to create practical propulsion machinery. In addition, the program supports current mission developments by examining special problems of a research nature.

Chemical propulsion systems are the mainstay of the transportation needs of the space program, notwithstanding the special advantages of nuclear and electrical propulsion. Among their applications are boosters, upper stages and thrust augmentors for launch vehicles, escape stages, lunar and planetary landing modules, and in-orbit maneuver, mid-course correction, attitude control, rendezvous, de-orbit and propellant settling systems for spacecraft. Chemical propulsion is also being applied to personal mobility devices, and future lunar and planetary exploration vehicles. In addition, chemical propellants are used for a variety of auxiliary devices such as ignitors, and stage separation systems. These applications represent a tremendous range of thrust levels, operating times, start and restart conditions, and propellant handling problems. Furthermore, the continued exploration of space will require increased capacity and versatility of these propulsion systems. The program of advanced research and technology to cover this array of applications and operating conditions must strike a balance between these complex requirements and the difficulties of finding practical and reliable solutions and must be managed with perception and perspective with regard to the schedule of potential needs. Such a balanced program will assure continued advancement of the propulsion capabilities of the nation's space program.

The work in chemical propulsion covers both liquid and solid propellant systems, and in fact combinations of the two types, called hybrids. Very advanced engine systems which use atmospheric air during flight through the sensible atmosphere are being examined. The content of the program includes not only the propulsion-oriented basic scientific and disciplinary technologies but in addition brings strong focus on the problems of design methods, fabrication and test procedures, practical operating limitations, and so forth, through tests of quasi-prototype hardware systems. From this work is gained an extremely valuable insight into developmental pitfalls and funding and facility requirements of any new system contemplated. This attempt to bridge the gap between academic research and technology investigations and development is an important and valuable aspect of the chemical propulsion program.

NASA field centers have a profound capability in chemical propulsion with high effectivity in covering the vast array of propulsion component and system types. This work is carried out both in-house by highly talented specialists using unique NASA facilities and by contract with industrial and academic organizations. Such contracts are managed closely by NASA specialists who are well versed in propulsion technology.

The requested funding of the chemical propulsion program in OART has been increased in FY 1967 in anticipation of meeting new requirements for extended orbital and lunar operations, planetary observation and landing missions. This program, which provides the roadbed for NASA space ventures, needs now to lay the groundwork for a new generation of high performance systems that will permit the accomplishment of more ambitious missions with reduction in cost of orbital, lunar and planetary space operations.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Supporting research and technology	$24,762,000	$33,500,000	$33,500,000
M-1 engine project	24,910,000	2,000,000	---
Large solid motor project	26,800,000	4,200,000	3,500,000
Small chemical propulsion flight projects	30,000	---	---
Total	$76,502,000	$39,700,000	$37,000,000

Distribution of Program Amount by Installation:

John F. Kennedy Space Center, NASA	---	$250,000	$250,000
Manned Spacecraft Center	---	500,000	500,000
Marshall Space Flight Center	3,721,000	4,800,000	6,500,000
Goddard Space Flight Center	550,000	550,000	550,000
Jet Propulsion Laboratory	3,858,000	3,707,000	3,700,000
Ames Research Center	---	540,000	500,000
Langley Research Center	1,369,000	2,877,000	2,900,000
Lewis Research Center	49,588,352	15,205,000	12,800,000
NASA Headquarters	11,972,422	11,271,000	9,300,000
Western Operations Office	5,443,226	---	---

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1965	1966	1967
Liquid Rocket Research and Advanced Technology.....	$11,500,000	$12,720,000	$12,700,000
Liquid Rocket Experimental Engineering.....	6,075,000	12,235,000	12,250,000
Solid Rocket Research and Advanced Technology.....	4,995,000	5,045,000	5,050,000
Solid Rocket Experimental Engineering.....	2,192,000	3,500,000	3,500,000
Total.....	$24,762,000	$33,500,000	$33,500,000

Liquid Rocket Research and Advanced Technology

This area of broadly based research-technology is applicable to all chemical propulsion and is therefore of major significance in the program. It encompasses studies of future requirements, conceptual work on engine cycles and systems to meet these requirements, examination of combustion processes and instabilities, investigation of disciplinary engineering areas such as pump design and related hydrodynamic behavior, examination of new materials and methods of fabrication, development of new instrumentation or testing techniques, compilation of engineering information for design, data tables, etc. This work, covered by nearly 200 tasks, provides the technological base needed for design and fabrication of new chemical propulsion systems.

Component and materials investigations include valves, seals, connectors, refractory materials, fibers, and resins. New oxidizers and fuels in gelled and in slush form are being characterized. A screening and development program has been under way for catalysts to use in liquid hydrogen-liquid oxygen engines as the primary method of ignition. The initial results have led to consideration for J-2 engines.

The alloys of pyrolytic graphite utilizing zirconium and hafnium are being manufactured by new processes which are the result of exploratory work supported by this office. Prior manufacturing processes were not rigorous enough nor could they be controlled to the degree needed for making the alloy form. Further, alloys of hafnium/tantalum have been manufactured under sponsorship of NASA by the Illinois Institute of Technology Research. These materials are the forerunners of a new class of metal alloys which will be applicable in the high temperature environment. The breadth of use can be from aircraft turbo-machines to higher temperature rocket engines to the external structure of hypersonic aircraft. The basic metallurgical technology is thereby adding to the industrial capability of the nation.

Combustion instability has been a continuous problem of the liquid rocket. Part of the problem has been in relating the theoretical parameters to designs of hardware. This impasse is being attacked by a concentrated and continuing effort. Engine dynamics, instability and propellant pumping also are being investigated. The realm of work is broad-based, incorporating basic work in fluid mechanics and aerothermochemistry, materials, and design technology.

The potential of thrust vector control, using the fluid amplifier, is being assessed for large engines. The system utilizes hot gas bled from the combustion chamber and injected into the exit nozzle to create shock patterns, thus applying a side thrust to the vehicle.

A typical supporting research problem is that of leakage detection. The purpose of work on this problem is to establish and document all modern methods and new laboratory methods into a standard. This standard will utilize correct technical language, leakage units, and operating procedures applicable to the field. This Leakage Detection Manual will be distributed throughout NASA, the Department of Defense, and the aerospace industry. The basic method, although the manual is not yet complete, is presently being used in the Surveyor program.

Liquid Rocket Experimental Engineering

The liquid rocket experimental engineering program is divided into three major categories: launch vehicle systems, space propulsion systems, and auxiliary propulsion systems.

Launch Vehicle Systems - Advanced engine concepts which offer greater performance capability than typical current engines have been under investigation at low funding levels in the broad-based chemical propulsion research technology program. Two major concepts have emerged. The first concept involves combustion at high pressures. This allows greater expansion in a conventional nozzle within a limited envelope. The second concept uses a so-called plug nozzle, again providing greater expansion within a limited volume but at lower combustion pressures. Although these concepts represent rather different technical approaches, either has the prospect of significant increases in performance capability when compared to current engines.

The diverse technologies of each concept will be explored with scale model hardware. Testing of various components such as pumps, injectors, combustion chambers and nozzles and the assembly of these components for a breadboard engine test will demonstrate the concepts under study to provide design information for advanced engine developments of the 1970's. The scale of these breadboard demonstrations will be such that the hardware concepts may also be employed to uprate Saturn vehicles. Modular concepts are under study which would allow use of a building block approach for application of a common module to several vehicle sizes with considerable reduction in development cost.

This activity supersedes and benefits from the M-1 engine project. As it became evident that post-Saturn vehicles would not be required until later than had been anticipated when the M-1 was initiated, the M-1 program was first rescheduled at a reduced funding level. The project is now being terminated in favor of the technological investigations of higher performing advanced oxygen-hydrogen engines for the large launch vehicles. Before termination of the M-1 engine program operational tests of large scale engine components, including the oxygen-hydrogen turbopump assemblies and the full scale combustion chamber, will provide scaling correlation factors that will apply to the development of large advanced engines of the future.

Experimental engineering work to be conducted in the next few years will begin with expansion of the effort now underway in high pressure pumping. Design studies for this fiscal year will define other components so that work on high pressure and toroidal or annular combustion devices, aerodynamically augmented plug nozzles, thrust vector control, etc., may be initiated. By the turn of the decade, a sound basis is expected for specifying a new generation of high performance engine systems.

Space Propulsion Systems - Solar probes, delivery of satellite spacecraft to earth orbit, and planetary orbiting and landing missions impose unique requirements on the propulsion system designed to perform these missions. Some of these are long-term missions requiring six months or more for a one-way trip. Most require very high energy release. Further, the acceleration that must be imparted to a space payload places a premium on the performance of the spacecraft system itself. Obviously, it is desirable to invest as little weight in propulsion systems as possible in order to maximize the real payload. The propellant performance aspects include not only high thrust per unit mass burning rate of propellants but also spontaneous ignitability, and for landing maneuvers, throttling capability.

The high energy deep-cryogenic fluorine-hydrogen propellant combination is attractive for upper stage vehicles where storage time requirements are not extensive. Work with these propellants is continuing with RL10 engines toward demonstrating the performance capabilities of a pump-fed engine configuration. Significant performance improvements are being measured in the current test program following modifications of flight weight engine components originally designed for oxygen-hydrogen service.

Attention is also being given the fluorine propellant feed system area through a program recently initiated to provide engineering criteria for the design, fabrication, inspection and servicing of fluorine feed system components such as flow lines, control valves and regulating equipment. Such system criteria will serve as a model for criteria applying to other fluorine containing oxidizers. For extended-time-in-space missions such as the planetary missions, extended Earth-orbit missions, lunar extended-stay-time missions, and planetary missions, there is a requirement for propulsion systems of low weight using high performing propellants that can be stored in the space environment for extended time with minimum evaporative loss. To enhance space storability, it is desirable to use oxidizer and fuel propellants with a common liquid range at temperatures where heat gains or losses are minimal.

High propellant bulk density is desirable to reduce the surface of tanks exposed to radiation and to meteoroid impact and to minimize the insulation required. The class of propellants that most nearly satisfies the requirements includes oxygen-difluoride (OF_2) or mixtures of oxygen and fluorine (FLOX) as oxidizers; high performance fuels with similar liquid ranges include liquified petroleum gases (LPG) and diborane (B_2H_6). While these propellants exhibit lower specific impulse than combinations such as O_2H_2 or F_2-H_2, the much higher bulk densities (liquid hydrogen has a density about 7% that of water) and overlapping liquid ranges are advantageous.

The space storable class of propellants involves very energetic oxidizers which burn at exhaust temperatures between 7000 and 8000°F, significantly higher than propellants currently in use. This fact poses a serious technical problem since cooling at such exhaust temperatures is difficult, particularly for the relatively small propulsion systems visualized for long-term missions in the next decade. There are a number of technical problems to be solved. Cooling techniques and materials of construction will be developed that will contain these high temperature combustion products. An OF_2-MMH program has been initiated to investigate the general cooling problem represented by this class of propellants. Problems of using oxygen difluoride in combination with liquified petroleum gases in a pressure-fed proplusion system application are being identified. A program to demonstrate the capabilities of a pump-fed engine utilizing these space storable propellants will be pursued in FY 1967. These programs will provide vehicle designers with information needed to assess realistically the potential capabilities of propulsion systems of this type and to lay the engineering foundation needed to promote orderly development in the future.

The majority of spacecraft systems currently under development use earth storable propellants, i.e. those normally liquid on earth. Less complex equipment associated with these systems would enhance mission reliability and result in significant weight savings, which translate directly to increased payload. Part of the space propulsion effort is directed towards this purpose. It is anticipated that many of the hardware design improvements will also be applicable to those systems employing more advanced propellant combinations.

Auxiliary Propulsion Systems - These systems embrace three categories of liquid propellants: monopropellants, earth storables, and cryogenics. In the monopropellant area research with a spontaneous catalyst is being put into practice with specifications for catalyst production, hydrazine rocket engine design, test program of flight type hardware, and a design handbook for engine development. Earth storable work includes continuation of engine designs for greatly extended life capability over the engines now in spacecraft use.

In FY 1966 a project was initiated to demonstrate techniques for using boil-off or direct propellant supply from tankage of advanced oxygen-hydrogen stages to provide auxiliary propulsion requirements. In FY 1967 breadboard hardware will be built and tested to demonstrate the expected higher performance and better system capability.

Solid Rocket Research and Advanced Technology

By virtue of reliable performance, intrinsic simplicity, compactness, ease of handling, ruggedness and early availability, the use of current and advanced state-of-the-art solid propellant motors for space flight propulsion can provide booster and spacecraft operations at reduced cost. Exploiting the unique advantages of solid-propellant motors will enhance the early and economic accomplishment of NASA space missions.

The Solid Propulsion Technology program is designed to provide the technology base for producing flexible and reliable solid and hybrid propulsion of high performance. Such an objective, of course, must be supported by competency maintained on a long range basis, particularly in the fundamental areas. Program flexibility is provided to allow pursuit of promising new concepts as they appear.

High performance solid propellants are now becoming operationally available. Such propellants are characterized by high flame temperatures, complex combustion, and in some cases, poorly defined physical and chemical properties. Efforts are being made to better understand the fundamental problems and to define the kinetics of decomposition, chemical erosivity, instability characteristics, propellant and metal combustion processes, two-phase flow behavior, sensitivity, processing characteristics, and others. In addition, there are a number of pressing technical requirements, for example: command stop, start, and thrust variation in solid propellant space motors which will receive research emphasis. Examination will be made of techniques for nondestructive testing to assure structural integrity of the propellant itself in the large rocket motors projected for the future. Further supporting research and technology to the Large Solid Motor Project will be required.

Hybrid systems offer advantages for certain missions. Problems in the application of hybrid propellant systems must be resolved before these systems can receive consideration for use.

Solid Rocket Experimental Engineering

This activity covers motors in three categories: launch vehicle, spacecraft, and auxiliary.

Launch Vehicle Motors - Launch vehicle motors are characterized by high thrust, long burning time, and large size. Diameters may be greater than 20 feet, and lengths may exceed 100 feet. Thrust levels for this class of motor are in the multimillion-pound region; burn times are generally two minutes or longer. This class of motor finds application primarily as first stage boosters of launch vehicles. The great weight and cost of these vehicles call for the most reliable propellants and materials. The major test work on 260" diameter, high-thrust motors is supported under the Large Solid Motor Project, but three important related programs are pursued under the experimental motor program.

The first is to devise instruments and systems for warning of potential failure in solid propulsion systems used for manned vehicles; instrumentation for interpreting the warning signals; and methods for terminating or reducing thrust, so that, if necessary, a safe escape could be made by astronauts. In prior years, a burn-through detection method was invented, and quench of combustion was demonstrated in a medium size motor. In FY 1967, the program will reach the point of system engineering for integration into the motor processing and checkout complex, and this system will be tested in realistic sub-scale motors, possibly of 120" diameter.

Second, a basic requirement for showing feasibility of the high-thrust motors is demonstration of vector control (steering systems). Initially, the program to do this establishes the design of prototype systems, including components such as hydraulic actuators and power supplies, so that a quantitative evaluation of competing systems can be made. This has been done for the secondary liquid injection system and is in process for an advanced flexible nozzle concept. Work will be done on those systems or components which are most attractive on the basis of reliability and cost effectiveness, by demonstration in motor tests in the size range of 15-25 inch diameter nozzles.

Third, methods for recovery and re-use of large motors are under investigation with the objectives of establishing designs and materials for nozzles, insulation and motor cases, so that multiple use can be made of each, and for establishing techniques for recovering, refurbishing and re-qualifying the major components of large solid propellant motors. The justification for the effort grows from the large unit cost of the components of large motors. Anaylsis indicates that more than 60% of the cost of large solid systems is represented by non-expended components, potentially re-usable. Recovery will be facilitated by the sturdy structures of large solid motors; metal thickness ranges from 3/4" to 2½"; ablative materials are 2" to 3" thick.

The work in prior fiscal years has concentrated on analysis, small motor testing, and dynamic modeling of water impact stresses. In fiscal year 1967, effort will involve test operation of cold-flow and hot-flow laboratory models; water impact testing of model motors, and assessment of the effects of water exposure on nozzle, case and insulation materials.

Sounding rockets are another class of launch vehicle motors for which appreciable improvement can result from technology investigations. Effort in FY 1967 will start work on motors incorporating new propellants and advanced structures. The designs will be governed by the goals of low cost, high reliability, and simplicity of use, rather than high specific impulse or high mass fraction. Two different classes of motor will be investigated, one for small meteorological sounding rockets, one for higher probe missions.

Spacecraft Motors - Solid motors for spacecraft application are generally of intermediate thrust, weight, and dimensions. In general, they are characterized by sophisticated designs and will make use of new high energy propellants. These motors are used primarily in the upper stages of small launch vehicles, or for deep-space, volume-limited missions. They are storable in space over extended periods of time, and require few subsystems or auxiliary components to be developed.

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The high performance system engineering program is investigating prototype motors with new high energy propellants and novel structural concepts. System definition studies of the most desirable concepts were completed in prior years and the process of motor manufacture and test will begin in FY 1967. This will also require the manufacture of relatively large amounts of new propellants. The test program will determine the effects of ignition at simulated altitude, the effects of space environment, and burning characteristics under spinning condition, in addition to the usual tests of propellant and structure.

Variable motors offer potential in special missions such as spacecraft landing, orbit injection or payload attitude control and maneuvering. They are characterized by greater mechanical complexity than the non-variable solid rocket motor, and as a result, they require appreciable development of structures and control.

The major effort on controllable motors is a program on hybrid propulsion engineering (a hybrid motor uses a liquid oxidizer and a solid fuel).

In Fiscal Year 1967, the engineering, fabrication and test program will continue with demonstrations of injector designs and material, nozzle and motor case design; solid propellant processing methods and quality control, and combustion dynamics and efficiency under start and stop transients.

Auxiliary Motors - The auxiliary motor class is represented by retro, ullage and emergency escape motors, whose primary requirement is a high degree of reliability and safety. This class of motors is well established in NASA programs, fulfilling a requirement that cannot be efficiently met by liquid propellant rockets.

System studies of advanced concepts have been made to define the materials, designs and operational characteristics which have potential for major gains in reliability, performance, and cost effectiveness. Motor test programs started in FY 1966 will continue in FY 1967. The primary costs will be for manufacture and test of motors which may contain a few hundred pounds of propellant (retro and ullage motors), to a few thousand pounds of propellant (escape motors). Novel concepts of reinforcement to obtain high strength in thin-wall grains may be introduced. Reliability will be established through test firing under all environmental extremes. Finally, the program will attempt to establish a relatively few designs which can be used for many vehicles and missions.

Large Solid Motor Project

	1965	1966	1967
Large solid motor project.....	$26,800,000	$4,200,000	$3,500,000

The objective of the large solid motor project is to establish the practicality of very large solid propellant rocket motors by demonstrating technology and manufacturing methods and by providing estimates of their cost and reliability.

This project was initiated in June, 1963, when, with NASA coordination, the Air Force let contracts to fabricate and test 260" diameter solid motors.

Acting on a DOD request, the NASA agreed to fund the program in FY 1965, and in March of 1965 assumed complete responsibility for the program.

In February, 1965, the first major test under the program was successfully carried out. A 156" diameter subscale motor delivered over three million pounds of thrust and burned for about one minute. The next test was the static firing of the first 260" diameter motor in September, 1965. The test was successful in all respects. The average thrust was over 3,000,000 pounds and a peak of more than 3,500,000 pounds was attained.

In FY 1965 NASA allocated $13.0 million to continue the contracts originally funded by DOD. The President's FY 1966 Budget did not provide funds to complete the contracted effort. After careful analysis of the possible alternatives, it was decided that maximum benefit to the government would result from completion of the technical effort, and in March of 1965, the NASA reprogrammed $13.8 million of FY 1965 funds for this purpose. Congressional action on the FY 1966 budget included the addition of a $6.2 million authorization for the continuation of large motor work beyond the program then current.

The next objective of the program will be to investigate and test additional motor features which will be necessary for vehicle stage applications. Of particular importance are the establishment of an efficient and reliable thrust vector control system and development of failure warning and combustion termination systems. Subscale tests with 156" diameter motors will be made prior to integration of such advanced components into 260" motor firings.

The ultimate objective of this program will be the fabrication and test firing of 260" motors generating a thrust level of about 7,000,000 pounds for two minutes, complete with all the basic design features necessary for vehicle application. This would allow subsequent initiation of a motor development program for any appropriate NASA vehicle program with high confidence in its design, fabrication procedures, performance capability, and cost.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — AERONAUTICS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION

The primary role of the Aeronautics program is to improve the efficiency, utility, and safety of aircraft. General objectives are:

1. To provide leadership in the generation of advanced aircraft concepts.

2. To seek technological advances needed to develop superior aircraft.

3. To supply industry with advanced data for the design of new aircraft.

The scope of the NASA aeronautical research program includes work in aerodynamics, structures, materials, air breathing propulsion, operational aspects, including safety and noise, and pilot and aircraft integration. Studies in these areas point to the most profitable paths for technological advances in the future. For example, the XV-5A fan-in-wing aircraft, the tilt-wing XC-142A V/STOL transport, and the variable-sweep concept for the F-111 all appeared several years ago as NASA research concepts having great promise. In the years between the first indication of the value of the concept and the first flights of the vehicles, NASA aided in the detailed formulation of the concepts and in substantiating the over-all capabilities of practical vehicles based on these concepts.

In addition, NASA has conducted extensive wind tunnel tests, simulator programs, and flight investigations using appropriate testbed aircraft to substantiate predicted performance and operational characteristics of these vehicles and to aid in the solution of problems of a developmental nature. In this regard, advanced technical development in support of military and civil aircraft procurement continues to be conducted. This work is performed in cooperation with government-sponsored contractors at the request of the cognizant government agencies.

Research in Aeronautics in FY 1967 will include studies directed toward improvement of subsonic aircraft; studies of new materials and structural design concepts required to fabricate reliable lightweight structures suitable for a long life under high temperature conditions for supersonic and hypersonic aircraft; studies of air-breathing propulsion cycles and engine components to increase efficiency and permit the design of efficient lightweight engines for V/STOL aircraft, supersonic transport, and hypersonic aircraft; and studies directed toward improving flight safety and increasing

operational flexibility of present and proposed aircraft, especially under adverse or "all weather" flight conditions.

Experimental research and development aircraft and engineering testpilot proficiency aircraft considered necessary to carry out and support the aeronautics effort are included under this program.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Supporting research and technology	$ 8,163,000	$10,261,000	$ 9,000,000
X-15 research aircraft	1,425,000	883,000	900,000
Supersonic transport	19,953,000	14,056,000	14,100,000
V/STOL aircraft	2,987,000	2,000,000	5,000,000
Hypersonic ramjet experiment	2,712,000	5,000,000	2,000,000
XB-70 flight research program	---	9,296,000	2,000,000
Total	$35,240,000	$41,496,000	$33,000,000

Distribution of Program Amount by Installation:

	1965	1966	1967
Ames Research Center	$ 6,167,000	$ 4,197,000	$ 5,400,000
Electronics Research Center	---	190,000	150,000
Flight Research Center	3,022,000	11,681,000	4,975,000
Langley Research Center	9,052,000	11,935,000	8,625,000
Lewis Research Center	13,859,000	12,377,000	12,625,000
NASA Headquarters	3,140,000	1,116,000	1,225,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1965	1966	1967
Aircraft aerodynamics	$ 1,307,000	$ 2,277,000	$ 1,600,000
Aircraft loads and structures	2,021,000	2,000,000	1,500,000
Air breathing propulsion	2,027,000	2,250,000	3,000,000
Aircraft operating problems	2,808,000	3,734,000	2,900,000
Total	$ 8,163,000	$10,261,000	$ 9,000,000

Aircraft Aerodynamics

Research on the aerodynamics of aircraft is a continuing program toward improvement of flight in the atmosphere. Generally, the problems are those of maximizing aerodynamic efficiency, achieving satisfactory levels of aerodynamic stability, and insuring adequate aerodynamic control over wider ranges of operating conditions.

For subsonic aircraft, further improvements in cruise performance, i.e., improvement in transonic drag rise characteristics, and reduction of boundary layer losses, of second-generation jet transports and new V/STOL types will be sought. Investigation of the stability and control for these types of aircraft will be continued.

For supersonic aircraft, aerodynamic research on transport configurations will be continued to improve the technology to extend the operating range of efficient supersonic vehicles and to improve sonic boom characteristics. Basic studies of configuration improvements and boundary layer phenomena at supersonic speeds will be conducted. A basic investigation of the stability and control of maneuverable missiles will be continued.

The difficulty of the aerodynamic problems of flight increases greatly at hypersonic speeds and altitudes, and increased research effort will be directed to the aerodynamics of aircraft shapes at Mach numbers above 4 or 5. This research is necessary to provide basic information for conceptual studies and performance predictions of future hypersonic cruise vehicles and recoverable reusable boosters. It will consist of investigation of flow fields, boundary layer development, skin friction, and heat transfer for winged configurations that include such practical features as air inlets and stabilizing surfaces. The dynamic stability and control requirements of hypersonic aircraft concepts will also be investigated.

The take-off and landing characteristics of advanced supersonic and promising hypersonic aircraft configurations will be assessed in large-scale wind tunnels. The trim, speed stability, and lateral-directional characteristics of various classes of aircraft with powered-lift systems for STOL operation will be further explored and design criteria for control systems in this mode of operation will be better established.

The funds requested are for contract studies, materials, models, and special instrumentation utilized in the in-house research. They include provision for wind tunnel support of projected NASA flight research programs, Department of Defense development of advanced aircraft and missiles systems, and aircraft related projects of other agencies of the government such as the Federal Aviation Agency

Aircraft Loads and Structures

A high degree of reliability and integrity is demanded of the airplane structure by the operators and users which include the military services and traveling public. Limitations of weight preclude the attainment of this reliability except to a limited degree by duplication of structural elements or by designing to low working stresses. The over-all objective of structures research is to achieve these dual and conflicting requirements of high efficiency with great integrity.

An accurate knowledge of the loads imposed on the structures is of course required for the attainment of these requirements. The important load sources are atmospheric turbulence, airplane maneuvers, landing and take-off and cabin pressurization. A research effort is being maintained to update and improve the definition of the structural loads in keeping with introduction of more advanced aircraft and changes in types of operation. The heating cycles associated with supersonic flight introduce further complexities in that this heating produces stresses in the structure which add to or subtract from the stresses due to loads and, therefore, must be accounted for in design. Current and planned research includes analytical studies aimed at development of procedures for inclusion of thermal stresses in structural design and experimental evaluation of thermal effects using the X-15 research airplane and the XB-70.

An improvement in structural efficiency can be obtained, particularly for high strength materials, by the use of sandwich type structures in which the conventional sheet and stringer is replaced by two thin sheets on each side of a low density core. The attachment of the face sheets to the core by welding or gluing has presented serious manufacturing and cost problems. As a result of the development of improved plastics in recent years a particularly promising structural concept is the use of glass fiber fabric or metal sandwich in which these newer plastics are used as the bonding agent. Research is being undertaken to evaluate these new materials in structural concepts under realistic environments.

Exploratory research will continue on promising structural concepts which may have merit for use in a hydrogen fueled hypersonic airplane. Formidable structural problems are involved in such an aircraft as a consequence of aerodynamic heating. The current experimental and analytical research represents an initial effort of a relatively long range program which will ultimately serve as the basis for an efficient and reliable long range hypersonic airplane.

Air Breathing Propulsion

Research in this program is directed toward increasing the performance of current and future aircraft through improvement in airbreathing engine components such as inlets, compressors, combustors, turbines, nozzles and materials to provide higher ratios of thrust-to-engine-weight, higher ratios of thrust-to-engine-volume, and lower specific fuel consumption. The research effort in this area also includes research on engine controls, lubricants and

fuels and the interaction effects of the propulsion system components on one another and of the propulsion system on the aircraft.

Research on subsonic vehicle concepts including V/STOL aircraft is being continued. Studies of the interaction of internal and external flows on the thrust and drag of various inlet and afterbody nozzle combinations will continue. One phase of this program is related to the increased net thrust obtainable with properly designed and positioned afterbody fairings. Basic studies emphasizing research leading to engines having high ratios of thrust-to-weight and thrust-to-volume for V/STOL application is planned. The V/STOL propulsion work is funded under the V/STOL project although the results are generally applicable to other subsonic vehicles.

The supersonic propulsion system effort is directed toward the better understanding of the operation of supersonic inlets, inlet distortion, and compressor stall, and includes basic research studies of boundary-shock interaction in regions of adverse pressure gradients as well as in the transonic throat region. Much of the propulsion research results in the supersonic speed regime are directed to the supersonic transport since this vehicle requires a technically advanced propulsion system in terms of efficiency in performance and weight as well as high reliability and long life. The work directed to the problems of the supersonic transport, although just as applicable to military vehicles, is described and funded under the Supersonic Transport project. A substantial effort can also be anticipated to aid the military services in the wind tunnel support of specific advanced aircraft and missile propulsion systems.

The effort devoted to hypersonic propulsion systems contains inlet research to determine the fundamental effects of such parameters as wall cooling, leading edge blunting, and fuel injection on the system performance. Since the supersonic combustion ramjet engine offers considerable promise at speeds above Mach 7, basic studies will be conducted to improve the understanding of supersonic mixing and diffusion, ignition delay and combustion, and dissociation and recombination. The work described under the Hypersonic Ramjet Experiment project will provide research information from a complete ramjet system as part of this over-all program. Adequate facilities are not now available for propulsion research, therefore, development will be undertaken of a new facility which will permit much needed propulsion research to be conducted.

Aircraft Operating Problems

Research in this area is directed toward improving flight safety and increasing the operational flexibility of current and proposed aircraft. Research in the fields of sonic boom and aircraft noise are also included in this program.

Piloted simulators and analytical techniques will be used to continue studies of the effects of atmospheric turbulence and the influence of aircraft structural flexibility on the pilot's ability to control the over-all system

within aircraft operational constraints. Piloted simulators will also be used to determine the instrument displays and piloting techniques required to cope with large amplitude airplane oscillations and a variable stability airplane will be flown in rough air to evaluate stability and control characteristics and piloting techniques for rough air flight. The feasibility of several techniques to detect clear air turbulence (for example, lasers, passive optical and microwave devices) will be investigated.

The jet engine noise problem is being given a high priority with a continuing effort underway to obtain fundamental information on the generation and propagation of noise from exhaust jets and the compressor and fan components of jet engines, leading to the design of acceptably quiet propulsion systems. Flight tests using steep approach techniques will be continued to determine the maximum operational glide slope for a variety of transport airplanes in connection with landing approach noise abatement procedures and the related problem of aircraft safety during such steep descents.

The greatest unknown factors with regard to the propagation of sonic boom pressure waves are those associated with the effects of various atmospheric variables such as temperature, turbulence, wind shears and humidity. These factors will be studied in an accelerated program which will also include the response of building structures, humans, and window glass to sonic boom pressure waves of various shapes and magnitude. The XB-70 will be utilized to determine the effects of aircraft size and weight on sonic boom generation.

Turbojet aircraft are still encountering serious difficulties in steering during taxiing and in stopping on wet runways. Studies are underway at the Langley Landing Loads Track to investigate the effects of various runway surface additives and tire trends on braking friction, and in FY 1967 these studies will be continued under full-scale operational conditions. Full-scale tests will also be made to determine the benefits, and information for the practical design, of an air jet ahead of the tire to clear away water and slush as a follow-up to the present exploratory studies.

A general purpose airborne simulator (a modified Jet-Star aircraft) will be used in flight tests to investigate the stability, control and performance characteristics of a variety of advanced design airplanes, such as the supersonic transport, and aerospace vehicles.

Preliminary work will be performed leading to a flight research program utilizing the F-111 airplane. The flight program will provide information on aerodynamic load and structural temperature distributions, aeroelastic effects, and handling qualities of a full-scale variable-sweep aircraft configuration.

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X-15 Research Aircraft

	1965	1966	1967
Aerodynamics	$18,000	$267,000	$160,000
Loads and structures	15,000	10,000	215,000
Propulsion	---	---	---
Operating problems	1,392,000	606,000	525,000
Total	$1,425,000	$883,000	$900,000

The X-15 research program, conducted in cooperation with the Department of Defense, is providing data on manned, maneuverable hypersonic flight. During the course of the flight test program, through calendar year 1965, more than 150 flights have been made, including more than 115 flights at speeds greater than a Mach number of 4. Of these flights, more than 75 have been made at Mach numbers above 5.

The X-15 remains the only research capability in the world for studying hypersonic flight in its true environment. Experimental results to date have given basic insight into problems of aerodynamics, structures, propulsion and operations during hypersonic flight. Of major importance, the X-15 results have given, and will continue to give, confidence and guidance to research in ground based hypersonic research facilities enabling exploration in depth of many hypersonic flight problems.

In addition to a continuing program in basic hypersonic flight research, the operational success of the X-15 program has opened its use to space sciences as a carrier vehicle for certain experiments requiring its unique performance capabilities. For example, research on horizon seekers for satellites; high-speed high-altitude photography and stellar ultraviolet radiation has been performed using the X-15 as a carrier vehicle.

In six and one-half years of flight test, from June 1959 to December 1965, the X-15 program not only has contributed to the increased confidence of designers of current high-performance aircraft, but has focused attention on the areas which required additional research. The future program will be directed toward these areas, to provide information for the next logical step in our flight research program which is manned, maneuverable hypersonic cruise flight.

Supersonic Transport

	1965	1966	1967
Aerodynamics	$640,000	$880,000	$1,300,000
Loads and structures	214,000	110,000	700,000
Propulsion	14,270,000	11,501,000	11,100,000
Operating problems	4,829,000	1,565,000	1,000,000
Total	$19,953,000	$14,056,000	$14,100,000

NASA's research effort and support for the national supersonic transport (SST) program will continue in FY 1967 at about the same level as in FY 1966, but with a substantial shift in emphasis. The Federal Aviation Agency and its contractors will by then be carrying the major activity in prototype configuration development, structural design, and development of the first-generation engines. NASA will maintain a major effort on advanced propulsion systems and materials for advanced engines, expand its operational research, carry major responsibility in noise and sonic boom research and make available its unique facilities and technical resources as needed during prototype development.

A large part of the requested funds will be used in the field of propulsion for continuing contract research on engine components and materials started in FY 1965 and 1966. In FY 1967, however, the contracted research program will be reduced and at the same time, the in-house effort will be increased to provide research information required for second-generation SST engine development.

Compressor and fan component research will be directed toward reduced weight and increased performance through utilization of such concepts as supersonic inflow compressors and variable geometry features. Turbine studies will be toward more effective cooling and stress alleviation techniques; promising configurations of rotating elements will be fabricated and evaluated experimentally. Combustor research will include consideration of advanced annular and swirl-type combustor cans, as well as integration of combustor and turbine stator to permit increased turbine inlet temperatures. Lubrication systems, lubricants, bearings, and seals research will also investigate various means of increasing operating temperatures, with emphasis on increasing the fatigue life of the bearings themselves.

Inlet research will be continued to provide design information applicable to both two-dimensional and three-dimensional types. Inlet-engine flow dynamics and inlet control systems will receive particular attention. Because of the large effect of exit nozzle performance on over-all flight efficiency, the effort in this area will be increased to determine performance limits and to find more effective methods for nozzle cooling.

The engine materials research will be aimed generally at metals with higher heat capability and longer fatigue life. Chromium, nickel and cobalt alloys will be investigated along with coatings to eliminate oxidation at higher operating temperatures. Methods for exploiting metal phase change and superalloy purification will be explored to achieve the long life desired in a commercial supersonic transport engine.

In the field of airframe structures, structural dynamics problems such as vibration and flutter will receive increased emphasis. Studies will be continued on establishing the characteristics of appropriate titanium alloys and other materials under realistic loads and temperature environments for the SST.

In the supersonic transport operating problems field simulation and flight studies will be made of the low-speed approach and landing problems of proposed configurations to define the ranges of airplane characteristics acceptable to the pilot and to devise means of achieving these characteristics. Following further definition of the handling qualities requirements for normal operating conditions for low-speed approach, additional restraints of adverse weather operation will be considered by analysis and ground simulation.

In the field of airframe aerodynamics, the optimization of performance, stability, and control characteristics over the entire operating speed range of the SST will be pursued. This continuing effort will be closely associated with the wind tunnel and related investigations carried out in the development of the SST prototypes, and with parallel investigations of sonic boom generation and propagation.

V/STOL Aircraft

	1965	1966	1967
Aerodynamics	$1,533,000	$740,000	$1,600,000
Loads and structures	99,000	8,000	200,000
Propulsion	449,000	314,000	1,000,000
Operating problems	906,000	938,000	2,200,000
Total	$2,987,000	$2,000,000	$5,000,000

A major part of the increase in funding in FY 1967 will result from studies of a new VTOL research airplane capable of providing more accurate information on the influence of all-weather landing operation capability on the design of high-performance tactical V/STOL types. A feasibility study will be initiated to determine the characteristics required of such a research airplane and to identify existing conventional high-performance aircraft which could be modified to provide the vehicle needed. Wind tunnel studies will be undertaken to determine the effectiveness of the modifications proposed. Actual modification of the existing vehicle, which the Air Force has agreed to provide from its inventory, may begin. Related flight studies of the requirements for pilot displays to effect safely such VTOL all-weather landing operation, begun in FY 1966, will continue using the NASA Bell 204B helicopter; a flight investigation of an advanced landing approach aid for STOL aircraft, recently initiated using a conventional transport airplane, will be extended in FY 1967 to more realistic approach conditions following procurement of a suitable STOL aircraft.

A substantial increase in effort is expected on short-haul (primarily commercial) transport research, based in large part on anticipated recommendations made as a result of current NASA-sponsored feasibility studies by three U.S. aircraft manufacturers. This research will include wind tunnel investigations, simulation, and flight studies.

Other wind tunnel research studies will continue aimed at providing basic information on such effects as aerodynamic interference and hot gas ingestion for representative military fighter and transport V/STOL configurations. Basic propulsion studies will be increased substantially, emphasizing research leading to engines having high ratios of thrust-to-weight and thrust-to-volume.

Flight and simulator research will also continue to provide more detailed information on the design requirements for satisfactory handling qualities of V/STOL aircraft, including helicopters. In addition to the NC-130C boundary layer control STOL aircraft and the X-14A and YHC-1A variable-stability VTOL research aircraft, the new X-22A tilt-duct and XV-5A fan-in-wing VTOL airplanes will be utilized to provide information on more realistic configurations and to provide correlation with wind tunnel and simulator predictions.

Based in part on requirements of the military services, it is planned that the wind tunnel and flight effort on compound helicopters started in 1966 will be increased; such programs will usually be conducted jointly with the services. Specific evaluation of structural dynamics and handling quality advantages or problems associated with the promising hingeless rotor concept will continue using the NASA XH-51N research helicopter.

Hypersonic Ramjet Experiment

	1965	1966	1967
Propulsion	$2,712,000	$5,000,000	$2,000,000

A feasibility study and design competition is nearing completion between the Garrett Corporation, the General Electric Corporation, and the Marquardt Corporation, to determine an optimum configuration for a liquid hydrogen fueled ramjet engine capable of being operated between Mach 3 and 8. In this speed regime, using a convertible combustion arrangement, both subsonic and supersonic combustion systems can be studied.

Upon completion of the current phase I studies, an evaluation will be made to select one or more of the study phase contractors to continue with detailed design, experimental wind tunnel verification, fabrication, and proof test of the selected concepts. This second phase of the program is expected to require 29 months for completion.

Since the research ramjet must be designed for the most severe anticipated operating conditions, structures must be capable of withstanding stagnation pressures approaching 5,000 psi and active cooling concepts must be devised to maintain structural integrity at stagnation temperatures of 4,700^{o}R.

XB-70/SST Flight Research Project

	1965	1966	1967
Aerodynamics	---	$5,146,000	---
Loads and structures	---	600,000	---
Propulsion	---	850,000	---
Operating problems	---	2,700,000	$2,000,000
Total	---	$9,296,000	$2,000,000

NASA, by virtue of its statutory responsibility for aeronautical research and technology within the United States Government, has the responsibility to provide the research information and advanced technology needed for design, development contruction, and flight test of the prototype supersonic transport.

The use of the USAF XB-70 aircraft as a research tool will be supported jointly by the USAF and NASA. It will provide NASA with the ability to validate its basic aerodynamic theories and experimental results obtained in ground facilities to account for, as examples, effects of vehicle size (Reynolds Number) on skin friction and heat transfer, effects of elastic structure deformation on aerodynamics and the effect of heat soak on this deformation, effects of vehicle inertia combined with low damping (high altitude) on vehicle control requirements, effects of vehicle size on sonic boom generation and propagation, inlet control system requirements and many others. All of these problems have and will continue to be the subject of major research efforts in analysis and ground based facilities; the XB-70 program will provide vital guidance and assessment of the soundness of these programs, assuring that major programs such as the supersonic transport will proceed on a sound basis.

The NASA portion of the XB-70 program is being conducted in two distinct phases. The first phase, which began in FY 1963, consisted of installation of instrumentation in the two XB-70A aircraft during manufacture and the acquisition of certain data of interest to NASA during the USAF flight test program. The second phase, beginning in FY 1966, consisted of continuation and expansion of the initial program and the initiation of research which could not be accommodated during the initial USAF flight program. In the first phase of this program, NASA funded only the costs associated with the instrumentation and data acquisition required for those measurements of interest to NASA. The major cost, that of operating the aircraft, was funded by the United States Air Force. In the second phase, which will be greatly accelerated in FY 1967, NASA will fund the costs associated with NASA's research program utilizing the XB-70 aircraft.

This program is obtaining results which are important to the Federal Aviation Agency in its role as manager of the United States Supersonic Transport program. The FAA is kept informed on the progress of the program on a continuing basis.

OFFICE OF TRACKING AND DATA ACQUISITION

TRACKING AND DATA ACQUISITION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The purpose of this program is to provide tracking and data acquisition support to meet the requirements of flight projects. Responsive and efficient support is provided for all NASA projects, and as mutually agreed, for projects of the Department of Defense, other government agencies, universities, private corporations, international organizations, and other countries engaged in mutual research endeavors.

Support is provided for manned and unmanned flights; for spacecraft, launch vehicles, sounding rockets, and research aircraft; for Earth orbital and sub-orbital missions, lunar and planetary missions, and space probes.

Types of support provided include tracking to determine the position and trajectory of vehicles in space, acquisition of data from scientific experiments and on the engineering performance of spacecraft and launch vehicle systems, transmission of commands from ground stations to spacecraft, communication of information between various ground facilities and mission control centers, and processing of the data acquired from the space vehicles. Without this vital support, the space research program would not be possible.

Tracking and data acquisition support is provided by a world-wide network of ground stations (including Department of Defense stations and instrumented ships), and by general purpose facilities in launch areas. These stations are linked together by a network of ground communications which provides the real-time information necessary for critical decisions. Facilities also are provided to process into meaningful form the large amounts of data which are collected from flight projects.

Tracking and data acquisition facilities are used for support of current missions. At the same time, they must be augmented to meet the requirements of missions in the immediate future. Concurrently, planning must proceed for projects which are even further in the future, and equipment and techniques must be developed to assure a sound technological approach for the support of the more complex mission requirements of the next generation.

The Research and Development appropriation provides funds for (a) the operation and maintenance of the world-wide facilities, (b) the procurement of equipment and modifications to adapt the facilities for new and changing flight project requirements, and (c) the development of advanced tracking and data acquisition equipment and techniques. The subsequent sections describe plans and related funding requirements to continue the Tracking and Data Acquisition program in each of these areas during FY 1967.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Operations	$95,254,000	$129,600,000	$199,000,000
Equipment	144,482,000	87,665,000	66,500,000
Supporting research and technology	13,500,000	13,800,000	13,800,000
Total	$253,236,000	$231,065,000	$279,300,000

Distribution of Program Amount by Installation:

	1965	1966	1967
Marshall Space Flight Center	$2,000,000	$1,500,000	$1,500,000
Goddard Space Flight Center	179,252,000	155,950,000	199,600,000
Jet Propulsion Laboratory	55,769,000	53,500,000	55,600,000
Wallops Station	5,100,000	5,835,000	6,400,000
Flight Research Center	1,900,000	1,880,000	2,100,000
Langley Research Center	2,200,000	2,000,000	2,100,000
NASA Headquarters	7,015,000	10,400,000	12,000,000

BASIS OF FUND REQUIREMENTS:

Operations

	1965	1966	1967
Manned space flight network	$23,118,000	$37,000,000	$60,000,000
Satellite network	25,063,000	29,000,000	33,700,000
Deep space network	19,040,000	26,500,000	32,800,000
Other instrumentation	5,930,000	6,600,000	7,000,000
Communications	17,478,000	24,000,000	57,000,000
Data processing	4,625,000	6,500,000	8,500,000
Total	$95,254,000	$129,600,000	$199,000,000

Manned Space Flight Network Operations

The Manned Space Flight Network, originally configured to support the Mercury program, is now actively supporting the Gemini missions. The network for Gemini support consists of seven primary land stations located at Cape Kennedy, Florida; Bermuda; Grand Canary Island; Carnarvon, Australia; Hawaii; Guaymas, Mexico; and Corpus Christi, Texas; two ships, the Rose Knot Victory and the Coastal Sentry Quebec; and six secondary land stations located at Kano, Nigeria; Tananarive, Madagascar; Canton Island; Point Arguello, California; White Sands, New Mexico; and Eglin Air Force Base, Florida.

Concurrently with providing full operational support for the Gemini program, the Manned Space Flight Network is being augmented for the Apollo program. Not only are significant equipment additions being made to existing stations, but land stations, ships, and instrumented aircraft are being added to the network.

The Manned Space Flight Network, as presently planned for Apollo, will consist of ten stations with 30-foot antennas, three stations with 85-foot antennas, one transportable station with a 30-foot antenna, five ships, eight instrumented aircraft, and three Deep Space Network stations with 85-foot antennas for backup during lunar missions. Staffing of stations and training of operating personnel are well under way to assure that the network will be ready to support Apollo missions beginning in early 1966.

A significant increase in operations costs will occur in FY 1967 as the network will be required to support both the Gemini program and increased activity in the Apollo program. Approximately one-half of the increase will be for the operation and maintenance of the Apollo instrumentation ships and aircraft which are under the responsibility of the National Range Division of the Department of Defense. Also in FY 1967, most of the new stations being constructed for support of the Apollo program will become operational. At existing stations, manning levels will increase due to Gemini/Apollo flight activity and the more advanced equipment required for the Apollo program. Additional funds will also be required for computer programming, network engineering, and logistic support associated with the new equipments and the increasing level of flight activity.

Satellite Network Operations

The Satellite Network includes the electronic stations of the Space Tracking and Data Acquisition Network (STADAN) managed by the Goddard Space Flight Center, and the optical camera tracking stations operated by the Smithsonian Astrophysical Observatory (SAO). The STADAN stations provide a tracking and data acquisition ground system which tracks, determines the status of each satellite, commands the satellite functions, and acquires stored or real-time data from the satellite. The optical camera tracking stations provide specialized services in precision orbital determination on certain satellites of scientific interest as well as backup support to STADAN during launch and early orbit tracking of all satellites.

The STADAN stations operate on a 24-hour day, seven-days per week basis. The workload of the network will continue to increase in FY 1967. Not only will more satellites be supported, but they will be more complex and carry more experiments which will result in an even greater increase in the control functions and data output to be handled by the stations. Impacting the workload in FY 1967 will be initial flights of the Applications Technology Satellite and the Biosatellite projects, and additional flights of the Orbiting Geophysical Observatory, the Orbiting Astronomical Observatory, and the Orbiting Solar Observatory.

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Increased operational costs in FY 1967 are due to the higher staffing levels and logistic support required to meet the greater workload and to operate facilities which are being installed at Goldstone, California; Rosman, North Carolina; and Toowoomba, Australia for support of the Applications Technology Satellite project.

Deep Space Network Operations

The Deep Space Network's primary function is to provide tracking and data acquisition support for unmanned lunar and planetary space flight. The network provides tracking data which are used to determine and make mid-course corrections to spacecraft trajectories, acquires engineering telemetry data concerning performance of the spacecraft as required, transmits commands to the spacecraft to execute the above functions, and records the scientific data which are acquired from the spacecraft. Three stations in the network, one each in Australia, Spain, and California, will provide a backup capability for the Apollo manned lunar missions.

The control center for the Deep Space Network is the Space Flight Operations Facility (SFOF) located at the Jet Propulsion Laboratory in Pasadena, California. The SFOF receives information transmitted via ground communications from stations of the Deep Space Network, processes the data, and displays the resulting information so that mission directors and associated project personnel can analyze real-time mission performance, make critical decisions concerning functions which must be executed by the spacecraft, and transmit instructions to the stations for commands that must be sent to the spacecraft.

The flight missions of the Lunar Orbiter, Surveyor, and Pioneer projects will continue through FY 1967. In addition, a Venus fly-by mission is scheduled for launch in late FY 1967. To meet the flight schedule, the Deep Space Network and the SFOF must support two or more missions simultaneously.

At the beginning of FY 1967, the Deep Space Network will consist of two operational 85-foot antenna facilities, S-band equipped, at each of the three longitudinal locations required to maintain continuous surveillance of a lunar or planetary mission. Staffing at all stations will increase to meet flight mission requirements. Stations with heavy workloads will require additional work shifts. The prototype 210-foot antenna facility at Goldstone will become operational during the first part of FY 1967, and will require single-shift staffing. The SFOF also will require additional staffing and computer capacity to handle the projected workload in FY 1967.

Other Instrumentation Operations

Instrumentation systems are operated in support of sounding rocket programs conducted at Fort Churchill, Canada, and Wallops Station, Virginia, and for the flight research programs at the Flight Research Center, California. General purpose tracking, telemetry, data acquisition, recording, timing, plotting, and communications systems are provided as well as special purpose optical and sound ranging (acoustical) equipment for specific missions.

The instrumentation required for support of missions launched from Wallops Station is operated by NASA contractors and by other government agencies such as the Weather Bureau, the National Bureau of Standards, the U.S. Navy, the U.S. Air Force, and the Military Sea Transportation Service. Funds required in FY 1967 reflect approximate costs which are being experienced in the current year with a slight increase for additional engineering effort needed in the areas of data analysis and computation, instrumentation development, trajectory determination and impact prediction, and quality assurance.

Effective January 1, 1966, management responsibility for the Fort Churchill facility was transferred from the U.S. Air Force to the National Research Council of Canada. Instrumentation at Fort Churchill is contractor operated and is funded jointly by the National Research Council and NASA as a cooperative effort. Costs to NASA will continue in FY 1967 at about the same level as the current year.

The Flight Research Center's Aerodynamic Test Range includes three sites located in the Nevada and Eastern California area. The site at Edwards Air Force Base is staffed by NASA personnel augmented by some contractor personnel. The Ely and Beatty sites in Nevada are contractor operated. Among the programs to be supported in FY 1967 will be the Lunar Lander Research Vehicle, the Lifting Reentry Research Vehicle, the space sciences experiment program using the X-15, the XB-70 flight program, and various small aircraft research projects including the studies on laminar flow.

Communications Operations

NASA's tracking stations and control centers are linked together by a single operational communications system operated by the Goddard Space Flight Center. Communications switching centers have been established at major locations such as Goddard, London, and Australia, to maximize circuit sharing. Requirements in most cases are being met by providing alternate voice/data circuits instead of straight voice circuits, thereby reducing the total number of circuits needed.

In the early Mercury missions, considerable reliance was placed on high frequency radio communications. As a result, network communications were limited and not of satisfactory reliability. Although this situation has improved with Gemini, it is still not possible to transmit sufficient voice, telemetry, and tracking data from remote stations to the Mission Control Center or to provide sufficient reliable voice up-data and commands from the Control Center to the spacecraft in real time.

In the Apollo program, the increased complexity of the missions and the number of vehicles to be supported have dictated the requirement for vesting complete responsibility for real-time mission control directly in a centrally located facility. To achieve the required centralized control, the remote sites must have sufficient communications with the central facility in terms of both reliability and capacity to provide flight control functions through remote operation from the central location.

The FY 1967 budget reflects the cost of providing the quality and volume of communications service necessary to meet the requirements of the Apollo program. Communications requirements will be met through the leasing of services provided by communications satellites as well as through conventional circuits. Communications service via satellite will be provided to six tracking stations: Carnarvon, Australia; Canary Island; Ascension; and the three Apollo insertion/injection ships. Fiscal year 1967 also reflects the cost of leasing the approximately seventy voice/data circuits, twenty-four teletype circuits, and two wideband channels required for Apollo.

Data Processing Operations

Information received in the form of tracking and telemetry from satellites and space probes must be processed into a form that is useful to both those performing the real-time control of the space vehicle and those responsible for analyzing the scientific data acquired by the spacecraft.

Tracking data are processed to provide orbital elements which are used to supply stations with predictions on future passes of the spacecraft and to provide position information that can be used by the scientific experimenters to determine where in the trajectory the scientific measurements were made.

Telemetry data must be processed to separate the information from the various scientific experiments aboard the spacecraft, to consolidate information from each experiment, to apply the necessary scaling factors and calibrations of the measuring instruments, and to correlate these measurements with the position data mentioned above. Processed data presented to the experimenters are the primary objective of the spacecraft missions which are undertaken to explore and understand space.

The increased number of spacecraft to be supported in FY 1967, in conjunction with the greater number of experiments carried per satellite, particularly in the observatory satellites, will result in a large increase in the telemetry data processing workload. Funds also will be required in FY 1967 to handle the projected increases in computer programming and orbital computations associated with such complex upcoming projects as the Orbiting Astronomical Observatory.

Equipment

	1965	1966	1967
Manned space flight network.....	$98,348,000	$50,300,000	$26,500,000
Satellite network.....	17,995,000	15,800,000	14,500,000
Deep space network.....	15,168,000	9,900,000	10,500,000
Other instrumentation.....	4,300,000	4,065,000	4,500,000
Communications.....	4,755,000	5,100,000	7,500,000
Data processing.....	3,916,000	2,500,000	3,000,000
Total.....	$144,482,000	$87,665,000	$66,500,000

Manned Space Flight Network Equipment

The Manned Space Flight Network is now supporting the Gemini Program in the areas of tracking, telemetry, command, and communications. Procurement and manufacture of equipment needed to meet the greatly increased requirements for support of the Apollo Saturn IB and Saturn V programs were initiated in FY 1964 and continued in FY 1965 and 1966. Funds are required in FY 1967 to incorporate additional capabilities in the network for support of the Apollo lunar missions and to meet costs of installing equipment at the stations and integrating hardware and facilities as a compatible, unified network.

The augmentation of the network for Apollo will provide the ground instrumentation support necessary to fulfill the presently defined Apollo program requirements; however, specific mission definition and associated tracking and data acquisition requirements definition are continuing efforts.

During the past year, the Air Force negotiated and awarded the contract for modification and equipping of the eight Apollo/Range Instrumentation Aircraft. These aircraft, initially authorized in FY 1965, will provide voice communications with the astronauts and telemetry coverage during injection of the Apollo spacecraft into the translunar trajectory and during the reentry into the earth's atmosphere. The negotiated value of the contract is substantially greater than forecast. The FY 1967 budget includes funds to cover the additional costs of this contract.

Fiscal year 1967 funds are also required for additions to the memory capacity of the on-site data processing equipment. A review of flight control, command, and display requirements has indicated that the memory capacity must be expanded by 50 per cent to cover the rendezvous, lunar landing, and Earth return phases of the lunar missions. Equipment and modifications to provide the necessary augmentation of memory capacity will be incorporated at 13 land stations for Apollo support.

Equipment must be added to the existing network control centers to enable operational control of the network during non-mission periods and simulations, and to provide the capability to assess network performance during mission periods. Funds required in FY 1967 are primarily for equipment to be installed for Apollo support in the Manned Space Flight Network control center at the Goddard Space Flight Center.

A review of airfield capability by the Air Force has indicated that additions and modifications to certain existing commercial airfields will be required in support of the eight Apollo Range Instrumentation Aircraft. A detailed on-site survey by the Air Force is underway to determine the extent of modifications required at several locations. Fiscal year 1967 funds will be required for these additions and modifications.

During FY 1967, facilties will be completed and equipment will be installed in nearly all of the network stations. Costs arising directly from this effort are those for systems engineering; for the shipment of equipment to the network stations; for the provision of network descriptive documentation, specifications, and manuals; for the provision of standard test equipment; and for the establishment of spare parts inventories needed to preclude long periods of station downtime during mission periods.

Satellite Network Equipment

During the past several years, the primary objective of the Satellite Network equipment program has been to achieve a general purpose capability which will meet the more complex support requirements of the advanced scientific and applications satellites, and at the same time accommodate the increasing workload on the network. The FY 1967 program represents a continuation of equipment augmentations and modifications which were initiated in prior years to meet this objective. It also includes funds for improvements, replacements, and recurring support items required to maintain the general purpose capability.

Fiscal year 1967 funds are required to complete modifications of the Range and Range Rate tracking systems at four operational sites. Initiated in FY 1966, these modifications involve a frequency change and improvements to incorporate greater systems performance gain.

For several years, a long range program has been under way to augment the network with high performance telemetry and command links to meet the expanding workload. In FY 1967, additional receivers, phase demodulators, and recording equipment will be procured to provide the number of telemetry links needed for the projected workload. Existing telemetry links will be improved by replacing mechanical polarization switches with more reliable solid-state components. Telemetry equipment also will be procured for the new 40-foot antenna facility in Alaska.

Command links procured with prior years funds have been used extensively, and certain deficiencies have been identified which necessitate corrective action to minimize operational complications and to prevent excessive maintenance. Included in the FY 1967 program are the replacement of tube transmitters with solid-state transmitters, replacement of the rim-mounted command antennas on the 40-foot and 85-foot dishes with smaller and more reliable antennas, and the replacement of existing command encoders at selected stations with a more flexible programmable encoder.

In FY 1967, new consoles will be provided at selected stations to centralize the switching of subsystems such as receivers, data handling equipment, tape recorders, command generators, and transmitters. Centralized control is necessary to minimize station turn-around time between passes and to allow the most efficient use of the expanding capability of network stations. This equipment will permit the station controller to select the configuration of subsystems necessary to support a given mission and to monitor remotely the operational performance of these subsystems.

Certain projects to be supported by the Satellite Network have specialized requirements which cannot be fulfilled by the general purpose network equipment. Fiscal year 1967 funds are required for equipment supplements at Alaska and Rosman for Nimbus B support and for modifications to the wideband telecommunications system. Funds are also needed for integration of the Applications Technology Satellite ground support equipment procured in FY 1965 and 1966.

The Satellite Network control center at the Goddard Space Flight Center must be adapted to meet the requirements of flight projects. In FY 1967, equipment additions will be necessary to support the Nimbus B mission and minor equipment modifications will be required for follow-on missions of the Orbiting Geophysical Observatory, the Orbiting Astronomical Observatory, and the Explorer series.

To maintain the capability of the network, a continuing test, calibration, and checkout program is required. FY 1967 funds will be used for replacement of the large dish optical calibration system with a more reliable and heavier duty unit. Additional quality assurance equipment will be procured for testing of ground systems under simulated operating conditions. Field calibration equipment with a near-real-time capability for analyzing antenna pattern measurement data also will be procured. At the present time, the antenna measurement data are returned to Goddard for analysis resulting in substantial delays in determining antenna anomalies.

Funds are required on a recurring basis for the repair and modification of facilities to sustain current operations and to improve network performance and reliability. In FY 1967, modification of some station facilities will be necessary to house equipment additions. Also required are funds for cabling, augmentation of station power systems, modification of air-conditioning systems, and facility repairs at the stations. Funds for procurement of spares and replacement parts also are included in the FY 1967 request.

Deep Space Network Equipment

The FY 1967 Deep Space Network equipment program will be directed toward assuring the capability of the network to meet the period of peak loading which is scheduled to occur in calendar year 1967. In addition, a program of required engineering changes, modifications, equipment replacement, and spares provisioning will be conducted to assure the required level of network performance and system reliability.

The major item of the Deep Space Network equipment cost in FY 1967 will be for station monitoring and control equipment. The purpose of this program is to implement a single standardized set of equipment at each site which will serve the needs of multiple flight programs. FY 1967 funds are required for modification of control and monitoring consoles to handle digital formats, and for procurement of communications buffers and line printers for all sites. These modifications, along with prior year equipment purchases, will provide a capability for continuous, semi-automatic monitoring of equipment performance at each station. It also will provide real-time data on the operational status

of each station to the Space Flight Operations Facility so that the necessary decisions can be made and corrective action initiated when required.

Low speed electric motors to drive the 85-foot antennas automatically at a sidereal rate will be procured in FY 1967 for the operational antennas. This drive is required for long periods of spacecraft coverage at planetary distances when the rotation of the Earth in relation to the spacecraft is extremely slow.

The Deep Space Network standard configuration includes a 10 kilowatt transmitter at each operational site. The only high power transmitter in the network is located at the Goldstone Venus research and development station. During the later months of the Mariner flight to Mars, this transmitter insured a reliable up-link between the ground and the spacecraft. It is planned to incorporate a high power transmitter capability at the 210-foot antenna facility at Goldstone. This requires an augmented power supply which will be procured with FY 1967 funds.

Support of both manned and unmanned flights by the Deep Space Network requires receiver compatibility with the Manned Space Flight Network. Improvements and modifications which have been made in the receiver systems for manned flight support must be incorporated into the Deep Space Network. These modifications will lessen the time required for checkout, signal acquisition, and frequency changeover and will provide for a wider tuning range.

The FY 1967 program includes funds for general purpose support which is required to sustain current operations and to improve network performance and reliability. Included are such items as generators, power system modifications, microwave modifications, calibration and test equipment, interface and integration equipment, intrasite communications, and cabling.

Fiscal year 1967 funds are required to continue modifications of the Space Flight Operations Facility for multiple mission support. This Control Center also will be provided with a capability for participation as an integral network element during mission simulations. Through such participation, the SFOF can determine network readiness for mission support and assess the level of performance to be expected. In addition, a capability will be provided for training of personnel at stations and the SFOF, thus improving the reliability of the entire network.

Other Instrumentation Equipment

A wide variety of fixed and mobile equipment is used to provide instrumentation support at Wallops Station and points off the main station, and at the Flight Research Center. This equipment is under a continuous preventive maintenance program to assure the necessary reliability for mission support. In addition, an improvement program is undertaken whereby individual subassemblies or components of major systems are modified or replaced to improve the range, speed, accuracy, and flexibility of the systems. The requirement

for these improvements is generated by the large number and types of rockets in the current and planned flight schedules of Wallops Station and by the high performance characteristics of the flight projects supported by the Flight Research Center.

During FY 1967, the Flight Research Center will continue to update the telemetry systems of the Aerodynamic Test Range. Equipment which was purchased for the Edwards site in FY 1966 will be installed and made operational. Similar equipment will be procured and installed at the Ely station. Display systems will be updated to meet program requirements. The radar at the Edwards site will be outfitted with a solid-state precision data system in order to decrease maintenance time.

At Wallops Station, funds will be required in FY 1967 to update the telemetry system on the 60-foot antenna, to modify surplus Department of Defense radars to meet NASA's requirements, and to modify and integrate range control systems. Funds are also included for the procurement of non-recoverable hardware required in support of the various missions.

Communications Equipment

Funds for FY 1967 reflect the continuation of a planned program to install switching equipment at major communication focal points. With the buildup of the Madrid complex, a solid-state switch will be installed to maximize circuit sharing and to handle the high speed data transmissions required by Apollo. A solid-state switch will also be installed at the Jet Propulsion Laboratory (JPL) to handle the high speed data from the Deep Space Network, and to interconnect circuits with Goddard Space Flight Center.

Funds will also be required in FY 1967 to provide a line concentration switch at Guam in support of Apollo and for major modification of the switching capability at Goddard to accommodate the increasing flow of communications. Expansions of the switching units at London, Canberra, and Hawaii will be required to handle the high speed data transmissions associated with Apollo.

Other modifications planned in FY 1967 include an upgrading of the Goddard and JPL teletype and voice systems. Recurring equipment items which are necessary to maintain and update existing systems will also be required. These include signal generators, modulating and demodulating devices, high frequency radio data modems, data quality monitors, data detection and error correction equipment, and distortion measuring units.

Data Processing Equipment

The operational data processing equipment will continuously require minor redesign, modification, and improvement as well as normal maintenance and repair. Although the data processing lines are made as flexible as possible, modifications must be made to the lines to satisfy requirements of new programs as the lifetimes and data transmissions of older satellites terminate. Funds in FY 1967 will continue to provide the components for these modifications and improvements.

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In FY 1967, an additional line of the high capacity Phase II Satellite Telemetry Automatic Reduction System (STARS) is to be procured by the Goddard Space Flight Center. This line is needed to meet the data processing requirements of the Nimbus B and the Applications Technology Satellite, and to serve as backup to other lines which will be loaded to capacity by such high data rate satellites as the Orbiting Geophysical Observatory (OGO), Polar Orbiting Geophysical Observatory (POGO), the Orbiting Astronomical Observatory (OAO), and the Interplanetary Monitoring Platform (IMP).

Additional telemetry reduction and processing equipment is needed to provide flexible, high speed reduction of data for quick-look analysis by experimenters. This is of increasing importance as spacecraft become more complex and have the capability of operating in various modes. This requires that decisions be made in monitoring experiments and in the data rates to be used. A flexible, high speed reduction capability provides, in rapid fashion, the information necessary to make these decisions.

Test equipment, spares, and replacements are needed to maintain the various data processing lines. All equipment must be maintained at peak operating levels to insure maximum data usage and operating efficiency.

Supporting Research and Technology

	1965	1966	1967
New systems.....	$1,580,000	$1,160,000	$500,000
Integrated systems analysis, development, and test.....	3,025,000	2,690,000	3,500,000
Antenna subsystems.....	2,511,000	2,150,000	1,600,000
Receiver and transmitter subsystems.....	2,674,000	2,700,000	2,300,000
Data handling and control.....	1,729,000	2,400,000	2,100,000
Data processing and reduction...	780,000	1,220,000	2,100,000
Spacecraft subsystems.....	1,201,000	1,480,000	1,700,000
Total.....	$13,500,000	$13,800,000	$13,800,000

Supporting Research and Technology (SR&T) is the activity whereby technology of advanced systems, components and techniques is developed which are then used to implement the various networks to meet the requirements of new flight projects, both manned and unmanned. Complementary spacecraft subsystems are developed as well as new equipment for ground instrumentation support. Operation of development sites is conducted so that the performance and reliability characteristics of new components and subsystems are proven before the equipment is committed to the network. Supporting Research and Technology effort is also directed at reduction of rising operations costs by investigating techniques which lead toward eventual station automation.

With the trend toward complex, long-duration flight projects, the FY 1967 SR&T program will place greater emphasis on improvements for increasing the reliability and lifetime of existing systems and for determining techniques for efficient utilization of these systems to meet upcoming requirements. The SR&T program is organized into seven functional areas of effort which are described below.

New Systems

Effort will begin in FY 1967 on aircraft-based optical and infrared tracking instrumentation systems which will be required in support of future NASA flight research programs, particularly atmospheric reentry projects. Field test and evaluation of the Airborne Range and Orbit Determination (AROD) system and the S-band interferometer will be concluded with FY 1966 funding.

Integrated Systems Analysis, Development, and Test

With network operations becoming a major expense, the effectiveness of present and planned operational techniques must be closely examined and evaluated. This program will use the method that has proved effective for equipping the networks, that is, using experimental sites to ensure rapid transition from concept to laboratory model to field implementation. Areas to be investigated in FY 1967 include training, simulation, and means of assuring reliable support during critical phases of a mission such as the Mars encounter.

Antenna Subsystems

As workload and mission complexity continue to increase, there is a correspondingly greater dependence upon antenna system reliability since a backup capability does not exist at most stations. Consequently, antenna subsystem design for servo drives, antenna structures, and wideband feeds, must incorporate the latest improvements in the state-of-the-art. In recent years, numerous mathematical tools have been developed which are valuable in designing antenna subsystems. Because of the existence of detailed mathematical models of the critical parts of the system, the 210-foot Advanced Antenna System (AAS) at Goldstone, California, was successfully built to performance specifications within the original budget and schedule estimates. In FY 1967, actual operational tests of the AAS will be employed to evaluate and refine the mathematical elements which were used in its design.

Receiver and Transmitter Subsystems

In FY 1967, the receiver effort will consist primarily of development of a broader data bandwidth capacity as well as automatic radio frequency control for pre-tracking calibration, signal acquisition, and actual mission tracking. Increasing the bandwidth of some of the current receivers is necessary to accommodate the support requirements of long-duration manned Earth orbital missions. Automatic radio frequency control is the first of

a series of alternatives being evaluated that show promise of providing partial automation of ground equipment for some of the critical control functions.

In the area of transmitter subsystems, effort will continue on improving the reliability of a 100 to 400 kilowatt power amplifier.

Data Handling and Control

Future spacecraft missions will be characterized by increasing complexity and long duration. This requires that the networks have increased operational flexibility and improved system reliability. Operational flexibility is becoming particularly critical in such areas as antenna redirection, frequency changing, and shifting to different demodulation formats. One of the areas to be investigated in FY 1967 will be the use of computer-to-computer control to achieve greater flexibility with existing station equipment. Critical parameters of station status which are monitored during actual missions will be analyzed, and preliminary definitions will be developed for adapting computers to the various tasks.

Data Processing and Reduction

Effort in this area is directed toward more efficient methods of processing, reducing, and displaying extremely large volumes of scientific data which are gathered, usually in magnetic tape form, from the many satellites and spacecraft in the NASA programs.

In FY 1967, a study will be initiated to determine to what extent the techniques developed for the Satellite Telemetry Automatic Reduction System (STARS) can be applied to meet future real-time mission control needs during flight. The initial step will consist of processing selected data immediately so that a limited number of critical decisions can be made by the experimenter in near-real-time.

Spacecraft Subsystems

Spaceborne electronic equipments are closely mated in capabilities with equipment used for the tracking and data acquisition networks. The advancement of component technology and technology for applying information theory is making possible appreciable increases in overall support capability through improvements in spacecraft subsystems.

In FY 1967, a standard solid-state telemetry transmitter operating at 136 megacycles will be developed which is suitable for use in a variety of small spacecraft. Over approximately a three year period, a family of standard, reliable, solid-state transmitters will be developed which can be applied to a wide variety of NASA programs.

Investigation of on-board data handling techniques will continue. In FY 1967, a study will be made to define on-board data handling systems using previously developed logic modules and memory units.

OFFICE OF TECHNOLOGY UTILIZATION — TECHNOLOGY UTILIZATION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The primary objective of the Technology Utilization program is to provide for the widest practicable and appropriate dissemination to industry of information concerning NASA activities and results which appear to have industrial applications potential. The NASA program offers U.S. industry unique opportunities to improve existing industrial techniques and to develop new products and methods. It is the purpose of Technology Utilization to assist in identifying quickly these many opportunities and to insure their expeditious dissemination for the benefit of American industry, and ultimately the individual U.S. citizen. Technology Utilization also includes projects to study and evaluate those factors which will improve our understanding of the implications of the space program.

SUMMARY OF RESOURCES REQUIREMENTS:

	1965	1966	1967
Identification	$1,235,000	$1,220,000	$1,165,000
Evaluation	645,000	680,000	650,000
Dissemination	1,970,000	2,000,000	2,085,000
Analysis	900,000	850,000	900,000
Total	$4,750,000	$4,750,000	$4,800,000

Distribution of Program Amount by Installation:

	1965	1966	1967
NASA Headquarters	$4,750,000	$4,750,000	$4,800,000

BASIS OF FUND REQUIREMENTS:

Identification

The Identification effort is carried out by NASA personnel; specialists from research institutes, universities and industry; and, by scientists and engineers working for NASA and NASA contractors. These personnel search for ideas, innovations, processes and techniques which appear to have potential for non-aerospace application and report them quickly to NASA Headquarters. These reports are now coming in at the rate of 1,200 per year and with the present emphasis on the implementation of the New Technology Reporting Clause

in NASA contracts the rate of reporting is expected to increase. The identification effort also includes the identification of incremental advances in technology. Research institutes, universities and private companies identify these incremental advances in technology by reviewing broad areas of space research and developing state-of-the-art summaries, called Technology Surveys. During FY 1965, contracts for 12 surveys were negotiated. This program will be continued at about the same level during FY 1966 and FY 1967.

Evaluation

The technical information reported to Headquarters is forwarded to a group of Research Institutes and evaluated for novelty, technical feasibility and relevance to non-aerospace industry. A preliminary review is conducted by the Illinois Institute of Technology Research Institute. Innovations of merit are then evaluated in detail by that Institute and one of four other contractors: Arthur D. Little, Batelle Memorial Institute, Stanford Research Institute, and Southwest Research Institute. The product of this evaluation is a flow of new items, processes and techniques having non-aerospace potential. These processes are then made available in one of several publications: Tech Briefs, Technology Utilization Notes, or Technology Utilization Handbooks. Tech Briefs are one to two page bulletins about innovations, published in this format in order that the new developments may reach the potential user as quickly as possible. The Technology Utilization Reports, Notes and Handbooks are more comprehensive publications resulting from in-depth evaluations by research contractors and preparation of more complete information on the subjects covered. Although the current emphasis on new technology reporting is expected to increase the rate of documents coming into the system, the funding requested for FY 1967 will permit continuation of this evaluation effort at about the same level as for FY 1966 and FY 1965.

Dissemination

Dissemination activities are focused on exploiting the normal channels of communication that are in existence or which can be developed. Two general techniques of dissemination are employed. The first is by mailing lists consisting of over 8,000 industrial companies and individuals who receive information in some cases on all Technology Utilization publications, and in others only those in their technical areas of interest. The second form of dissemination is through experimental regional dissemination centers. The first experimental regional program was established in January, 1962, with the Midwest Research Institute (MRI) at Kansas City, Missouri. MRI has employed a broad, generalized approach in disseminating ideas and innovations to over 1,000 industrial firms in the Midwest area. During FY 1967, MRI will continue the basic program and develop new programs for working more closely with the Midwestern industry on a problem solving basis, using computer support from the Aerospace Research Applications Center (ARAC) at Indiana University. This center was established in January, 1963. It offers three basic services: (1) Industrial Applications Service, a weekly dissemination to companies of the Technology Utilization publications with follow-up applications engineering service, (2) Selective Dissemination Service,

a bi-weekly computer read-out of the new additions to the NASA magnetic tapes to provide companies with current announcements of items coming into the information system; and, (3) Retrospective Search Service, which are responses to special technical questions, accomplished by computer searching of the entire file of NASA documents (now totalling approximately 200,000 items). During FY 1964 and FY 1965, six Centers in addition to MRI and ARAC were established. These are at Wayne State University (Detroit); the University of Pittsburgh; University of Maryland; Southeastern State College at Durant, Oklahoma; the North Carolina Science and Technology Research Center; and the University of New Mexico. These Centers are serving over 120 member companies with more than 3,000 firms receiving some degree of service. Fiscal year 1967 funds will be used to support current programs at these Centers with appropriate modifications and improvements; and also provide support for several pilot projects with other agencies. In addition, two new experimental dissemination centers are planned.

Analysis

In recognition of the much broader impact of NASA programs than simply that of a major one in advancing science and technology, support is given to a study program to analyze the impact of the space program on the regional and local economy, and on industries, private institutions and different types of manpower. The principal aim here is to have researchers assist in characterizing NASA's impact as it has affected their regions and to develop analyses which lead to consideration of improved policies within the constraints of existing legislation. Under one grant, for example, a study is being made of the distribution of subcontracts under the Gemini program, regional differences in the distribution of NASA and the other Federal expenditures, the role of Defense/Space programs in the national economy, and the supply and demand for scientific manpower. These and similar studies will be conducted during FY 1967 to enhance NASA's understanding of the implications of the space program.

A recognition of the need to solve critical management problems and possibly to develop wholly new techniques for managing such a large and complex research and development enterprise as the NASA led to the support of study areas that include the organization and management of large R&D projects, the diversified roles of the research director, the government-industry contracting system, conditions under which the transfer of new technology takes place in the economy, and top level policy and decision-making in large R&D organizations. During FY 1967 NASA will continue to support a modest program of research on such management problems, the solution of which will promote increased management efficiency both within the agency and within those industries with whom NASA has contacts.

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