National Aeronautics and Space Administration

BUDGET ESTIMATES

FISCAL YEAR 1964

Volume II

RESEARCH, DEVELOPMENT AND OPERATION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

MANNED SPACECRAFT SYSTEMS

OBJECTIVES:

The ultimate objective of the development of manned spacecraft systems is to provide the capability for a broad program of manned space exploration which will achieve and maintain a position of leadership for the United States. A specific goal in acquiring this capability is to land man on the moon and return him safely to earth.

The first United States manned spacecraft system, project Mercury, demonstrated man's ability to function as an integral part of a space exploration vehicle and to enhance the flight missions by his observations and judgment. Flights have gradually increased in duration from a few minutes to more than nine hours, and will soon culminate in a one-day earth-orbital mission under the One-Day Mission project. Despite the major significance of the Mercury accomplishments, manned penetration of space has just begun, and subsequent developments in projects Gemini and Apollo will greatly expand upon the basic technology acquired from project Mercury. In addition to longer flight duration, areas of expansion will include spacecraft maneuvering; rendezvous and docking; life support of multi-man crews; extravehicular activity of man in space; maneuvering re-entry; improved techniques of recovery; space navigation; circumlunar as well as lunar orbital flights; and finally lunar landing.

SUMMARY OF RESOURCES REQUIREMENTS:

	1962	1963	1964
Funds			
Supporting research and technology.....	$5,164,000	$8,100,000	$21,100,000
Mercury.....	14,600,000	3,342,000	---
One-Day mission.....	16,460,000	17,957,000	---
Gemini.....	54,959,000	232,838,000	306,300,000
Apollo.....	75,618,000	435,784,000	1,207,400,000
Mission Control Center operations.....	---	10,500,000	21,800,000
Subtotal, direct R&D costs.....	$166,801,000	$708,521,000	$1,556,600,000
Personnel costs.....	12,739,000	30,282,000	47,976,000
Operation of installations	13,652,000	27,893,000	42,865,000
Total costs.....	$193,192,000	$766,696,000	$1,647,441,000

	1962	1963	1964
Personnel			
NASA Headquarters.....	159	288	400
Manned Spacecraft Center....	1,553	3,006	3,730
Langley Research Center.....	24	3	4
Flight Research Center.....	6	41	53
Marshall Space Flight Center	2	89	465
Launch Operations Center....	5	29	40
Western Operations Office...	12	120	147
North Eastern Office.....	-	4	5
Total personnel.....	1,761	3,580	4,844

PROGRAM JUSTIFICATION:

The first step beyond projects Mercury and One-Day Mission is the Gemini project which will place two men in earth orbit to explore long duration flight and to develop the techniques of space rendezvous. The long duration flights of Gemini will investigate the physiological and psychological effects on the crew as well as the reliability of spacecraft systems for periods of time in space which are comparable to the Apollo lunar mission. The Apollo three-man spacecraft will be used to carry man on earth-orbital, circumlunar, lunar orbit and lunar landing and return missions.

Where the Mercury spacecraft circled the earth in fixed orbits without maneuvering capability, the Gemini spacecraft will carry small thrust units which will be used to influence its orbital path. This maneuverability will enable the Gemini spacecraft to rendezvous and dock with another vehicle in orbit. The several phases of a rendezvous and docking operation will be investigated by progressive steps in the Gemini project to perfect techniques and gain experience prior to the lunar rendezvous to be employed in project Apollo. The first phase of the Gemini rendezvous operation will involve the coordination of two launches. The first launch will place an unmanned target vehicle in earth orbit. The launch of the manned spacecraft will then be timed to minimize maneuvering in orbit to accomplish the rendezvous with the target vehicle. Demonstration of this phase of rendezvous will identify problems to be faced at a later date when the Apollo lunar excursion module must be launched from the surface of the moon to rendezvous with the command and service modules in lunar orbit prior to the return trip to the earth. The Gemini project will proceed to develop the techniques required to accomplish the final phases of rendezvous such as terminal guidance maneuvers to achieve target proximity and docking with the target vehicle. This type of docking maneuver will be necessary in Apollo to allow the two crew members in the lunar excursion module to return to the command module for the trip back to earth.

Gemini will also be used to proof test techniques and equipment for Apollo. Examples other than the development of long duration and rendezvous techniques are investigations of extravehicular activity and controlled re-entry. A pressure suit with integral life support equipment is being developed for space tests outside the Gemini spacecraft. This development should eventually lead to extravehicular equipment suitable for use on the lunar surface. The Gemini spacecraft is designed to explore the use of roll modulated lift to accomplish corrections in its re-entry trajectory. The same technique will be applied to the Apollo spacecraft for increased landing accuracy upon its return to earth. Gemini will make major contributions toward lunar flight as well as accomplish significant achievements per se, but the much more advanced hardware of the Apollo project is necessary to execute a manned lunar landing and return.

The Apollo spacecraft will play a substantial role in establishing our national leadership in the major space science and engineering fields. It will establish a background of knowledge and experience to be tapped for future space explorations and for technological benefits to mankind.

The Apollo spacecraft project includes the design, development, construction, and test of a versatile multi-manned spacecraft system. The spacecraft consists of three separate modules: the command module, the service module, and the lunar excursion module. Each module is design to fulfill specific mission requirements. Development of the Apollo spacecraft hardware involves a variety of flight missions, both unmanned and manned, prior to flight to the moon's surface. These flights will be used to test the spacecraft and launch vehicles under space conditions, train the flight crews, and develop the complex operational capability required for lunar flight.

The flight missions for the Apollo spacecraft progress in three phases: (1) suborbital and earth orbital flights, (2) rendezvous flights conducted in earth orbit, and (3) lunar flights. Spacecraft modules will be qualified in suborbital and earth orbital missions. Suborbital flights using Little Joe II solid propellant test launch vehicles will be used to qualify the abort propulsion system and the spacecraft landing system. Manned long-duration earth orbital flights of the command and service modules using Saturn launch vehicles will develop reliable spacecraft systems and train the flight crews. Manned earth orbital rendezvous flights of the command module, the service module, and the lunar excursion module are scheduled using the more powerful Saturn B launch vehicles. The Saturn B vehicle will permit the development of the lunar excursion module rendezvous technique using prototype lunar mission Apollo hardware. The Advanced Saturn vehicle will be used for lunar missions.

While industrial contractors conduct a major part of the spacecraft development effort, applied research and development, crew training, testing and evaluation, flight operations, mission control, and program control are functions of the Manned Spacecraft Center under the direction of the Office of Manned Space Flight. Supporting research and development is also supplied by all NASA Centers.

Presently planned flight schedule for Gemini and Apollo is as follows:

Project/Mission	Calendar Year	Launch Location
Gemini		
Sub-orbital	1963	WSMR/AMR
Long duration	1964	AMR
Rendezvous and docking	1964-1965	AMR
Apollo		
Module qualification	1963-1964	WSMR
Manned earth orbital	1965-1966	AMR
Manned earth orbital rendezvous	1966-1967	AMR
Manned circumlunar, lunar orbital and lunar landing	1967-1970	AMR

EXPLANATION OF FUNDS REQUESTED:

Supporting research and technology	1962	1963	1964
Direct R&D costs.....	$5,164,000	$8,100,000	$21,100,000
Personnel costs.....	1,118,000	2,125,000	3,041,000
Operation of installations.....	1,168,000	1,998,000	2,805,000
Total costs.....	$7,450,000	$12,223,000	$26,946,000
Total personnel.....	154	251	312

Spacecraft supporting research and technology provides supporting engineering and development effort for approved spacecraft projects to assure the capability for rapid development of reliable, high performance spacecraft systems. Characteristically, problems arise during the development of a spacecraft which must be solved before design or development can proceed effectively. This effort provides the technological base for solutions to potential problems and, in addition, provides components and systems with improved reliability and performance.

Ultimate spacecraft reliability and performance is achieved as a result of broad systems and hardware development which complements the effort of the spacecraft development contractors. This effort ensures the soundness of the primary technical approach to the spacecraft projects.

Significant among past accomplishments is the development work on the paraglider which has evolved as the primary recovery mode for the Gemini spacecraft. Other accomplishments include afterbody ablative coating which reduced structural weight and provided increased protection to the spacecraft systems, and refinement in the art of small thrust chamber design to improve performance which had heretofore been a continuing operational problem.

Supporting research and technology can be classified into four principal areas: materials and structures development and analysis; system development and analysis; flight operational methods and systems; and simulation, training and human factors. During fiscal year 1964, primary emphasis will be in the spacecraft materials and structures area. This will include a study involving the detailed analysis of the behavior of Apollo-type structures in high energy acoustic fields. Also, a study of thermal loads associated with Apollo super circular reentry will be continued. In the area of systems development and analysis, tasks will be undertaken which include the configuration of a large single parachute to backup the three-chute cluster being developed for Apollo. NASA will also continue the search for techniques for transmitting radio signals during reentry "blackout". In addition, configuration of hardware components as backups to systems being procured for Gemini and Apollo spacecraft will be undertaken. Studies in flight operational methods and systems will include development of emergency operating procedures to be used in Apollo spacecraft operation, and extravehicular locomotion in preparation for lunar landing operations. In simulation, training, and human factors, studies cover the development of visual techniques and hardware for simulation of Apollo missions, and evaluation of the performance of humans under the stresses of space flight acceleration.

In fiscal year 1964, the Gemini and Apollo spacecraft will be in the developmental and test phases. The need for the development of alternate subsystems will be more critical during these phases in order to prevent schedule slippages.

Gemini	1962	1963	1964
Spacecraft	$30,329,000	$153,900,000	$196,200,000
Operations	---	6,300,000	14,600,000
Launch vehicles:			
Titan II	22,391,000	59,280,000	46,900,000
Atlas	---	400,000	15,900,000
Agena	2,000,000	9,900,000	32,000,000
Supporting development	239,000	3,058,000	700,000
Subtotal, direct R&D costs	$54,959,000	$232,838,000	$306,300,000
Personnel costs	1,898,000	7,075,000	15,099,000
Operation of installations	2,058,000	6,534,000	13,940,000
Total costs	$58,915,000	$246,447,000	$335,339,000
Total personnel	263	832	1,546

Project Gemini will consist of a series of long duration missions, followed by a series of rendezvous missions, while in earth orbit. For the long duration missions, the Gemini spacecraft will be put into a nominal 150 nautical mile earth orbit for periods of one week or more. The spacecraft will be returned to a land recovery site within the continental United States.

The rendezvous mission will normally be a two-day flight of the Gemini spacecraft. The target vehicle, a specially configured Agena D, will be put into orbit prior to the Gemini spacecraft launch. The orbital pattern of the target vehicle will be accurately determined by ground tracking stations. The Gemini spacecraft will then be launched to perform rendezvous. Rendezvous of the spacecraft and target vehicle can be accomplished by commanding orbit changes of the spacecraft and/or the target vehicle. Final docking of the spacecraft with the target vehicle is under the manual control of the astronauts.

For both the long duration and rendezvous missions, the Gemini spacecraft will use a controlled reentry, that is a reentry trajectory controlled by the astronauts, instead of a pure ballistic reentry as in Mercury, followed by a land landing using the paraglider. The paraglider is a triangular shaped fabric wing mounted on inflatable booms. The spacecraft is suspended beneath the paraglider by a system of cables that allow sufficient flight control to land at a preselected site somewhat like an airplane.

The two-man Gemini spacecraft is the successor to the Mercury spacecraft and is based largely on Mercury technology. It is necessary, however, to develop new subsystems such as reaction control, on-board electrical power, and in-space maneuvering and control, to meet the mission requirements of long duration and rendezvous.

Spacecraft

The Gemini two-man spacecraft will be approximately 50% larger than the Mercury spacecraft, and will weigh about 7,000 pounds. It has been designed to allow easy access to modular subsystems, providing checkout, repair, and replacement with minimum launch delay. The spacecraft is equipped with several unique subsystems, such as aircraft-type ejection seats for astronaut abort in case of emergencies. An inertial guidance system together with a rendezvous radar provide the information necessary for the spacecraft to carry out the rendezvous with the Agena target. The inertial guidance system also provides information for controlling the spacecraft to the predetermined recovery site and serves as backup in case of failure of the Gemini launch vehicle guidance system during launch. For the first time in a spacecraft, a fuel cell, similar to that to be used in Apollo, will serve as the primary electrical power. On-board spacecraft propulsion is provided for attitude control, maneuvering, and retro-fire. A paraglider or parawing, deployed from the spacecraft at about 50,000 feet altitude, allows the Gemini to make an aircraft-type landing on land.

Project Gemini was approved in December 1961 and a contract for the spacecraft development was let to McDonnell Aircraft Corporation that same month. Peak manpower at McDonnell Aircraft Corporation of approximately 2,900 will occur in fiscal year 1963. Approximately 55 per cent of the total spacecraft contract with McDonnell Aircraft Corporation is subcontracted to other companies.

Gemini plans provide for the development and production of 12 two-man spacecraft of which three will be refurbished for reuse. Fiscal year 1963 funds have been used for the design and development of the spacecraft, its subsystems, the paraglider, and associated development tests.

A major milestone, the full scale spacecraft mockup was accomplished in August 1962. Successful tests of the dual ejection seats, and flight tests of the one-half scale paraglider were accomplished in the fall of 1962. Design drawings of the spacecraft were released in October 1962 and assembly of the first spacecraft was undertaken.

Five spacecraft will be delivered in fiscal year 1964. Fiscal year 1964 spacecraft funds will be used for the production of these and other spacecraft, including the paraglider, launch services support, and associated development tests, such as project Orbit for spacecraft reliability ground test.

The fiscal year 1964 spacecraft funding estimates are based on evaluation experience gained from project Mercury and review of contractor manpower projections.

Operations

Operational support required for the conduct of flight missions can be classified into three major categories: flight, recovery and crew. Flight operations consist of the planning and conduct of Gemini flight missions from lift-off to landing. Before an operation can be conducted, considerable planning and study must go into the development of the actual flight trajectory and the techniques for the various phases of the operation, such as rendezvous and docking. Flight control personnel are trained to operate the control center and outlying network stations at points along the ground track of the flight. The U. S. Weather Bureau plays a vital role by providing world-wide weather information. Fiscal year 1963 funds provide for development of the trajectories to be used in the long duration and rendezvous flights and for the training of personnel to be used as flight controllers. The requested fiscal year 1964 funds will be used to support costs for flight control teams at network sites, earth weather surveys, and studies to determine operational techniques for rendezvous, docking, and earth orbit maneuvering. The cost estimate for fiscal year 1964 is based on actual experience with the Mercury program.

Recovery operations include the planning and employment of forces needed to effect a successful recovery of the spacecraft and flight crew at any time during the actual flight. A communications network must be established to provide the coordination and direction to the recovery forces. Ships and airplanes must be deployed to predetermined sites throughout the world for both planned and contingency recovery. Part of these forces must be equipped with suitable direction finding as well as specialized retrieval equipment. Fiscal year 1963 funds support the determination of operational procedures

for recovery of the Gemini spacecraft and crew, testing of the spacecraft landing systems, prototype recovery systems equipment, and procurement of handling and retrieval equipment and electronic location aids. The major portion of the fiscal year 1964 funds will be used to defray the costs of planned and contingency forces for the first flights, and a smaller amount for continuation of the fiscal year 1963 efforts. These cost estimates are based on experience gained during the Mercury flights.

Crew operations consist of the equipment and activities necessary for space crews to participate in engineering development, mission planning, and flight training. Fiscal year 1963 funds provide the design and initial development of mission simulators, a checking simulator, and system trainers. Fiscal year 1964 funds will provide for the completion, delivery, and operation of this equipment. The mission simulators allow operation of simulated spacecraft crew stations under realistic conditions in order to evaluate and improve design, plan primary and alternate missions, and train for each specific flight. The docking simulator will provide the basic equipment for investigations essential to design of docking hardware, window visibility, and flight control systems. This device will then be available for development of and training in flight control techniques for docking. The system trainers consist of animated displays of spacecraft systems used to provide rapid, dynamic instruction in system operating details. Funding estimates for fiscal year 1964 are based on contractor proposals from McDonnell Aircraft Corporation for the simulators and trainers, and on Mercury experience for the training itself.

Launch vehicles

The Gemini launch vehicle will be a Titan II modified to increase reliability and astronaut safety. The Gemini launch vehicle is required to insert the Gemini spacecraft into a precise earth orbit with a minimum of launch delays. Primary development effort consists of: incorporation of radio guidance in lieu of the Titan II inertial guidance system, development of a malfunction detection system to allow astronaut abort, addition of a redundant control system, and development of special checkout equipment and test facilities.

The Martin-Marietta Corporation was engaged by contract in January 1962 through the Air Force Space Systems Division to provide a total of 15 Gemini launch vehicles. Subsystem and primary Gemini launch vehicle development have progressed satisfactorily in fiscal year 1963. Development of the Gemini launch vehicle during fiscal year 1963 will allow delivery of the first five launch vehicles in fiscal year 1964. The Vertical Test Facility for integration and checkout of electrical, hydraulic, and mechanical subsystems of the Gemini launch vehicle will be completed at the Martin-Marietta plant during fiscal year 1963.

Critical components of the Gemini launch vehicle, such as the malfunction detection system, will be flight tested on Air Force Titan II ICBM's during

fiscal years 1963 and 1964 prior to the first Gemini flight to gain flight reliability data. Flight data from many standard Air Force Titan II's will be obtained before the first Gemini flight.

Fiscal year 1964 funds will be used for production of additional vehicles, launch support services, propellants, and preflight testing. Funding estimates were developed by the Air Force Space Systems Division, based upon their experience in the Titan II ballistic missile development and production program.

The Atlas D will be used to boost the Agena D target vehicle into orbit. A total of eight Atlas vehicles will be procured from the General Dynamics Corporation/Astronautics Division, through the Air Force. Fiscal year 1963 funds provide for the engineering definition of the Atlas/Agena configuration. Fiscal year 1964 funds will be used to purchase Atlas boosters for the first Atlas/Agena launchings. The Atlas fiscal year 1964 fund estimates were developed by the Air Force Space Systems Division and General Dynamics/Astronautics Division, as derived from the costs experienced in the Atlas ballistic missile program.

In March 1962, NASA contracted with the Lockheed Missiles and Space Company, through Air Force Space Systems Division, for the Agena procurement. The specially configured Agena D target vehicle is being designed and components developed with fiscal year 1963 funds. Development of the multiple restart propulsion system, and other Gemini-peculiar subsystems, is progressing satisfactorily.

Fiscal year 1964 funds will be used for Agena vehicle manufacture, test site support, development testing, and will allow the delivery of one vehicle in fiscal year 1964. The fiscal year 1964 funding estimates were developed by Air Force Space Systems Division, the Lockheed Missiles and Space Company, and NASA, based upon comparative costs in other NASA and AF programs involving Agena vehicles modified for space purposes.

Supporting development

Supporting development covers those contracts and activities which are not in the main stream of spacecraft development but directly support its development. Included in this category are funds required for Department of Defense (DOD) test support, studies of rendezvous techniques, and development contracts for such items as an extra-vehicular life support system for the astronauts.

During fiscal year 1963 these funds provided primarily such items as the development of bioinstrumentation; DOD support for ejection seat, parachute, and paraglider tests; development of pressure suits, survival kits, and food and waste management systems; study contracts in the areas of rendezvous and guidance; and astronaut abort simulations.

The fiscal year 1964 funds will be used primarily for the continued development of the extravehicular suit, purchase of production pressure suits and the associated maintenance, procurement of production food and waste management systems, development of "out-of-the-window" visual displays for the mission simulator, and astronaut flight simulator training.

Apollo	1962	1963	1964
Spacecraft:	($69,869,000)	($350,124,000)	($1,031,400,000)
Command and service modules	60,000,000	269,224,000	661,200,000
(NAA prime contract)	(33,000,000)	(160,829,000)	(396,800,000)
(Subcontracts)	(27,000,000)	(108,395,000)	(264,400,000)
Lunar excursion module	---	32,000,000	230,000,000
Guidance and navigation system	7,932,000	45,000,000	130,700,000
Instrumentation and scientific equipment	1,937,000	3,900,000	9,500,000
Operations	---	1,000,000	16,000,000
Launch vehicles:	(2,200,000)	(59,721,000)	(135,000,000)
Little Joe II	1,250,000	4,500,000	5,000,000
Saturn	950,000	55,221,000	75,000,000
Saturn B	---	---	55,000,000
Supporting development	1,257,000	5,000,000	25,000,000
R&D facilities	2,292,000	19,939,000	---
Subtotal, direct R&D costs	$75,618,000	$435,784,000	$1,207,400,000
Personnel costs	4,327,000	14,183,000	29,728,000
Operation of installations	4,614,000	12,845,000	26,020,000
Total costs	$84,559,000	$462,812,000	$1,263,148,000
Total personnel	597	1,682	2,975

Spacecraft

The Apollo spacecraft is composed of separate modules, each designed to fulfill specific mission requirements. The command module houses the three-man crew, serves as the control center for spacecraft operation and is designed to safely reenter the earth's atmosphere at a velocity of about 25,000 miles per hour upon return from the moon. The service module houses many of the spacecraft support systems and the major propulsion system for mission abort, mid-course corrections, and injection into and out of lunar orbit. The lunar excursion module is a special-purpose shuttle or space ferry for the two men making the lunar landing. It contains the necessary systems for descending from lunar orbit, performing the lunar landing and take-off,

and accomplishing the lunar orbit rendezvous with the command and service modules.

The lunar landing mission is to be performed using the lunar orbit rendezvous method, a technique utilizing a single Advanced Saturn launch vehicle. The Advanced Saturn launches the three-module spacecraft into earth orbit and then into the translunar trajectory. Upon approaching the moon, the spacecraft is placed into lunar orbit by the service module propulsion system. Once in lunar orbit, two of the three men transfer to the lunar excursion module, separate from the command and service modules, and descend and land on the lunar surface. A twenty-four hour stay with capability for an additional twenty-four hours is provided for exploration of the lunar surface near the landing site. After take-off from the moon, a rendezvous with the command and service modules is accomplished in lunar orbit. After the crew of two has completed the transfer from the lunar excursion module to the command module, the service module propels itself and the command module on a transearth trajectory. The lunar excursion module is left in lunar orbit. The service module is jettisoned prior to atmosphere reentry and the command module serves as the reentry vehicle.

The overall scheduling of flight missions for the Apollo spacecraft program progresses in three phases: (1) suborbital and earth orbital flights, (2) circumlunar and lunar orbital flights, and (3) lunar landing flights.

The spacecraft modules will be qualified in suborbital and earth orbital missions. Suborbital flights using Little Joe II solid propellant rocket launch vehicles will be used to qualify the abort propulsion system and the spacecraft landing system. Manned long-duration earth orbital flights of the command and service modules, using Saturn launch vehicles, will develop reliable spacecraft systems and train the flight crews. Manned earth orbital rendezvous flights of command module, service module, and partially fueled lunar excursion module are scheduled, using the more powerful Saturn B launch vehicles. The Saturn B vehicle will permit the development of the lunar excursion module rendezvous technique using prototype lunar mission Apollo hardware.

The entire Apollo spacecraft together with the Advanced Saturn launch vehicle, will be used for manned circumlunar and/or lunar-orbital flights to develop operational techniques in the lunar environment and to conduct scientific experiments in cislunar space.

Lunar landing missions using the entire Apollo spacecraft, launched by the Advanced Saturn launch vehicle, will be made to explore the lunar surface and to conduct scientific experiments in the lunar environment.

Command and service modules

In December 1961, the Space and Information Systems Division of the North American Aviation Corporation (NAA) was selected as a prime contractor

to design, develop, and fabricate two of the major modules of the Apollo spacecraft. In addition, NAA was assigned the responsibility for design and fabrication of the spacecraft-to-launch vehicle adapter, integration of the lunar excursion module into the spacecraft system, integration of test and scientific and other government-furnished equipment into the spacecraft, assembly and test of the complete spacecraft, and support of spacecraft preparation for flight tests.

The two major modules of the spacecraft built by NAA are the command module, which houses the three-man crew and which is the only part of the spacecraft to be soft landed on earth upon the completion of a mission; and the service module, which contains the spacecraft propulsion system and houses spacecraft equipment and expendables which are not required during reentry.

The command module is a blunt, conically shaped body which has an aerodynamic lift-to-drag ratio of approximately one-half. This aerodynamic lift allows the command module to maneuver in the atmosphere and, hence, to land anywhere on the surface of the earth within an area approximately 5,000 miles long and 400 miles wide. The command module is thirteen feet in diameter and weighs approximately five tons. It is protected from the heat of reentry by an ablative material which is fastened to its external surface. The command module contains communications, attitude control, attitude stabilization, environmental control, electrical power supply batteries, earth landing, and crew support subsystems. Also contained within the command module are the guidance and navigation system and instrumentation displays. The internal volume provided for the three-man crew is approximately 300 cubic feet, slightly larger than a typical office building passenger elevator interior. Attached to the command module, but jettisoned early in the flight, is a launch escape system which provides for abort of the command module in case of an on-the-pad or early-in-flight launch vehicle catastrophe.

The service module contains a 22,000 pound thrust, hypergolic-fueled propulsion system, an attitude control system, hydrogen-oxygen fuel cells for electrical power supply, radiators for the spacecraft cooling, radar, and the major supply of expendables for the life support system and the electrical power supply. The service module weighs approximately twenty-five tons fully loaded with propellants and approximately five tons empty. Its diameter is thirteen feet and the over-all length is approximately twenty feet.

During fiscal year 1963, preliminary design of the command and service modules will be completed and the detailed design and development effort will be underway. All major subsystems will be placed under subcontract and ten development spacecraft fabricated. The first development spacecraft was delivered in August 1962 and has been undergoing water flotation and seaworthiness testing since that time. Impact tests, on both land and water, parachute, and landing system development are underway. Spacecraft and launch vehicle dynamics tests will be underway in the Marshall Space Flight

Center Vertical Dynamics Test Facility using an Apollo spacecraft and a flight prototype Saturn launch vehicle.

In December 1962, a detailed mockup of the command module was completed and subjected to formal review by NASA for internal and external arrangement. The other eight development spacecraft required will be completed during fiscal year 1963 and will be used for studying the service module arrangement, for interface compatibility tests, and for individual systems installation planning.

Most of the activity during the current year is in preliminary spacecraft and subsystem design and in testing of the basic conceptual design. Fiscal year 1964 will be devoted to intensive component and subsystem fabrication, testing and qualification, and spacecraft fabrication. A total of twelve development spacecraft will be fabricated in fiscal year 1964. The first two spacecraft for long-duration manned orbital flights will be fabricated. Additional spacecraft will be in various stages of manufacturing to support the delivery schedule in fiscal year 1965 of a man-qualified spacecraft every three months. By the end of fiscal year 1964, most spacecraft subsystems for manned orbital flight will have completed ground qualification testing. In addition, the abort and earth landing systems will have been tested under a simulated off-the-pad mission abort, and initial Little Joe II flight tests will have been conducted at White Sands Missile Range, New Mexico. In fiscal year 1964, three Saturn launches are planned from the Launch Operations Center to determine spacecraft and launch vehicle compatibility and to develop the abort sensing systems to a high state of reliability.

In addition to the pad abort and Little Joe II flight tests, the command and service module propulsion system development tests will be conducted at White Sands. These propulsion tests are essential for developing the required high reliability of the spacecraft propulsion systems for the multi-start 7 to 14-day operating cycle these systems must sustain.

Ground support equipment requirements will be assessed during fiscal year 1963, and design of major ground support equipment items will be initiated. In fiscal year 1964, design will be substantially completed and fabrication of this equipment initiated. Initial ground support equipment deliveries are required on a schedule to support the early White Sands abort tests and the Saturn flights. Because these early developmental spacecraft are relatively simple in construction and carry only selected systems on board, the ground support requirements can be met with interim, simplified equipment. However, in fiscal year 1964 the complete ground support equipment required for the first manned orbital flight must be developed and delivered.

In fiscal year 1963, detailed engineering design will commence on simulation equipment essential to crew training prior to the lunar mission. This equipment consists of two mission simulators, one part task simulator, the Gemini docking trainer, and several system trainers. A description of the

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purpose of these trainers is contained in the following "Operations" narrative section. By the end of fiscal year 1964, manufacturing will be complete and, with the exception of one mission simulator, all equipment will be operational. This remaining simulator is scheduled to be operational at the Launch Operations Center in early fiscal year 1965.

The amount required during fiscal year 1964 is based on North American's cost proposal, which includes sub-contractor costs approximating 40% of the proposal. This proposal was analyzed in detail by NASA personnel of the Manned Spacecraft Center and the Office of Manned Space Flight. Through this analysis, it was possible to reduce the contractor's proposal to the amount requested by (1) elimination of similar hardware integration and development efforts among prime contractor and sub-contractors, and (2) reassessment and abbreviation of the testing effort not considered essential to the program. In assessing the contractor's proposal for development and production costs, experience data from project Mercury and other space programs were used as a basis for evaluation. The Apollo effort and dollar requirements will increase in fiscal year 1964 to meet planned design release dates which are prerequisite to meeting scheduled launch dates. Accordingly, the North American manpower assigned directly to the Apollo project will reach a maximum level of 9,200 by the end of fiscal year 1964, compared with 8,200 at the end of fiscal year 1963. Major subcontractor effort will require 8,400 people by the end of fiscal year 1964 compared with 7,600 at the end of fiscal year 1963.

Lunar excursion module

The lunar excursion module (LEM) is the Apollo spacecraft module which transports the astronauts and scientific payload from lunar orbit to the lunar surface and returns to lunar orbit to rendezvous with the command and service modules. It has been under development by the Grumman Aircraft Engineering Corporation, under contract to the Manned Spacecraft Center, since December 1962. This module must have the capability of performing separation, lunar descent, landing, lunar ascent, rendezvous, and docking, independent of the mother spacecraft. It is essentially a self-contained vehicle, weighing about 12 tons, which contains its own electrical power, guidance and control, communications, propulsion, and crew support systems. Due to the moon's relatively weak gravitational field and lack of an atmosphere, the lunar excursion module does not need the structural and heat resistant provisions that are required in the command module for safe reentry into the earth's atmosphere and recovery on the earth's surface. Its design can therefore accentuate the features essential for lunar landing, take-off, and rendezvous. Windows with a broad field of view will provide the astronauts visual reference during these critical maneuvers.

The propulsion system will utilize earth-storable, hypergolic bipropellants and will have a pressurized propellant feed system. It is planned that the LEM will be a staged configuration in which the propulsion system (engine and tanks) used to land on the moon will be left there and a separate propulsion system will be used to take off from the lunar surface and

rendezvous with the mother spacecraft. Major effort will be expended to develop the extremely high reliability required for these propulsion systems and the spacecraft stabilization and control systems.

The LEM development is now in the design study phase, leading to the definition of a detailed configuration by the end of fiscal year 1963. Concurrent with these design studies, subcontractors will be selected and development work will be undertaken on critical components and portions of the hardware. These include subsystems required for environmental control, stabilization and control, propulsion, electrical power, and communications.

In fiscal year 1964, a propulsion test unit will be constructed and propulsion tests initiated. This propulsion test unit will be a throttable rocket engine which will permit the spacecraft to hover above the lunar surface while a landing site is being selected by the astronauts. In addition, a structural model will be constructed to test the basic structure design and to investigate provisions required to protect the astronaut from the hazards of radiation and meteoroids. Another model will be constructed and tests initiated to develop the landing gear for landing on the lunar surface. The landing gear is a critical system which must be amenable to modification without significantly affecting the overall spacecraft design. This will permit improvements to be made in landing gear design as lunar surface data are obtained from the unmanned Ranger and Surveyor flights.

During fiscal year 1964, manufacture of flight test articles for use on Saturn and Little Joe II launch vehicles will commence. In addition, manufacture will be started on ground and hover test vehicles which will be used to test the landing characteristics of the vehicle in a simulated lunar environment. Trade-off studies will be conducted during this period to insure sufficient provisions in the development program for adequate crew safety.

The fiscal year 1964 estimate is the second increment of a contract negotiated with the Grumman Aircraft Corporation for the total development and production of the lunar excursion module. Since the contract was not negotiated until mid-fiscal year 1963, only limited funds were required in fiscal year 1963 to initiate the build-up in personnel, and selection of major subcontractors. It is estimated that Grumman will have approximately 800 people directly assigned to the project by the end of the current fiscal year. To meet presently established schedules, the manpower requirements will necessarily have to reach their maximum level in fiscal year 1964. Accordingly, the dollar requirement will increase, consistent with the other major elements of the Apollo project. By the end of fiscal year 1964, approximately 4,000 people, including those employed by major subcontractors, will be directly assigned to the project.

Guidance and navigation system

The functions of the Apollo guidance and navigation system are to determine the position, velocity, and trajectory of the spacecraft; and to

control the spacecraft's engines and reentry lift for the precise maneuvers necessary for the flight to the moon, lunar orbit, lunar landing and take-off, lunar orbit rendezvous, and the return to earth at a preselected landing site.

The guidance and navigation system consists of three major components: the inertial subsystem, the guidance computer, and the optical subsystem. The inertial subsystem consists of a gimbaled platform, gyroscopes, accelerometers and associated electronics, and is used to establish a reference in space and to measure velocity and course corrections applied by the propulsion systems or by aerodynamic maneuvers. The guidance computer is used to determine the trajectory, to compute required velocity changes, and to send engine start and cut-off signals to the propulsion systems or to signal for proper orientation of the aerodynamic lift vector during atmospheric reentry. The optical subsystem, consisting of a scanning telescope and a space sextant, is used to find the craft's position in space, and to align the inertial platform prior to each maneuver.

The contractor team selected to provide the Apollo guidance and navigation system, under the direction of the Manned Spacecraft Center, is as follows:

(a) The Instrumentation Laboratory of the Massachusetts Institute of Technology, to develop the system, to fabricate initial prototypes, and to provide technical direction of the industrial manufacturers of production systems.

(b) The AC Spark Plug Division of General Motors Corporation, of Milwaukee, Wisconsin, and of Wakefield, Massachusetts, to produce the inertial platforms, to assemble and test the entire guidance and navigation system, and to provide ground support equipment.

(c) The Raytheon Corporation of Bedford, Massachusetts, to produce the Apollo guidance computer and its associated ground support equipment.

(d) The Kollsman Instrument Corporation of Elmhurst, New York, to provide the optical subsystem.

The guidance and navigation system has been under development since fiscal year 1962 at the Instrumentation Laboratory of the Massachusetts Institute of Technology. During the last quarter of fiscal year 1962, the above-mentioned industrial supporting contractors were selected to assist MIT and to produce operational systems. This team of contractors will provide guidance and navigation equipment for both the command module and the lunar excursion module. Wherever possible, identical equipment will be used in both modules.

In fiscal year 1963, broad guidance and navigation concepts will be established and command module equipment designs finalized. Experimental and development models will undergo reliability and environmental testing. In fiscal year 1964, prototype guidance systems are to be developed and intensive ground testing will be underway.

The fiscal year 1964 estimate is based on contracts already negotiated with certain of the guidance and navigation contractors, and cost proposals received from the other participating contractors. In assessing the proposals submitted by the various contractors, the development and production costs of the Polaris guidance system provided the primary basis for evaluating these proposals. Added to this experience factor was the allowance for size, complexity, and higher reliability required for the guidance and navigation system to be used in command and lunar excursion modules.

Based on established schedules, the guidance and navigation effort will increase in fiscal year 1964. MIT and industrial contract personnel assigned to project Apollo will reach 2,200 by the end of fiscal year 1963, and will peak at approximately 2,900 in mid-fiscal year 1964.

Instrumentation and scientific equipment

These funds are used to develop and procure the specialized flight research and development instrumentation required during the development phase of spacecraft flight testing and the scientific equipment for in-space and lunar scientific experiments. The instrumentation is to be developed, fabricated or procured by the Manned Spacecraft Center and is provided to the spacecraft contractors for installation in the appropriate spacecraft modules. This instrumentation is required to obtain the detailed engineering test data for evaluation of spacecraft system performance under critical operating conditions. Included are sensors, transducers, telemetry transmitters, appropriate transmitting antennas and ground support equipment.

The scientific equipment is required for scientific measurements in space, as well as on the lunar surface. This equipment will also be developed, fabricated or procured by Manned Spacecraft Center and provided to the spacecraft contractors for installation in the spacecraft. Typical scientific equipment includes special cameras, magnetometers, seismographs and radiation measuring devices.

During fiscal year 1963, emphasis was on the design, procurement, fabrication, test and qualification of initial flight research and development instrumentation equipment. Initial deliveries of flight hardware were made to North American Aviation for first Apollo spacecraft flight tests.

Fiscal year 1964 funds will be employed to design, procure, fabricate, and test additional flight research and development instrumentation for eight Apollo spacecraft flight tests. Research, development, and procure-

ment of specialized scientific devices such as cameras, TV systems, magnetometers, and seismographs will be initiated to meet lunar landing mission requirements. This equipment will be undergoing extensive testing to ensure that highly reliable and accurate scientific equipment will be available for the manned missions that begin in fiscal year 1965.

The fiscal year 1964 costs are Manned Spacecraft Center estimates based on their present assessment of requirements in this area, and their past experience in procurement of similar equipment for Mercury and Gemini.

Operations

Operational support required for the conduct of flight missions can be classified into three major categories: flight, recovery, and crew. Flight operations include operation planning, pre-flight checkout of the spacecraft, and control of flight execution from lift-off to landing. Personnel must be trained to operate the Mission Control Center and outlying stations to control the various phases of the Apollo flights. In fiscal year 1963 funds are provided for studies on the Apollo trajectories and flight control techniques, and to initiate a program to predict the space environmental conditions to be encountered on specific flights. Fiscal year 1964 funds will be used to continue the above study efforts and provide funds for the training of flight control personnel. The funding requirements are based on NASA experience gained from project Mercury, and on data supplied by the U. S. Weather Bureau.

Recovery operations include the efforts required to effect either a land or sea recovery of the Apollo spacecraft and crew at any time during the flight. Adequate planning and study must be accomplished to provide an operational recovery capability for the Apollo missions. Recovery forces must be equipped with direction finding and location aids. Determination of the sites for deployment of planned and contingency forces is necessary. The fiscal year 1963 efforts include: evaluation of recovery operation techniques, tests of the spacecraft landing and recovery systems, development and procurement of electronic and visual location systems and procurement of handling and retrieval equipment. Fiscal year 1964 funds will be used to continue the above studies and evaluations, and to provide for the procurement of additional recovery force equipment. The funding estimate is based on experience with the Mercury and Gemini projects.

Crew operations provide for space crew training and integration of their activities with the engineering development, mission planning, and the flight missions. In fiscal year 1963, training equipment requirements were defined and necessary designs were initiated. The equipment requirements include mission simulators, a part-task simulator, a docking trainer, and system trainers. The mission simulators allow manned simulated missions to be "flown" under realistic conditions to evaluate and improve spacecraft design, to be planned in primary and alternate missions, and to allow training for each specific flight. The part-task simulator provides training in a selected portion of the flight trajectory, thereby allowing con-

centrated practice on difficult flight tasks with a minimum of operation time and expense. The docking trainer will be used for instruction in the critical docking maneuvers. The system trainers consist of animated displays of spacecraft systems thereby providing rapid and dynamic instruction in system operation details.

The design and fabrication of these trainers will be completed in fiscal year 1964 and is supported within the funds requested in the command and service module section above. The fiscal year 1964 crew operations estimate will provide simulator maintenance and operation, academic and survival instruction, a free flight lunar landing trainer, centrifuge training, weightlessness training, and support studies to solve the problem of using optical navigation equipments while wearing the pressure suit helmet.

Launch vehicles

The Convair Division of the General Dynamics Corporation was selected to design, develop, and fabricate the Little Joe II solid propellant rocket vehicle in May 1962. Little Joe II is to be used as a "workhorse" vehicle to qualify the launch escape system and the command module structure prior to manned flights. These flight tests are required to establish high crew safety for the ascent flight phase through the atmosphere. Although much smaller than the Saturn, the Little Joe II, with appropriate modules of the spacecraft attached, is able to duplicate critical early phases of the ascent trajectory of the Saturn launch vehicle.

The Little Joe II vehicle utilizes a total of up to 7 modified Algol rockets. The firing sequence and number of rockets utilized varies according to the desired flight trajectory for a particular launch. The Algol rocket was developed for the Scout launch vehicle and is produced by the Aerojet Corporation. The major modification of the rocket for use in Little Joe II consisted of canting the nozzle to aim the rocket thrust vector through the center of gravity of the vehicle. The Little Joe II is nearly as large as the Atlas launch vehicle and has up to half again the thrust of the Atlas. The maximum diameter is 13 feet and over all length is 50 feet. Initial weight is approximately 90 tons.

Detailed design and developmental effort on the Little Joe II vehicle will be substantially completed in fiscal year 1963. The fiscal year 1964 funding will permit the fabrication of four Little Joe II vehicles, provide long leadtime hardware for additional vehicles, and provide operational support for initial flight test missions. The first flights will be at maximum dynamic pressure (highest structural load conditions), and will be conducted in fiscal year 1964. Additional vehicles will be flown in fiscal year 1965 to qualify the prototype spacecraft and launch escape system prior to first manned flight.

The Saturn launch vehicle will be used as the booster for long duration (two-week) manned flights in earth orbit. These flights will verify the

spacecraft and subsystem reliability required for the lunar missions as well as provide for crew training. Funding for Saturn development is discussed under the Launch Vehicle and Propulsion Systems program. The funding requested here is for the procurement of operational vehicles after the tenth Saturn development launch vehicle. The manned orbital missions with operational Saturns will begin in 1965. Saturn vehicles for six flights are planned. The funding requested is based on NASA analysis of contractor estimates.

The Saturn B launch vehicle will test the lunar mission spacecraft configuration in earth orbit and permit the testing of rendezvous techniques using lunar mission spacecraft modules. These tests are essential because they permit the development and flight qualification of the entire lunar spacecraft system much earlier than if it were necessary to wait for the availability of the Advanced Saturn launch vehicle. This approach permits lunar missions to be launched with the earliest man-rated Advanced Saturn vehicle. The Saturn B will be qualified in a series of flights in fiscal year 1966. The funding required for the development of this vehicle is requested in the Launch Vehicle and Propulsion Systems program. The funding requested here is for the procurement of long lead time hardware for the first operational vehicles. The funding requested is based upon NASA estimates.

Supporting development

Funds are required to pay for utilizing Department of Defense installations for direct test support for the Apollo spacecraft development effort. They cover wind tunnel tests at Arnold Engineering Development Center, Tullahoma, Tennessee, test support at the White Sands Missile Range in New Mexico, and test support at the Joint Parachute Test Facility in El Centro, California. The procurement of propellants for the service module propulsion development is also included.

Apollo wind tunnel tests are required to furnish design information for the spacecraft and to confirm the design philosophy. The total wind tunnel program for Apollo entails the use of a number of wind tunnels throughout the country. A number of wind tunnel tests are being conducted at the Langley Research Center and Ames Research Center. These tests are a part of normal center project support activities. Arnold Engineering Development Center tests utilize that Center's unique facilities, and are funded in accord with standard test support reimbursement procedures. These tests yield measurements of the static and dynamic forces, moments and pressures. Also, heat transfer measurements will be made to provide thermal design information.

Operations at White Sands are required to support qualification tests of the Apollo launch escape system in abort situations and to qualify the spacecraft structure at maximum dynamic pressure. These qualification tests will be accomplished by flights, using the Little Joe II launch vehicle and by simulating pad abort conditions. The White Sands Missile

Range allows land recovery of the test vehicles assuring higher probability of recovery of on-board recorded data. Fiscal year 1963 efforts were directed primarily toward readying the launching pad and its associated equipment, and performing one pad abort test. Fiscal year 1964 funds will be used to reimburse the Army for test expenditures at the White Sands Missile Range. The first flight test is scheduled in early fiscal year 1964. Funds will also be used to reimburse the Army for expenditures associated with support of the Apollo spacecraft propulsion test facility at WSMR which are above normal range support requirements.

Fiscal year 1964 funds will be used for continuing range support to the Navy and Air Force at the Joint Parachute Test Facility, El Centro, California, for the drop test program portion of the parachute development program. In fiscal year 1963, the parachute development program developed the drogue stabilizing parachute, the light-weight single main chute, and a number of three-parachute cluster drops were completed. Pre-qualification drop tests will be performed in fiscal year 1964, in which the parachute cluster will be mated with the other components of the earth-landing system. These pre-qualification tests will be completed prior to the first Little Joe II test flight in 1964.

Also included in this area are funds for studies directly in support of the Apollo spacecraft development effort which are not part of the prime or associate contractor development effort. These are studies that lead to improvements in the areas of flight operations, communications, and guidance and navigation. Also included are costs to develop and test subsystems not included in the prime contract. In a program as large as Apollo, it is essential that selected potential problem areas, subsystems, and components be explored outside of the prime contractor activity. This activity provides the depth and answers required to effectively cope with development difficulties. It ensures that the best components are being used in the prime effort.

Funds are also provided to initiate work on a high energy propulsion system for the service module to serve as backup to the lower energy non-cryogenic propellants. The increased performance of the high energy propellants would accommodate a significant increase in spacecraft weight and still permit the lunar missions to be flown with the Advanced Saturn launch vehicle. This effort would therefore provide for any significant spacecraft growth caused by unforeseen major development difficulties. The funds requested are based on NASA experience with related developments.

Mission Control Center operations

	1962	1963	1964
Direct R&D costs.....	---	$10,500,000	$21,800,000

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The Mission Control Center in Houston, Texas will exercise primary responsibility for command of all manned space flight missions beginning in mid-1964. A Construction of Facilities project is providing the Mission Control Center building and its equipment. This project supports the planning and operations of the Center, its integration with the other elements of the ground operational support system, and its initial operation for simulation and training exercises. Planning conducted in this project provides the conceptual design of the land-based landing/recovery operations complex for manned space flight.

The Mission Control Center, in order to perform its command function, must have immediately available to it tracking and telemetry data received from the ground network so that real time decisions may be made during the various portions of the flight. It must contain a large computing complex, containing pre-planned alternative courses of action for use in any of a vast number of contingency situations, and which is sufficient in size to permit the computation of real time flight information needed by the flight controllers in reaching their decisions. It must contain the necessary equipment for extensive use of closed-loop simulation exercises for training and system checkout and for direction of the world wide tracking network. It must include all the communications processing and control equipment associated with flight, simulation, and network control.

The Mission Control Center is to be housed in a three-story building, with two wings as follows:

(1) The mission operations wing, containing approximately 113,000 square feet, including:

(a) A computer complex composed of approximately four IBM 7094 computers to perform the following principal functions:

(1) Processing in real time spacecraft telemetry and tracking data, using information provided by the ground instrumentation network.

(2) Providing real time computer logic to permit the ground-based flight controllers to select alternatives in event of emergency or any necessity to change the flight plan.

(3) Providing trajectory and other data signals for use in closed-loop simulation exercises which are necessary for checkout of all ground facilities, including the Mission Control Center itself, and for flight controller training.

(4) Providing real time antenna acquisition and other remote control data for dissemination to the stations in the ground network.

(b) A communications center composed of communications processing and control equipment for directing the flow of the following types of data:

(1) Voice communications to and from the spacecraft via relay through the remote sites.

(2) The transmission of commands, tracking data, and other information to the spacecraft.

(3) Spacecraft telemetry data from remote sites.

(4) Tracking data from remote sites.

(5) Teletype communications to and from the various ground network sites.

(6) Television signals from the Launch Operations Center and one or more remote sites, as required.

(c) Two mission operations control rooms where consoles and displays are located for use of flight controller personnel in conducting the missions. One room will be used for a flight mission while the other is engaged in simulation exercises in preparation for a later mission.

(d) A simulation area containing various types of ground support equipment, such as that located at remote sites in the network, so that various closed-loop simulation exercises may be conducted without use of the actual flight equipment.

(e) A meteorological support area with equipment to provide the means of displaying and evaluating atmospheric weather, cosmic phenomena, radio propagation data, meteorite storm and space radiation intensity data, and other meteorological information upon which the success of the missions may depend.

(f) A recovery area containing maps and other displays necessary for centralized control of all recovery forces and equipment, wherever deployed.

(2) The laboratory, engineering and technical services wing, containing approximately 132,000 square feet, including:

(a) Support laboratories for analysis of data reduction procedures, the development of computer programs and routines, evaluation of space-to-ground communications procedures, evaluation of display and control devices, and the preparation of simulation materials.

(b) Technical services areas and engineering offices. Office space for approximately 500 NASA and 200 contractor personnel will be provided. These are the personnel engaged in flight operations activities. Technical services areas to be provided include briefing, drafting, and photographic processing areas.

Fiscal year 1963 funds are being utilized to develop the operational concept of the center, to begin its implementation and integration with the other elements of the ground operational support system, and to provide the operational concept of the landing/recovery operations complex which will be associated with the Mission Control Center as a future part of the ground operational support system. Specifically, the following are being accomplished in fiscal year 1963:

(1) Operational concept design of the Mission Control Center and information-flow studies for Gemini rendezvous and Apollo missions. This work is being accomplished under contract with the Western Development Laboratories of the Philco Corporation, Palo Alto, California.

(2) Establishment of an interim computer facility using rented computers, and the preparation of fundamental mission computer programs and simulation computer programs.

(3) Design of permanent computer complex and initiation of procurement of the computers to be used therein. A contract has recently being signed for this work with the Federal Systems Division of the International Business Machines Corporation, Rockville, Maryland.

(4) Design and specification of control, display, simulation, and communications equipment and initiation of procurement of this equipment, and initial ground operational support system integration efforts. Proposals from various contractors for this work currently are being evaluated. The contractor chosen will be known as the Mission Control Center implementation contractor.

(5) Conceptual design of the instrumentation and control systems which will be necessary in landing areas including the tracking, telemetry, and communications systems required. This will be accomplished by the contractor selected to perform the work listed immediately above.

Estimates of fiscal year 1964 fund requirements are based on cost projections prepared by the conceptual design contractor, Philco Corporation. These were modified, after careful analysis, by NASA personnel, with experience of project Mercury being given substantial weight. These funds will be utilized to accomplish the following:

(1) Completion of all mission logic and simulation computer programs necessary for Gemini rendezvous flights and Saturn Apollo flights, installation and checkout of the entire computer complex, and operation during simulation exercises. This will be accomplished under the existing contract with the Federal Systems Division of IBM.

(2) Installation and checkout of all other Mission Control Center equipment, operation during simulation exercises, completion of integration of the Mission Control Center with the ground network, the Launch Operations Center, and the recovery control centers. This work will be accomplished by the Mission Control Center implementation contractor, currently being selected.

Building construction began in December, 1962. The interim computing facility will be ready by January 15, 1963, and equipment installation will begin in May of 1963. The Mission Control Center, including the computer complex, must be sufficiently complete to permit initiation of simulation exercises in February of 1964 and ready for flight operational use in July of 1964.

Projects for which no direct R&D costs are anticipated in fiscal year 1964.

Mercury	1962	1963	1964
Direct R&D costs.....	$14,600,000	$3,342,000	$ ---
Personnel costs.....	4,805,000	229,000	---
Operation of installations....	5,172,000	214,000	---
Total costs.....	$24,577,000	$3,785,000	$ ---
Total personnel.....	665	27	---

One-day mission	1962	1963	1964
Direct R&D costs.....	$16,460,000	$17,957,000	$ ---
Personnel costs.....	591,000	6,670,000	108,000
Operation of installations....	640,000	6,302,000	100,000
Total costs.....	$17,691,000	$30,929,000	$208,000
Total personnel.....	82	788	11

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

LAUNCH VEHICLE AND PROPULSION SYSTEMS

OBJECTIVES:

The Launch Vehicle and Propulsion Systems program supports, through the development of the required vehicle and propulsion systems, the primary mission of the Office of Manned Space Flight, the manned exploration of space. The current goal is to achieve manned lunar landing and return to earth during this decade.

The program, as currently approved, consists of the development of three major launch vehicles to be used in missions leading to manned lunar landing. The progress of the launch vehicle and propulsion program is indicated by the launch of the third Saturn on November 16, 1962. The launch was completely successful as were the first two. The progression planned in the development launch vehicles and propulsion systems is indicated by the weight carrying capabilities of the vehicles: Saturn will place approximately 10 tons in earth orbit; Saturn B will place 15 tons in earth orbit; and the Advanced Saturn will place in excess of 100 tons in earth orbit and will have a capability for over a 40 ton load on escape missions.

SUMMARY OF RESOURCES REQUIREMENTS:

Funds	1962	1963	1964
Launch vehicle supporting technology.....	$6,719,000	$8,800,000	$16,900,000
Propulsion supporting technology.....	4,707,000	7,950,000	22,500,000
Launch operations supporting technology.....	1,162,000	3,000,000	7,600,000
Saturn.....	193,326,000	190,710,000	93,800,000
Saturn B.....	---	18,750,000	68,600,000
Advanced Saturn.....	57,375,000	328,600,000	733,000,000
M-1 engine.....	16,705,000	35,000,000	45,000,000
H-1 engine.....	5,662,000	5,260,000	5,200,000
RL-10 engine.....	16,332,000	32,645,000	32,600,000
F-1 engine.....	48,320,000	50,800,000	54,100,000
J-2 engine.....	33,635,000	44,542,000	48,200,000
Range instrumentation.....	---	---	20,000,000
Range support.....	2,210,000	8,000,000	21,000,000
Subtotal, direct R&D costs.....	$386,153,000	$734,057,000	$1,168,500,000

	1962	1963	1964
Personnel costs.....	$48,574,000	$72,291,000	$82,243,000
Operation of installations..	33,321,155	46,460,717	68,711,000
Total costs.....	$468,048,155	$852,808,717	$1,319,454,000

Personnel

NASA Headquarters.....	184	238	274
Marshall Space Flight Center	5,039	6,136	6,135
Launch Operations Center....	286	629	980
Pacific Launch Operations Office.....	6	-	-
Western Operations Office...	11	102	121
Lewis Research Center.....	-	123	195
North Eastern Office.....	-	4	5
Total personnel.....	5,526	7,232	7,710

The cognizant Headquarters office responsible for program management is the Office of Manned Space Flight. Project management is assigned to the Marshall Space Flight Center for both vehicles and engines, except for the M-1 engine which is under the management of the Lewis Research Center.

PROGRAM JUSTIFICATION:

This program includes the development of vehicles, propulsion, and ground and launch support equipment required to build and launch the man-rated vehicles necessary for manned space flight. Current effort is oriented almost exclusively to the requirements of the initial manned lunar landing and return. To accommodate the immediate requirements of manned lunar landing there are now approved for development three vehicles of varying capabilities. The Saturn is now undergoing flight tests and will be used as a platform for testing the Apollo spacecraft, and for extended earth orbital missions. The Saturn B, through increased second stage capability, will be used to perfect the rendezvous technique, to provide reentry testing of the total Apollo spacecraft, and to serve as a test bed for certain components of the Advanced Saturn. The Advanced Saturn will provide the initial booster capability to perform circumlunar missions and a manned lunar landing and return.

Pacing the vehicle developments are separately authorized engine projects associated with the vehicle stages. The RL-10 will be used in the second stage of Saturn; H-1 engines will power the first stages of the Saturn and Saturn B. The J-2 engine will be used in the second stage of the Saturn B and the second and third stage of the Advanced Saturn. The F-1 engine will propel the first stage of the Advanced Saturn. In addition, the

M-1 engine is under development as the second stage engine for use in a possible NOVA class vehicle.

EXPLANATION OF FUNDS REQUESTED:

	1962	1963	1964
Launch vehicle supporting technology	$6,719,000	$8,800,000	$16,900,000
Propulsion supporting technology....	4,707,000	7,950,000	22,500,000
Subtotal, direct R&D costs.....	$11,426,000	$16,750,000	$39,400,000
Personnel costs.....	846,000	1,125,000	1,156,000
Operation of installations.....	555,155	637,717	761,000
Total costs.....	$12,827,155	$18,512,717	$41,317,000
Total personnel	97	107	106

Launch vehicle supporting technology covers the effort to advance technology required in support of the design, development, and manufacture of man-rated launch vehicles; to solve technical problems discovered in launch vehicles currently under design; and to study advanced design concepts and vehicle systems for application to space missions.

As vehicles are developed, it becomes apparent that some components and subsystems must be improved to assure that final equipment will meet performance and reliability requirements. The launch vehicle supporting technology project makes such improvements possible. It also provides for state-of-the-art improvements which assure that advanced vehicles will meet performance requirements within cost and time goals. These efforts are applied to selected problem areas of high cost programs, and the assurance and gains derived are usually worth many times the investment.

In fiscal year 1963, the major launch vehicle technology efforts were directed toward improvement of the state-of-the-art as it applies to existing development and study projects. This was done through exploratory and conceptual design studies which identified possible approaches which might be taken. Included were such undertakings as the development of structural adhesives; leak detection technique improvement; development of fabrication techniques using new metals or plastics; and research to determine mode of failure of electronic parts. These initial efforts have made it possible to expand these studies in more technical depth.

During fiscal year 1964 emphasis will be placed on follow-on studies in areas with the greatest potential and on incorporating advanced propulsion concepts into vehicles. The primary objective is to provide more practical and economical systems. Efforts will also include operational and systems analysis. Mathematical study models will be developed to

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determine trade-offs between the major system parameters, such as performance, reliability, cost patterns and ways and means to improve economic effectiveness.

General aerodynamic performance will be studied. Analyses will be made of aerodynamic and base heating, and of the aerodynamic behavior of launch vehicles having specific configurations. Technical areas of investigation will include atmospheric turbulence and its effects on vehicle performance, loads, stability and control, turbulent boundary layers, pressure distribution, flow phenomena, and heat transfer rates.

Efforts will be continued on stress analysis investigations of specific launch vehicle designs; investigations of techniques of fabricating large launch vehicle structures, substructures, and materials; quality assurance provisions for over-all vehicle systems, subsystems, and components; and on techniques for utilizing advanced materials for launch vehicle application studies of the behavior of vehicle systems and components in the environment of space. The increasing size of launch vehicles requires development of new techniques for efficiently fabricating large diameter tanks, bulkheads, and piping.

Research and development on guidance and navigation systems and on their electronic, mechanical, and electromechanical components will be undertaken. Integrated systems for guidance of vehicles in aerodynamic and space environments, dynamics of vehicles and parameters in guidance, and design and performance specifications for systems and components will be investigated. Experimental and theoretical studies will be conducted using analog and other simulation devices.

Investigations will be made of the development of control systems and control system components. Particular attention will be given to the development of automatic control sensors and circuitry. The development or selection of sensors for detecting and measuring phenomena and of transducers for translating these measurements into other forms for transmission or recording will be emphasized. Techniques for thrust vector control, such as secondary injection, will be considered for specific vehicle designs along with investigations of general flight dynamic characteristics.

The propulsion supporting technology project is required to demonstrate the operational feasibility or reliability of engine or engine component concepts. This is necessary to bridge the gap between exploratory investigations and actual hardware development. There are basically two categories of propulsion technology. Liquid propulsion effort is oriented toward improvement of designs in state-of-the-art engines, both in booster and spacecraft propulsion systems. Solid motor technology effort is directed toward providing knowledge concerning solid propellant motors so that choices can be made between liquid and solid propellant propulsion systems for vehicles.

Liquid engine development programs have been based substantially on state-of-the-art technology. This has been extended to larger thrust engines

and toward use of hydrogen/oxygen propellants. The rapid progress made in the NASA propulsion developments has essentially depleted the available technology and it is necessary to implement experimental examination in depth of concepts for improved designs of components and engine systems. Such progress is essential to the expeditious attainment of NASA's total mission objectives.

Liquid propulsion supporting technology consists of two areas: booster propulsion systems and spacecraft propulsion systems.

In the development of large booster engines several major technical problems have arisen. These problems are general in nature and will continue until sound fundamental solutions are found and applied. Examples are problems of combustion driven oscillations and pump stall during the transient starting operations. Both jeopardize engine operation and either may result in engine failure and destruction. The supporting technology funds required will allow investigation of problems of this nature using a more basic approach than can be followed in the tightly scheduled development program for each engine. Such investigations lead to design or operational procedure modifications which should eliminate these occurrences. Design or procedure modifications will be tested in full-scale prototypes.

Investigations undertaken during fiscal years 1962 and 1963 have produced many new and significant design concepts, such as booster engine simplification, new materials, new cooling techniques, improved control systems, and advanced nozzles. Many of these concepts have been tested on a component or model hardware basis. These model-proven components and techniques need to be demonstrated on prototype, experimental engines to establish their true engine feasibility and reliability. Such work is necessary on full-scale, rather than small scale models.

It is also necessary to study specific booster engine fabrication and development problems associated with the construction of large booster engine systems. These engines incorporate the use of high combustion chamber pressures. Much attention will be paid to simplification and integration of the high pressure components into one thrust-producing unit.

In the area of spacecraft propulsion systems, the systems presently being developed for use in manned spacecraft are conservative, state-of-the-art designs and practice. Because the missions will depend on engine system reliability, problems which arise in development must be examined in depth since there is only an extremely limited use history. For instance, a problem exists currently in reaction control system development. There is a need for dependable positive propellant expulsion tankage, low power demand, fast-acting solenoid valves, and precise impulse delivery. The technical support of such improved component work comes from supporting technology funds. Other current problems include developing a man-rated variable thrust engine, and the storage of propellants in space for extended periods of time.

The payload-carrying capability of spacecraft systems can be improved substantially by use of high-impulse propellants and advanced engine systems. To develop highly reliable propulsion equipment of advanced design type requires a longer time than is available for the earliest manned lunar landing mission. Nevertheless, such improvements must be pursued and the technology developed in programs parallel to the principal effort. Prototype development of systems will be stressed using cryogenic propellants. The technical problems involved in storage, micrometeorite protection, pressurization, and starting these high performance propellants under zero conditions will be examined.

Solid propulsion technology provides detailed technical information on the use of solid propellant motors in vehicle systems and is planned to exploit the characteristics of solid propellant motors in manned space missions. These characteristics include simplicity, reliability, ease of launch preparation, relative ease in attaining high thrust, and growth potential.

During 1962, large solid motors of thrust levels of up to 750,000 pounds were tested. The required burning time of 130 seconds was achieved in 120 inch diameter motors. Improvements were made in thrust vector control, ignition, nozzle and chamber materials, and insulation. System application studies were initiated to better define motor and system component requirements. Several concepts for the transportation and handling of very large size motors were determined. A preliminary vehicle warning system study will improve man-rated capability. A survey of the existing industrial capabilities to manufacture and produce large motors was completed. The program for fiscal year 1964 increases the emphasis in application and integration of solid propulsion elements into flight systems. Tasks started in prior years in line with this objective will be continued and other related tasks will be initiated. The project is based on the utilization of the large solid motor which will be developed in the program established in November 1962, by the Department of Defense and NASA.

The proposed fiscal year 1964 program will advance the NASA program to the subscale fabrication and testing stage. Data resulting from this effort will provide a basis for later full scale developments. The supporting development program is scheduled to provide the pre-development technology to make it possible to initiate NOVA stage hardware development in fiscal year 1965. The potential application of various solid propulsion elements will be analyzed and defined and their benefits will be determined. Special system problems growing from the use of solid propellant motors and stages will be investigated. These areas of attention include shipping and handling networks, integration of the motors into stage clusters, and definition of motor characteristics for various vehicle performance requirements. Continuation of stage and system reliability studies is planned to further define critical areas, the value of redundancy, and the scope of testing in development programs.

The safety and hazard classification of large solids will be better defined, and acoustic and vibration effects on stage and vehicle components will be studied further. Large motor inspection and repair methods will be investigated to maximize reliability, and manufacturing facilities for development and production motors will be studied for future planning needs as necessary to establish the logistic stream of supply.

Maximum performance and reliability of subsystems components will be achieved by further development and test. These efforts include an abort sensing and implementation system, standard test methods for the acceptance of large motors, and improved materials for case construction. Propellant processing studies to lower cost and improve physical properties will be undertaken, and a study will be initiated to determine the optimum propellant charge designs for various performance requirements.

Launch operations supporting technology

	1962	1963	1964
Direct R&D costs.....	$1,162,000	$3,000,000	$7,600,000
Personnel costs.....	171,000	177,000	307,000
Operation of installations.....	194,000	324,000	714,000
Total costs.....	$ 1,527,000	$ 3,501,000	$ 8,621,000
Total personnel.....	19	25	33

Launch operations supporting technology provides an insight into the potential requirements generated by new or reconfigured launch vehicles. This includes investigations, studies and development of prototype hardware, systems techniques, and methods to develop or improve launch concepts to reflect the requirements for reliability and safety.

Information gained from previous investigation and studies has been incorporated into the construction plans for the Saturn, Saturn B, and Advanced Saturn launch complexes 34, 37 and 39 at the Launch Operations Center, and has dictated modifications to other launching pads which will be used for the One-Day and Gemini missions. Included are such items as flame deflectors, vehicle hold down and support arms, automatic checkout and umbilical services modifications. Launch complex 39 basic concepts, pad siting, and assembly and checkout techniques are also a direct outgrowth of earlier studies.

Fiscal year 1963 effort is being channeled primarily to launch facility concepts, including concepts for large thrust vehicles, launch site hazards, rescue and escape systems, launch pad erosion resulting from the use of solid propellants, and service structure concepts. Additional effort will be devoted to launch facility instrumentation concepts including acoustic measurement, data acquisition systems and improvements of data transmission and recording.

During fiscal year 1964 activities are planned for the following:

Launch facilities studies - These studies are to provide facility concepts for large thrust and solid motor vehicles, design parameters applicable to over-water vehicle launchings, feasibility studies of off-shore launch facilities for larger vehicles, and preliminary design of launch facilities to support missions anticipated for launch vehicle systems larger than Advanced Saturn. These concepts are required to provide for a timely and economical development of possible future facilities.

Launch ground support equipment studies - This effort is to develop new or improved ground support equipment to match concurrently the growth of vehicle systems requirements. It will cover the areas of solid propellant exhaust erosion effects, launcher-transporter changes to support various vehicle configurations, studies related to launch and exhaust deflector systems, and the development of solid state switching for control of propellant transfer and other systems. The effort is required to achieve necessary safety, flexibility and efficiency in launch operations.

Launch operations techniques - This work will improve the vehicle assembly and launch site checkout techniques to reduce the time consumed and to provide a more safe and reliable operation during launch.

Launch site hazards studies - These studies are to ensure maximum reduction of launch site hazards to personnel and material. Investigations will be made for developing new methods of cryogenic propellant storage and transfer and maximum protection of personnel and equipment from nuclear, acoustical or explosive energy by adequate separation of vehicle and launch pads.

Space fragment hazards studies - The increase in the number of space vehicle launchings and in the size of booster vehicles will present serious hazards from falling expended booster vehicle fragments. These studies will cover a dual approach to this problem. One area will establish by mathematical analysis the probabilities of earth impact and casualties by orbital space vehicles and determine the limits of controlled booster reentry or destruct. The other will develop methods of positive identification of the vehicle and launch from particular space fragments, to determine the country and/or agency of origin. Analysis of returned space fragments will be covered under this area.

Saturn

	1962	1963	1964
S-I stage.....	$83,284,000	$69,057,000	$26,500,000
S-IV stage.....	52,191,000	43,700,000	25,500,000
Vehicle instrument unit.....	404,000	1,280,000	3,000,000
Guidance system.....	16,050,000	12,251,000	2,000,000
H-1 engine procurement.....	10,250,000	7,900,000	2,800,000
RL-10 engine procurement.....	11,918,000	12,650,000	3,400,000
System integration.....	19,229,000	43,872,000	30,600,000
Subtotal, direct R&D costs..	$193,326,000	$190,710,000	$93,800,000
Personnel costs.....	38,067,000	40,044,000	32,107,000
Operation of installations....	26,147,000	27,192,000	32,722,000
Total costs.....	$257,540,000	$257,946,000	$158,629,000
Total personnel.....	4,329	3,954	3,051

The objective of the Saturn development project is to develop a two-stage vehicle capable of placing 20,000 pounds in low earth orbit. This payload is more than five times the weight of the project Mercury capsule. Saturn flights will test the escape system, abort system, command module and service module in orbit and during the reentry phase to verify the Apollo spacecraft and subsystem reliability. Saturn will be the first vehicle to orbit a manned Apollo spacecraft. The first stage of the Saturn will also be used as the booster for the Saturn B vehicle. In addition, Saturn will be used in development tests of the Advanced Saturn guidance system and the initial development phase of the automatic checkout system.

The Saturn is a two-stage vehicle using a cluster of engines for each stage. The vehicle stands 122 feet high, is 21.4 feet in diameter, has a fin span of approximately 40 feet, and carries the equivalent of more than 10 railroad tank car loads of propellant. The first stage (S-I) is now under development at the Marshall Space Flight Center. The Center will produce a total of eight of these stages. Production of two additional development stages and all operational stages is under contract to the Chrysler Corporation Space Division. The Chrysler effort will be accomplished at the Michoud Plant in New Orleans, Louisiana. This stage uses eight H-1 engines which provide 1.5 million pounds thrust.

The second stage (S-IV) is being developed and produced by the Douglas Aircraft Company, Santa Monica, California. This stage utilizes a cluster of six RL-10 liquid hydrogen/liquid oxygen engines which produce a total thrust of 90,000 pounds.

The Saturn development flight schedule consists of a total of ten launches with two types of vehicles, designated "Block I" and "Block II". Four Block I vehicles will be flight tested using a live first stage and an inert upper stage. The six Block II flight vehicles will fly with live stages. The four Block I vehicles will be flight tested by the end of fiscal year 1963. In fiscal year 1964, four Block II flights will take place. The first of these flights will mark the initial use of a liquid hydrogen/liquid oxygen stage in a Saturn class vehicle. During the fiscal year, orbital testing of the first Apollo boilerplate capsule and the acceptance firing of the first Chrysler produced stage will be accomplished.

S-I stage

Successful launches of the S-I (Block I configuration) were accomplished on October 27, 1961, April 25, 1962, and November 16, 1962. These test flights demonstrated the technical feasibility of clustering engines and propellant tanks. Moreover, actual flights proved the structural integrity of the vehicle design, the adequacy of vehicle control concepts, and the adequacy of the ground support equipment for checkout and launch. A fourth vehicle is scheduled for launching in late fiscal year 1963, which will complete the Block I development flights.

During fiscal year 1964, engineering design improvements will be accomplished by Chrysler Corporation Space Division on the S-I stage, and associated ground support and test equipment. Incremental funding will be completed for S-I components and materials for three vehicle stages scheduled for delivery during fiscal year 1964 and for hardware items related to stages for two vehicles planned for delivery in fiscal year 1965.

Completion of assembly and checkout will prepare four vehicles for acceptance testing. Procurement of spare parts, instrumentation, and propellants for these static tests will also be accomplished.

S-IV stage

The first successful hot firing of the six RL-10 engine cluster on the S-IV stage occurred on August 17, 1962. A full duration (7 minutes) hot firing occurred on October 4, 1962. Completion of the battleship tests, initiation of the all-systems tests, and the acceptance test of the first two stage vehicle will be accomplished in fiscal year 1963. The required level of confidence for the first flight test of an S-IV stage will be attained from these ground tests.

In fiscal year 1964, the first live flight of an S-IV stage will mark a significant milestone in the manned lunar landing program. This flight test of liquid hydrogen/liquid oxygen propellants in a Saturn class vehicle is in the initial step toward development of large-size vehicles required for later mission use. Design improvement and continued development engineering of the S-IV stage along with associated design modifications of the ground support equipment and special test equipment will be conducted

by the Douglas Aircraft Corporation. Component, material and spare parts deliveries for four stages produced in fiscal year 1964 and procurement for two stages to be delivered in fiscal year 1965 will be made.

Continuation of the all-systems testing at the Sacramento Field Station and acceptance testing of S-IV stages needed for four vehicles are scheduled for fiscal year 1964. Large quantities of propellants and high-pressure gases will be procured and consumed to support an extensive hot firing program. Modification and replacement of special test equipment, assembly and structural fixtures, and other associated tooling will be accomplished. Final assembly, checkout and acceptance testing of three vehicles will be accomplished prior to shipment to the Launch Operations Center. Assembly and checkout of two additional vehicles is to start during fiscal year 1964.

Vehicle instrument unit

The instrument unit houses the guidance and stabilization systems, telemetering equipment, power supply batteries and inverters, and in-flight air conditioning equipment. The unit is located between the S-IV stage and the Apollo payload.

During fiscal year 1963, a major part of the development testing will be completed. This involves the use of three hardware assemblies; the systems development unit, the dynamic test unit, and the structural test unit. Improvements made evident by tests will be reflected in the eighth development Saturn and follow-on vehicles.

During fiscal year 1964, a major part of the fabrication, assembly, and checkout of units for five Saturns will be accomplished. The program also covers development vibration and structural testing of units for the eighth Saturn and for later instrument unit configuration.

Guidance system

Vehicles prior to the seventh Saturn will use the ST-90 inertial platform (modified Jupiter equipment) with the ST-124 as a passenger on the third through the sixth launch. The guidance and stabilization system for the seventh Saturn and later vehicles will primarily consist of the ST-124 inertial platform, the ASC-15 digital computer, the GSP-24 guidance signal processor, and a control computer.

The procurement of additional hardware will take place in fiscal year 1963. ST-124s will be produced for vehicles through the tenth Saturn, ASC-15s for vehicles through the seventh and for the ninth vehicle, with incremental funding for ST-120s for the eighth and tenth vehicles, and 6 GSP-24s will be incrementally funded for vehicles through the seventh.

The fiscal year 1964 funding supports sustaining engineering effort for hardware deliveries, the complete guidance system procurement for vehicles

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through the tenth with incremental coverage on spare parts, and funding for flight evaluation efforts.

H-1 engine procurement

All engines for Saturn vehicle development will be delivered during fiscal year 1963. The funding in fiscal year 1964 is required to provide contractor field engineering, spare parts, and associated services to the Marshall Space Flight Center, Michoud Plant and the Launch Operations Center. In addition, these funds will provide for engineering change modification kits which will become necessary due to solution of development problems experienced in R&D testing, and improvements generated through the continuing engine development program.

RL-10 engine procurement

All RL-10 engines to be procured for the Saturn development program will be delivered during fiscal year 1963. The funding for fiscal year 1964 is required for contractor field engineering, spare parts, and associated services to Marshall Space Flight Center, Douglas Aircraft Company and the Launch Operations Center.

System integration

As the Apollo spacecraft and the Saturn vehicle development evolve, the designs must be constantly integrated. In addition, integration testing must be performed and the design revised when incompatibilities of systems arise. By the end of fiscal year 1963, the major portion of design integration and early system integration testing will be performed. In fiscal year 1964, emphasis will be placed on system integration testing of the vehicle, including both S-I and S-IV stages, guidance system, vehicle instrument unit, H-1 and RL-10 engines and the Apollo command and service modules. The fiscal year 1964 funding also provides for resident engineering services, ground support equipment, replacement and/or refurbishing of firing assessories, propellant servicing hardware, launcher, launcher arms and deflectors which may normally be damaged in even the most successful launches. Procurement of ground support equipment for the Saturn development program will be completed in fiscal year 1964.

Saturn B

	1962	1963	1964
S-IB stage.....	---	$3,600,000	$13,500,000
S-IVB stage.....	---	10,000,000	19,100,000
Vehicle instrument unit.....	---	---	6,000,000
Guidance system.....	---	---	5,200,000
H-1 engine procurement.....	---	1,700,000	3,700,000
J-2 engine procurement.....	---	2,050,000	4,200,000
System integration.....	---	1,400,000	16,900,000
Subtotal, direct R&D cost....	---	$18,750,000	$68,600,000

	1962	1963	1964
Personnel costs.....	$281,000	2,561,000	4,457,000
Operation of installations.....	185,000	1,447,000	2,911,000
Total costs.....	$466,000	22,758,000	$75,968,000
Total personnel.....	32	242	408

The objective of the Saturn B development project is to develop a two-stage vehicle capable of placing 30,000 pounds in low earth orbit. This payload is one and a half times the payload capacity of the Saturn. The Saturn B will provide a reliable launch vehicle to meet intermediate Apollo spacecraft development requirements. The vehicle will be capable of placing the Apollo spacecraft in earth orbit for systems testing and for rendezvous testing of the lunar excursion module and the command module. A second objective of the vehicle is to advance by approximately 14 months flight tests of the S-IVB/Apollo spacecraft combination to assure the timely completion of the Advanced Saturn launch vehicle.

The Saturn B configuration is a two-stage vehicle using a cluster of H-1 engines in the first stage (S-1B) and a single J-2 engine in the second stage (S-IVB). The vehicle stands 143 feet high by 21.7 feet in diameter. It carries a propellant load equivalent to the capacity of 15 railroad tank cars. The first stage (S-1B) is a modification of the Saturn S-I stage and is being developed by Marshall Space Flight Center. Proven functional hardware will be identical in the first stages for both vehicles. The second stage (S-IVB) is being developed by the Douglas Aircraft Company, and will utilize a single J-2 liquid hydrogen/liquid oxygen engine providing 200,000 pounds thrust. The basic development of the S-IVB stage is being accomplished for the Advanced Saturn launch vehicle, and will require only functional changes and proper interstage structures to provide for the Saturn B/Apollo missions. The basic tankage structure, electrical and mechanical systems remain unchanged.

The funding for fiscal year 1964 will be used to provide the required acceleration of the S-IVB stage because of the earlier flight testing schedule required for Saturn B. These funds will also provide for flight hardware and design modifications from the basic S-IVB stage of the Advanced Saturn design. The schedule acceleration of the S-IVB stage requires that manpower, tooling and materials be phased into the program more than one year earlier than originally intended for Advanced Saturn.

The Saturn B offers the earliest development of payload launch capability necessary to support earth orbital missions of the entire Apollo system. In addition, the Saturn B program will assure high reliability for the Advanced Saturn vehicle system by earlier integration and testing of the J-2 engine.

The currently planned flight test schedule consists of four developmental flights. All developmental flights will be accomplished with live stages. However, since the S-IB first stage will have been proven in the development of Saturn, the major emphasis will be on the S-IVB stage testing and system development. Each of these flights will carry Apollo spacecraft payloads in the boilerplate or prototype configuration.

S-IB stage

The S-I stage will have had five years of development and two years of flight testing on the Saturn prior to its use as the S-IB stage on this vehicle. The four developmental flights can thus give major emphasis to the development of the S-IVB stage.

The fiscal year 1964 funding for the S-I stage will provide completed criteria and specifications for Saturn B vehicle requirements. Engineering design effort will be completed to accommodate this stage to the S-IVB stage and necessary instrumentation, electrical networks, and other systems. Procurement of all structural and electrical items for the dynamic test stage and the first two development flight stages will be initiated. In addition, long lead time structural components will be procured for vehicles three and four.

Initial tooling procurement for the modified interstage structure between the S-IB and S-IVB stages will be provided. Structural fabrication of the first flight stage will be completed and structural fabrication for the second vehicle will be initiated.

S-IVB stage

Establishment of design criteria and completion of preliminary design for the S-IVB stage and ground support equipment will be accomplished in fiscal year 1963. Completion of hydrostatic stage testing will be accomplished in fiscal year 1964, and fabrication of the first flight stage will be about complete and early fabrication will be underway for the second flight stage.

Engineering design modifications of the basic S-IVB/Advanced Saturn stage will be made to adapt it to the Saturn B vehicle requirements. The principal areas of modification will be the forward and aft skirts and interstage structure. Attitude control system alterations will be made to recognize more exacting separation requirements on the Saturn B vehicle. Procurement of all structural items, electrical items, and assembly hardware for the first two flight vehicles will be initiated. Long lead structural procurements for the third and fourth vehicles will be undertaken. Procurement of tooling required for the S-IVB/Saturn B modification will be completed. Procurement of ground support equipment for minor functional equipment changes will also be initiated.

Vehicle instrument unit

The instrument unit houses guidance and stabilization units, telemetering equipment, power supplies and an unpressurized cooling system. The unit is located between the S-IVB stage and the Apollo payload.

There are no fiscal year 1963 dollar requirements for this equipment since the Advanced Saturn instrument unit will be the basis for the Saturn B design. Advantage will be taken of the lower structural loads imposed by the smaller payloads to reduce the weight of the instrument unit. To prove this modified design, considerable testing using a structural test unit, a vibration test unit, a dynamic test unit, and a system development test unit will be required. These test units are being provided for the Advanced Saturn program. However, all except the structural test unit must be modified to the Saturn B configuration to get valid test results for this vehicle.

Saturn B and Advanced Saturn manufacturing schedules have been coordinated to provide the most efficient use of Advanced Saturn tooling. However, since the programs partially overlap, additional tooling will be required for the Saturn B project, and there will be instrumentation differences between Saturn B and Advanced Saturn due to different missions. When test equipment cannot be adapted from one configuration to another, additional test equipment will be required.

Initial procurement will be made of long lead time structural components required for the first Saturn B flight.

Guidance system

The guidance system consists primarily of the ST-124 inertial platform, the ASC-15 digital computer, the GSP-24 guidance signal processor, and a control computer. This equipment is housed in the instrument unit.

There are no fiscal year 1963 dollar requirements for this equipment. In fiscal year 1964 procurement will be initiated for ST-124s for four vehicles and ASC-15 and GSP-24s for three vehicles. The initial development costs were funded under the Saturn project and it is planned that future modifications will be covered under the Advanced Saturn project. Likewise, future development and testing will be conducted under the Advanced Saturn except for the environmental testing on the Saturn B dynamic test vehicle. Tooling and special test equipment, not required for the Advanced Saturn, will also be procured.

H-1 engine procurement

The fiscal year 1964 funding will provide the final increment for 15 flight engines and 2 spare engines to be delivered in the fiscal year and the initial increment for long lead hardware for 17 flight engines to be delivered in fiscal year 1965. Included in the costs are propellants for

the acceptance tests of the 17 engines to be delivered in fiscal year 1964, support services, spare parts, field engineering, training, ground support equipment and modification and/or retro-fitting of previously delivered engines because of improvements brought about by continued product improvement.

J-2 engine procurement

The fiscal year 1964 funding will provide the final increment for 2 test engines and 1 flight engine to be delivered during the fiscal year and the initial increment for long lead hardware for 1 test engine, 3 flight engines and 1 spare to be delivered in fiscal year 1965. The estimate also includes spare parts, ground support equipment field services, and propellants for acceptance testing of the 3 engines to be delivered in fiscal year 1964.

System integration

System analysis of the Saturn B launch vehicle and associated ground equipment will be nearly completed in fiscal year 1964. The systems analysis includes interface design and documentation between the ground support equipment and the launch vehicle, the S-IB and the S-IVB stages, the S-IVB stage and the instrument unit, and the Apollo payload. Other investigations include vehicle performance and weight control, stage separation, payload separation, emergency detection system studies, trajectory and mission profile determinations, wind tunnel testing and vehicle control studies and simulation tests.

Advanced Saturn

	1962	1963	1964
S-1C stage	$22,575,000	$144,500,000	$291,600,000
S-II stage	19,284,000	92,500,000	181,400,000
S-IVB stage	2,500,000	32,100,000	82,300,000
Vehicle instrument unit	---	2,600,000	17,000,000
Guidance system	7,590,000	11,000,000	16,000,000
F-1 engine procurement	3,400,000	21,600,000	53,100,000
J-2 engine procurement	1,700,000	9,800,000	16,600,000
Support	326,000	14,500,000	75,000,000
Subtotal, direct R&D costs	$57,375,000	$328,600,000	$733,000,000
Personnel costs	7,213,000	24,859,000	39,013,000
Operation of installations	4,901,000	14,906,000	27,730,000
Total costs	$ 69,489,000	$368,365,000	$799,743,000
Total personnel	822	2,524	3,601

The Advanced Saturn is the most powerful launch vehicle now under development. It will have capability to perform manned orbital operations;

manned circumlunar navigation and lunar landing; unmanned earth orbital operations; and unmanned instrumented lunar and deep space exploration. It is now being developed to land a man on the moon in this decade.

With the Advanced Saturn the payload capability for earth orbital missions will be increased more than 50 fold (i.e., in excess of 100 tons). The vehicle will also develop sufficient thrust for achieving escape trajectories for payloads exceeding 40 tons.

The enormity of the Advanced Saturn can be understood by comparisons. The vehicle is as tall as a 35 story building and weighs as much as a Navy destroyer. It is filled with 100 railroad tank cars of fuel, 80 percent of which is consumed in 2½ minutes. The Advanced Saturn is being developed by a logical extension of techniques and principles already developed. However, metals and insulation must be improved to meet increased heat and vibrations conditions. New design of advanced ground support equipment steps off from the experience gained during preceding launch vehicle projects. New tooling is required to meet the larger size and weight of the new stages. Proven fabrication methods will be used to develop improved methods of forming the thicker metals of the advanced stages. Altered methods of assembly are being devised since this must be accomplished in the vertical position to prevent the stages from deforming due to their own weight. Studies and experiments will determine how the advanced stages will be handled, transported, and assembled at the launch sites. Because of the vehicle's bulk, additional safety procedures must be developed, telemetry stations must be expanded, and improved ways must be found to protect and service the vehicle after assembly.

Prior to the first manned vehicle flight a tremendous research, development and test effort will be required because of the immense size, complexity, and high reliability and safety requirements. To accomplish this, many tasks never before undertaken in this size and scope must be done. Ground static firings of stages and systems; dynamic testing of the entire vehicle; reliability testing of stages, systems, subsystems and components; and structural testing of the propellant tankages and interstages are prime examples.

The Advanced Saturn project was initiated in fiscal year 1961 through establishment of conceptual and preliminary design studies. In fiscal year 1962 all major contracts were placed. During the current year the program moved forward with the establishment of manufacturing and testing resources, and the beginning of fabrication and testing of components and subassemblies. Fiscal year 1964 activities will increase as ground stages are delivered and the testing program develops.

S-IC stage

The Advanced Saturn is designed as a three-stage vehicle to support the primary mission of manned lunar landing and return.

The first or booster stage, the S-IC, will be 138 feet high and have a diameter of 33 feet. Five F-1 engines will provide a total sea level thrust of 7.5 million pounds. The propellants will be liquid oxygen (LOX) oxidizer and RP-1 (Kerosene) fuel. The engines will be arranged in a square pattern of four gimballed outside engines for vehicle flight control, and one fixed engine located in the center. The weight of the stage without propellants will be about 300,000 pounds. The propellant capacity will be 4,400,000 pounds.

The Boeing Company, Aero-Space Division, was selected as the stage development and production contractor, and awarded a contract in February 1962. Marshall Space Flight Center is developing the preliminary design criteria and will assemble and test the first ground test articles at Huntsville, Alabama, with Boeing assistance. Boeing is fabricating the components for the ground test and flight articles and will assemble one of the ground test stages, in addition to the flight stages, at the Government-owned-contractor-operated Michoud Plant near New Orleans, Louisiana.

Development draws heavily upon test facilities now available at Marshall, and upon new facilities planned for the Michoud Plant in Louisiana and the Mississippi Test Facility at Pearl River, Mississippi.

During fiscal year 1962 and continuing into fiscal year 1963, preliminary design concepts were prepared by Marshall Space Flight Center. Boeing's major emphasis was on detail design, facility planning, tooling and test equipment acquisitions, supporting research studies, initial component testing and qualification of various stage components. Certain hardware items have been procured for the ground test articles and for the first and second flight test vehicles. Fabrication has commenced for static, dynamic and structural test vehicles.

In fiscal year 1964 emphasis will continue on the completion of detail design of ground and first flight vehicles. As a result of the tests performed with the ground test stages, redesign and modification will be accomplished on structures, propulsion, electrical instrumentation and control for the flight stages. The static test stage and structural test stage will be assembled and testing operations will be initiated. Fabrication of the dynamic test stage will be complete and structural assembly essentially completed. Fabrication of the systems checkout stage and first flight stage will be nearly complete, and work on the second flight stage will be initiated. Hardware procurement for the third and fourth flight stages will be accomplished.

S-II stage

The second stage, the S-II, will be 81.5 feet high and 33 feet in diameter. Five J-2 engines will provide a total thrust of one million pounds at altitude. The high energy propellants will be liquid oxygen (LOX) oxidizer and liquid hydrogen (LH_2) fuel. The dry weight of the S-II stage will be approximately 75,000 pounds, and the propellant capacity will be

930,000 pounds. The five J-2 engines will be mounted with their center lines parallel to the stage center line. Four movable control engines will be arranged concentrically and equally spaced about a fixed center engine.

North American Aviation (NAA), Space and Information Systems Division, was selected as the second stage contractor, and was awarded an initial contract in October 1961 for the S-II stage. NAA will design, develop, fabricate, test and checkout nine flight stages, 1 non-operative (dummy) stage and 6 ground test vehicles. The major manufacturing and assembly activities for the S-II stage are being conducted at NAA's Seal Beach, California facility.

During fiscal years 1962 and 1963 major effort related to preliminary and detailed designs, procurement of special tooling and test equipment to support the assembly operations, procurement of components to support the test program for design verification and qualification, procurement of hardware and initiation of fabrication for all ground test articles, one dummy flight stage and the first flight test vehicle.

In fiscal year 1964 design, fabrication drawings and procurement specification will be completed. Fabrication, assembly and installation on test stands and initiation of testing operations will be accomplished for battleship and structural test stages. Final assembly will be completed on the static test stage and dynamic test stage, with the latter having been delivered to Marshall. The facilities checkout vehicle and the second, third, and fourth flight vehicle will be in various stages of manufacture. Initiation of procurement for long lead time items will be accomplished through the sixth flight vehicle.

S-IVB stage

The third stage, the S-IVB, will be 58 feet high and 260 inches in diameter. One J-2 engine will provide a thrust of 200,000 pounds at altitude. The dry weight of the S-IVB stage will be about 21,000 pounds, and the propellant capacity 230,000 pounds. The single J-2 engine will be gimbal mounted to provide flight control.

Douglas Aircraft Company (DAC) was selected in December 1961, as the developer for the third stage since the S-IVB was a modification of the S-IV stage, which was under contract with DAC. DAC will furnish eight flight stages, two non-operative (dummy) stages and five ground test vehicles. The major manufacturing and assembly activities are being conducted at DAC's Santa Monica, California plant.

The funding in fiscal years 1962 and 1963 provides for detail design, facilities planning, and hardware procurement for three of the five ground test articles and the first flight test vehicle. Structural testing for qualification of components is being accomplished.

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In fiscal year 1964 structural design will be refined, and the ground test program will be underway. The structural facilities checkout and dynamic vehicles will be complete, with the latter ready for shipment to Marshall Space Flight Center. Basic structural assembly of the all-systems vehicle will be complete, with structural assembly of the first flight vehicle nearing its midpoint. Fabrication of parts on the second flight vehicle will be complete and will be initiated for third flight vehicle.

Vehicle instrument unit

The vehicle instrument unit houses the guidance and stabilization units, telemetering equipment, power supplies, and an unpressurized cooling system. It is located between the S-IVB stage and the payload.

The fiscal year 1963 funding provides for initial design, procurement, and testing efforts on the instrument unit. To prove the design, various ground test units are required, namely a structural unit, a vibration test unit, a dynamic test unit, and a systems development test unit. By the end of the fiscal year, the design of the structure will be completed and vibration testing of subassemblies started.

The fiscal year 1964 effort will result in completion of design of additional items such as the unpressurized cooling system, the electrical system for the ground test units, and ground support equipment. Design of the electrical system for the first flight vehicle will be approximately 75 percent complete. Fabrication of the structures for the ground test units will be completed. Installation of the electrical and unpressurized cooling systems in the systems development test unit will also be completed. Procurement of hardware for the first flight will be initiated and procurement of all tooling and special test equipment completed for fabrication, assembly, and testing of all instrument unit components and systems.

Guidance system

The guidance system consists primarily of an inertial platform, a digital computer, a guidance signal processor, and a control computer. This equipment is housed in the instrument unit.

The fiscal year 1963 funds provided for the continuance of guidance system research and development based on previous work accomplished under the Saturn program. 75 percent of the design changes to the ST-124 inertial platform and the ASC-15 digital computer, imposed by Advanced Saturn requirements, will be accomplished and procurement of this hardware initiated for the systems development test unit. Design, development and improvement of the function and reliability of guidance components such as a guidance signal processor, control computer, control signal processor, azimuth alignment package, accelerometers and rate gyros will be accomplished.

The fiscal year 1964 program will result in completion of the design changes and modifications on the ST-124 inertial platform dictated by

Advanced Saturn requirements. Design of the modified ASC-15 digital computer will be completed except for modifications resulting from system experience. Design, development, and prototype testing of guidance components and instrumentation will continue. The inertial platform and the digital computer equipment for the system development test unit will be delivered and tested. Procurement will be initiated for the inertial platform, the digital computer, and backup spares for the first flight vehicle. Guidance instrumentation components for the ground test units will be procured, and procurement will be initiated for long lead items and spares for the first Advanced Saturn flight. Procurement of tooling and special test equipment will be completed for production and testing of the inertial platform, guidance computer, guidance signal processor, and ground support equipment.

Principal participants in the program are International Business Machines at Owego, New York for the digital computer and guidance signal processor, and Bendix Corporation at Teterboro, New Jersey for the inertial platform.

F-1 engine procurement

Both the F-1 and J-2 engines are being developed by the Rocketdyne Division of North American Aviation, Inc. under separate contracts and are to be supplied to the respective stage contractors for the ground test and flight articles as Government furnished equipment. Production facilities will be provided at Canoga Park, California.

In fiscal years 1962 and 1963, four "hard" mockups were delivered and long lead time hardware procurement for 14 engines initiated, twelve of which are in the process of fabrication. In fiscal year 1964, one additional "hard" mockup together with 10 engines are to be delivered. Long lead time hardware procurement will be initiated for 23 additional engines. Twenty F-1 engines will be in various stages of fabrication. Also included in fiscal year 1964 are costs of modifications and retro-fitting of previously delivered engines as a result of experience gained during pre-flight rating tests. Propellants for engines delivered in fiscal year 1964 will also be procured.

J-2 engine procurement

In fiscal year 1964 five "hard" mockups and 15 J-2 engines will be delivered, procurement of which was initiated in prior years. Long lead-time hardware will be procured for 10 engines. Twenty-six of the engines for which procurement was initiated in current and prior fiscal years will be in various stages of manufacture. Propellants for engines delivered in fiscal year 1964 will also be procured.

Support

In fiscal years 1962 and 1963, studies and investigations were conducted and hardware procured to support experimental test programs. In fiscal year 1964 design development will continue for vehicle system ground support equip-

ment. Design development and prototype testing of telemetry and range safety equipment will continue. Design of universal transporter hardware will also be in process.

Hardware for evaluation and ground test stages will be procured. Procurement will be completed for component equipment and services to support Advanced Saturn and analytical investigations in ground test programs. Equipment will be secured to support full-scale dynamic tests at the Marshall Space Flight Center.

A marine vessel will be procured and modified for transportation of upper stages from the west coast to the Mississippi Test Facility, Marshall Space Flight Center, and the Launch Operations Center. Transportation support for bulky hardware and major subassemblies from Wichita to Michoud and Huntsville, and from Michoud to Huntsville will be required. Marshall Space Flight Center will provide for local transportation of ground test components.

Wind tunnel studies will continue at Arnold Engineering Development Center (Tennessee), Langley Research Center, and Cornell Aeronautical Laboratories (New York) with specific investigations concentrated on critical vehicle areas. The reliability program effort will continue, as will product improvement of liquid hydrogen propulsion components. Studies will be initiated for advanced structural applications and more detailed aerodynamic analysis and follow-up effort will begin for programs already established.

M-1 engine	1962	1963	1964
Engine development.....	$4,100,000	$23,100,000	$33,300,000
Test equipment.....	7,100,000	9,200,000	5,700,000
Facilities.....	5,494,000	1,200,000	---
Propellants.....	11,000	1,500,000	6,000,000
Subtotal, direct R&D costs..	$16,705,000	$35,000,000	$45,000,000
Personnel costs.....	202,000	884,000	1,930,000
Operation of installations....	134,000	345,000	772,000
Total costs.....	$ 17,041,000	$ 36,229,000	$ 47,702,000
Total personnel.....	23	126	202

The M-1 engine was conceived as a state-of-the-art engine intended for use in upper stages of possible large vehicles of the NOVA class. It will provide 1,200,000 pounds of thrust using the high energy combination of liquid oxygen and liquid hydrogen. Development of the engine began in April 1962, by the Aerojet-General Corporation, Sacramento, California, and is under the technical direction of the Lewis Research Center, Cleveland, Ohio.

The proposed engine is 25 feet high, measures 15 feet across the nozzle, and weighs 10 tons. It sill consume approximately 85 tons of propellant per minute. Its 1,200,000 thrust level represents a six-fold increase over the largest liquid hydrogen engine now under development, the J-2. Development to date has centered on specific equipment fabrication and testing in addition to preparation of critical facilities. Long lead-time hardware items have been ordered and major engine parts are being fabricated. Test stands are being modified to test the large hydrogen-fueled engine components.

With the decision to delay NOVA, a longer and more orderly development program can produce a more advanced M-1 engine of higher performance and greater flexibility. Consequently, required funding during the early stages of the program was reduced from that originally planned. A study has also been initiated by Aerojet to determine where more advanced state-of-the-art, consistent with delayed NOVA development, can be incorporated into the engine. Because of the modified approach to the engine development, a definitized contract will not be negotiated until early 1963. Major component testing will start in late 1963 and continue until 1965 when actual engine testing will start. The preliminary flight rating test is scheduled for 1967 and the qualification test for 1969.

Fiscal year 1964 funds are required for engineering design, component design and fabrication, component testing, procurement of long lead-time hardware items, and assembly of the first engine systems for test and propellants. The M-1 consumes approximately 280,000 gallons of liquid hydrogen in a single duration run of 250 seconds, requiring over 5,000 tons of liquid hydrogen and 30,000 tons of liquid oxygen to support even the early stages of the program.

H-1 engine	1962	1963	1964
Engine development.....	$4,950,000	$4,510,000	$4,500,000
Test equipment.....	---	---	---
Facilities.....	---	100,000	---
Propellants.....	712,000	650,000	700,000
Subtotal, direct R&D costs..	$5,662,000	$5,260,000	$5,200,000
Personnel costs.....	352,000	370,000	295,000
Operation of installations....	230,000	208,000	193,000
Total costs.....	$6,244,000	$5,838,000	$5,688,000
Total personnel.....	40	35	27

The H-1 rocket engine is being developed for use in the first stage of the Saturn and Saturn B launch vehicles. It produces 188,000 pounds of thrust, burning a mixture of liquid oxygen and kerosene for 150 seconds duration. The H-1 is being developed and produced by the Rocketdyne Division of North American Aviation, Inc..

This engine development was started by the Army in September 1958, in a 165,000 pounds thrust version. This development was successful although, subsequently, it was decided that the higher thrust level of 188,000 pounds was required. This development was undertaken in 1961. The engine is now in both a development and a production status. The present design is operating successfully as an engine system at 165,000 pounds thrust. However, certain components require improvement for stable performance and service life at the 188,000 pound thrust level. An example of component improvement is the investigation of the soundness of replacing the present nickel thrust chamber tubes with stainless steel tubes to provide higher strength essential for 188,000 pound thrust. The nickel tubes have been found to be satisfactory at 165,000 pound thrust, but marginal at the higher thrust. The development program also includes investigation of operational problems which appear during test or vehicle operation of the engine. This effort is in addition to bringing the engine to the status necessary to pass the qualification test scheduled for mid-1964.

The H-1 engine has been used successfully in the first three Saturn launches. In each case the cluster of 165,000 pound engines operated satisfactorily. This lower thrust engine will be used in one additional Saturn development vehicle. The 188,000 pound version will be used in the remaining six development vehicles and in all the operational Saturn and Saturn B vehicles.

The funding requirements for fiscal year 1964 provides for continued developmental improvement of the engine at a minimum rate, component improvements required for the qualification test and release of the engine for manned flight, and for the solution of test and operational problems.

RL-10 engine	1962	1963	1964
Engine development.....	$11,157,000	$22,330,000	$25,300,000
Test equipment.....	3,125,000	1,427,000	---
Facilities.....	---	238,000	---
Propellants.....	2,050,000	8,650,000	7,300,000
Subtotal, direct R&D costs.	$16,332,000	$32,645,000	$32,600,000
Personnel costs.....	387,000	593,000	688,000
Operation of installations...	253,000	336,000	448,000
Total costs.....	$16,972,000	$33,574,000	$33,736,000
Total personnel.....	44	56	63

The RL-10 engine is used in clusters of six in the S-IV stage of the Saturn vehicle and in pairs in the second stage of the Centaur vehicle. The engine produces 15,000 pounds of thrust for 450 seconds duration, burning

the high energy combination of liquid oxygen and liquid hydrogen. It is under development and production by Pratt and Whitney Aircraft, Division of United Aircraft Corporation in West Palm Beach, Florida, and East Hartford, Connecticut.

With funds provided by the Advanced Research Projects Agency, development of the RL-10 A-1 engine was started in late 1958 by the Air Force as a power plant for the Centaur vehicle. Responsibility for the project was transferred to NASA in 1961. Since that time an advanced version of the engine, the RL-10 A-3 has been under development utilizing most of the elements in the original development program. The RL-10 A-3 passed its preliminary flight rating test (PFRT) in July 1962, and has been cleared for flight use.

The A-3 version represents a considerable advance in rocket engine technology. It is the first operational engine employing liquid hydrogen as a propellant. It is also less complicated and consequently more reliable than other engines. For instance, a gas generator used to drive the fuel pump was eliminated, with this function now accomplished by using the hydrogen propellant to drive the turbine for pumping.

The use of liquid hydrogen has required the development of new technology because of the low temperature of liquid hydrogen (-423°F). Its low density, about 1/15th that of water, requires large storage facilities and vehicle tanks and increases the difficulty of pumping. The coldest rocket propellant previously used was liquid oxygen which boils at -297°F, over 100°F above liquid hydrogen.

Primary engine development effort during fiscal year 1964 will be directed toward a program for qualification of components and the engine system. Development in support of the engine production program and vehicle ground and flight test programs will continue. Refinement of the "instant start" capability, reduction of overboard leakage of propellants and pressurants during normal operations and vehicle coast phase, and optimization of the engine components for the individual vehicle use will be stressed. In addition emphasis will be placed on increased reliability and product improvement in preparation for early manned flights.

Considerable progress has been made to provide an engine with a variable thrust down to 1/10th of its present rated value of 15,000 pounds. This engine characteristic will be required for use in advanced spacecraft. Therefore, the development of a variable thrust capability in the RL-10 will be continued during fiscal year 1964.

For the total RL-10 program in fiscal year 1964, four complete new engine systems will be used. These engines will be modified and reworked so that work equivalent to the fabrication of 30 engines will be accomplished. Approximately 810 engine test firings are planned with about 50 scheduled for a full duration run. Approximately 13,000,000 gallons (4,000 tons) of liquid

hydrogen and 13,000 tons of liquid oxygen will be required in this program. Approximately one third of the total funds requested will be used to procure engine systems and components consumed in this year's effort.

F-1 engine	1962	1963	1964
Engine development.....	$44,284,000	$42,500,000	$43,500,000
Test equipment.....	---	---	3,000,000
Facilities.....	1,000,000	---	---
Propellants.....	3,036,000	8,300,000	7,600,000
Subtotal, direct R&D costs..	$48,320,000	$50,800,000	$54,100,000
Personnel costs.....	465,000	815,000	830,000
Operation of installations....	308,000	465,000	546,000
Total costs.....	$49,093,000	$52,080,000	$55,476,000
Total personnel.....	53	77	76

The 1,500,000 pounds thrust F-1 engine will be used in clusters of 5 to power the Advanced Saturn vehicles with manned payloads for lunar explorations. The F-1 is the largest single rocket engine under development by the free world and upon its successful development hinges the capability that will enable this country to make its first manned approach to the moon.

The F-1 engine is being developed by the Rocketdyne Division of North American Aviation. Engineering and fabrication activities are centered at Canoga Park, California, with engine testing at the Edwards Air Force Base. Because of the manned mission which the F-1 engine will support, a detailed and thorough testing program has been planned to assure an extremely high reliability of performance and an early date of availability. Objectives are being achieved despite the current lack of suitable technology to extrapolate information available on propulsion units only 1/10 the thrust capacity of the F-1.

The development of the F-1 engine was begun under a NASA contract in January 1959. Because no facilities existed which were designed to withstand the high operating pressures of this equipment, initial tests were conducted at a lower thrust level than the rated value. The first thrust chamber firing test was conducted 3 months after the start of the program with subsequent tests reaching the one million lb. thrust mark. Initial facilities permitted runs of only a few seconds duration.

The construction of a new test stand complex at Edwards permitted the firing of the first complete experimental engine in May of 1961. A year later, in May 1962, development had progressed to the point where an F-1 engine was fired for 150 seconds, its rated duration, at full thrust of 1,500,000 pounds. During this rated run, approximately 60,000 gallons of liquid oxygen and 40,000 gallons of kerosene were consumed.

Current development activity is concerned with verifying that the F-1 design can meet its performance requirements as a sound and dependable engine. This period of development is expected to culminate in early fiscal year 1964 with the completion of a preliminary flight rating test (PFRT), which is a formal series of tests which the engine must pass successfully before it can be used in testing flight vehicle stages.

In fiscal year 1964, a very intensive test program is planned to eliminate design shortcomings and permit the completion of PFRT. A peak of design, fabrication and test activity will be reached at the beginning of fiscal year 1964 in order to meet the PFRT date. This date is critical since it will certify the flight worthiness of the F-1 engine for use in development of the Advanced Saturn. Engine deliveries for this purpose will begin in October 1963. A higher degree of engine reliability, however, is required for manned payloads. Mission reliability requirements dictate that the F-1 engine must demonstrate completely acceptable performance during 75 consecutive full duration runs before it can operate with a manned payload in the Advanced Saturn. There are many operational factors which are stringently monitored during these reliability tests. Faults in any of these will necessitate redesign and improvements in the engine.

To obtain the reliability required for manned missions, a follow-on development program has been initiated. Its scope and activity will reach full proportions during fiscal year 1964, immediately after the PFRT demonstrations have been completed. This continued R&D program will be completed in 1966 with the qualification of the engine for manned flight use. The components of the engine will be improved by operating the F-1 under extreme limits and environmental conditions, and by redesigning and proof testing components where necessary. Twenty-one problem areas are being singled out for investigation. Of prime importance is the resolution of the problem of rough combustion, which, should it occur, could seriously damage the engine and endanger the vehicle and the entire mission. Because of the fundamental nature of this problem, both research and development effort will be involved. Experienced personnel from various sources will be recruited for this investigation. Improved reliability will also be explored by exercising stringent controls in quality of fabrication, cleanliness of the engine system, and the development of improved and automatic procedures for its operation.

The exploratory nature of the development effort to seek and correct areas of design weakness will require greater testing activity, which will produce a larger attrition rate on engines and components. The planned test program during fiscal year 1964 includes approximately 250 engine test firings. During the year, twelve complete engines and ten equivalent engines (components) will be fabricated and used. In addition, approximately 40,000 tons of kerosene and 130,000 tons of liquid oxygen will be required.

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J-2 engine	1962	1963	1964
Engine development.....	$31,597,000	$35,542,000	$38,550,000
Test equipment.....	---	---	1,400,000
Facilities.....	---	---	---
Propellants.....	2,038,000	9,000,000	8,250,000
Subtotal, direct R&D costs...	$33,635,000	$44,542,000	$48,200,000
Personnel costs.....	536,000	773,000	896,000
Operation of installations.....	353,000	433,000	587,000
Total costs.....	$34,524,000	$45,748,000	$49,683,000
Total personnel.....	61	73	82

In 1960 it became apparent that a high performance liquid hydrogen-liquid oxygen propellant system was required in the upper stages of Saturn class vehicles to increase payload-carrying capabilities. To meet this requirement, a contract was let to Rocketdyne in September 1960 to develop the J-2 engine. This 200,000 pound thrust rocket engine will have 13 times the thrust of the RL-10, the first operational engine using liquid hydrogen as a fuel. The J-2 weighs approximately 1 ton, is 10 feet long, and 6½ feet in diameter. A single J-2 engine will power the second stage of the Saturn B and the third stage of the Advanced Saturn, and a cluster of five will supply the propulsion for the second stage of the Advanced Saturn.

The basic engine design was completed 6 months after the start of the program, and the first J-2 engine (thrust chamber with propellant pumps) was test-fired in January 1962. In an October 1962 test, a J-2 engine was fired at full thrust (200,000 lb.) for a duration of 250 seconds. A new requirement has been imposed on the J-2 to extend its operational duration from 250 to 500 seconds. This has been occasioned by a change in the operational requirements for the Saturn B and Advanced Saturn vehicles.

A relatively mild form of rough combustion has been encountered and overcome. Its cause was ascribed in part to operation of the engine at low fuel temperatures. The use of a new type of combustion suppressor with the injector has provided a stabilizing influence. Difficulty with the inability of the liquid hydrogen pumps to maintain undisturbed flow also appears to have been resolved by the development of a new starting technique.

The J-2 development program will be entering its fourth year at the beginning of fiscal year 1964. Approximately 400 engine tests will have been accomplished by this time with the major objectives being the development of a technique for cooling down and starting the engine, attainment of rated performance, evaluation of component performance and service life, and the operation of the J-2 at a flight simulated altitude. A peak of design, fabrication, and test activities will be reached at the beginning of fiscal year 1964.

Early in fiscal year 1964 the PFRT will be accomplished to determine the flight worthiness of the J-2, and actual engine delivery for use in the Saturn B booster will begin in June 1964. Altitude simulation tests of the J-2 with a nozzle extension will be conducted in fiscal year 1964 as part of a program to improve performanceof the S-IVB stage of the Saturn B and the Advanced Saturn vehicles. An investigation of the vibration characteristics will be conducted and the ability of the engine system to adjust itself to variations in either liquid hydrogen or oxygen flows will be investigated. Late in fiscal year 1964, the design of the J-2 engine to undergo qualification testing leading to manned flight will be released.

The resolution of problems necessary to meet the scheduled completion of PFRT will place an exceptional demand on the J-2 program during fiscal year 1964. The need to complete PFRT on schedule is an urgent requirement since the first PFRT type engine for vehicle use must be delivered during the early part of the year. Similarly, completion of J-2 qualification during 1965 requires that an intensive development program be undertaken after PFRT to increase the reliability of the engine to the very high level (99%) required for manned flight. Approximately 425 engine systems tests are scheduled and several new and eighteen rebuilt engines will be required. Propellant requirements for fiscal year 1964 will be approximately 5,000 tons of liquid hydrogen and 32,000 tons of liquid oxygen.

Range Instrumentation	1962	1963	1964
Advanced instrumentation.....	---	---	$3,300,000
Design data and measurement instrumentation.....	---	---	4,800,000
Safety instrumentation.....	---	---	3,450,000
Launch support instrumentation.	---	---	3,890,000
Range telemetry expansion for Merritt Island launch area...	---	---	4,560,000
Subtotal, direct R&D costs...	---	---	$20,000,000
Personnel costs.....	---	---	333,000
Operation of installations.....	---	---	783,000
Total costs.....	---	---	$21,116,000
Total personnel.....	---	---	36

This project provides for the design, development and procurement of launch instrumentation required to measure and record performance of development and operational vehicles of the manned lunar landing program. Included are the development of new or updating of existing instrumentation to provide compatibility with the new or modified vehicle configurations.

Advanced instrumentation

This includes the development of an accurate short range (lift-off to 500 yards) tracking system which will operate through flame plasma; the development of a system to measure vehicle sway and flex on the pad to prevent excess structural loading; the development of new ground telemetry equipment with frequencies higher than 2300 MC to provide compatibility with instrumentation in the Saturn; and development of data reduction and display equipment, analog to digital conversion equipment, and instrumentation data transmission techniques.

Design data and measurement instrumentation

These estimates cover the development and procurement of equipment which will be utilized to obtain information for future design purposes or for measuring and recording detailed performance during the launch of operational vehicles in the Merritt Island launch area. This will require the development and procurement of mobile, high performance photographic, optical, and acoustic measurement data and tracking equipment.

Safety instrumentation

Request includes the development and procurement of equipment required for the Merritt Island launch area to insure launch area and range safety. High resolution radar tracking and range safety television systems will be developed and procured to supply critical information for the range safety officer. A new command control transmitter will be procured to insure that command and range safety signals are received by the vehicle under all conditions of flight. Instrumentation will also be procured to determine toxicity of fumes, nuclear radiation, temperature humidity, and wind patterns in the Merritt Island launch area to insure safety of personnel.

Launch support instrumentation

The development and procurement of instrumentation and equipment required to coordinate the instrumentation installations in the Merritt Island launch area are included here. Funds will be utilized to procure timing equipment for distribution of the Atlantic Missile Range timing signals, synchronization equipment for countdown and instrumentation synchronization, equipment for acquisition and processing of weather data, equipment for accurate transmission of data between instrumentation stations, and equipment for electromagnetic spectrum surveillance and determination. This equipment is essential and will become critical as launch activities increase.

Range telemetry expansion for Merritt Island launch area

The NASA fiscal year 1963 construction program provided for the construction of a Central Telemetry Facility and associated equipment in the Merritt Island launch area in support of range instrumentation needs. There are now new requirements to provide telemetry support capabilities for the

simultaneous handling of multivehicle countdowns, launchings at 15 to 30 minute intervals, and simultaneous orbital flyby. These new requirements represent a major increase of up to 42 links in the number of telemetry links within the station and will require a commensurate increase in the recording facilities. The funds for this item cover the procurement of the additional equipment that will be needed to satisfy the increased requirements and are above and beyond the requirements for the equipment that was installed in the original facility under the turn-key concept.

Range support	1962	1963	1964
Air Force salaries and related expenses	$524,000	$759,000	$1,000,000
Range contractor support	1,483,000	3,100,000	10,000,000
Equipment, supplies and material	83,000	2,739,000	6,400,000
Maintenance, repair and alteration	120,000	1,402,000	3,600,000
Subtotal, direct R&D costs	$2,210,000	$8,000,000	$21,000,000
Personnel costs	54,000	90,000	231,000
Operation of installations	61,000	167,000	544,000
Total costs	$2,325,000	$8,257,000	$21,775,000
Total personnel	6	13	25

This project provides the funding required to cover the range operating costs, personnel, materials, and services, necessary for the NASA manned flight programs under the terms of a joint NASA/DOD agreement. The costs apply primarily to the new Merritt Island launch area, but also include support for operations conducted at Cape Canaveral on Saturn launch complex 34 and 37.

During fiscal year 1963, support was provided for Saturn launches from complex 34, construction on complex 37, planning and development for the Merritt Island launch area, and some advance procurement of materials for that area. All the required land in the new area will have been purchased by the end of fiscal year 1964 and most of the basic land improvements will have been accomplished. By the end of fiscal year 1964 the land area on which NASA manned programs are supported will have increased to over 100,000 acres. In addition, certain major buildings will have been completed and occupied and work on launch complex 39, the Advanced Saturn complex, will be well underway. Also launch rates of Saturn on complex 34 will have increased, and complex 37 will have become operational. Range support requirements are consistent with the overall build up in NASA activities associated with the manned lunar landing program.

Air Force salaries and related expenses

This provides for the reimbursement of direct salaries and expenses of Air Force civilian and military personnel engaged directly in the support of the NASA manned lunar landing program. Increases in fiscal year 1964 reflect the additional coordination and supervision required as NASA activities expand.

Range contractor support

Salaries and related expenses for Air Force procured contractor personnel required to support the NASA manned lunar landing program are covered here. In general these people are security guards, fire fighters, car and truck drivers, laborers, food service and dispensary personnel, telemetry station operations, data reduction people, photographic service personnel and planning and design engineers. Average employee cost is approaching $10,000 per year and an estimated 1,000 man-years of effort is required.

Equipment, supplies and material

This category provides for the basic equipment, usable supplies and stock material required by the range contractor and Air Force personnel in support of the manned lunar landing program. The increased requirement is a direct reflection of the expansion into the new area. It includes the purchase of such equipment items as general and special purpose vehicles (cranes, fork lifts, and flat beds), shop equipment, security station equipment, fire post basic supplies, mobile field generators for on-site work where power lines are not available, office furniture and supplies, petroleum products, repair parts, handtools, photographic supplies, medical supplies and general stock parts.

Maintenance, repair and alteration

Maintenance, repair, and alteration of facilities and equipment used in direct support of the NASA program in the Merritt Island launch area are funded here. Also included are repairs to all existing and newly purchased equipment, such as motor vehicles, ground powered equipment, communications equipment, and shop tools.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

AEROSPACE MEDICINE

OBJECTIVES:

The objectives of the Aerospace Medicine program are to provide operational medical support to space flight missions and to conduct development and test of systems and components to insure the effective performance and safety of the astronauts in flight and on the ground.

SUMMARY OF RESOURCES REQUIREMENTS:

Funds	1962	1963	1964
Experimental studies	$ 5,827,000	$ 2,936,000	$ 8,125,000
Crew systems	934,000	3,614,000	3,950,000
Biomedical in-flight experiments	889,000	250,000	3,125,000
Medical operations	204,000	200,000	1,500,000
Sub-total, direct R&D costs	$ 7,854,000	$ 7,000,000	$16,700,000
Personnel costs	1,040,000	1,815,000	2,430,000
Operation of installations	1,236,000	1,996,000	2,710,000
Total costs	$10,130,000	$10,811,000	$21,840,000
Personnel			
NASA Headquarters	72	71	76
Manned Spacecraft Center	65	128	165
Total personnel	137	199	241

The cognizance for this program is in the Office of Manned Space Flight, NASA Headquarters, with support at the Manned Spacecraft Center.

PROGRAM JUSTIFICATIONS:

The aerospace medicine objectives for project Mercury have been achieved. Medical data from these flights revealed no significant physiological abnormalities that could be attributed to space flight. Studies for the Mercury program concluded that weightlessness and "g" forces would be of little or no consequence for the planned missions. The Mercury flights demonstrated the validity of these studies. In addition, the Mercury flights proved that the crew equipment and bioinstrumentation, and the concepts upon which their development was based are valid. As a result, few biomedical changes are necessary for the One-Day flight in the spring of 1963. The primary alteration being made to existing Mercury space medicine procedures

and equipment for that flight is the extension of the environmental control system to a twenty-four hour capability.

Projects Gemini and Apollo create many basically new problems. Radiation poses a threat to the astronaut in the longer Apollo flights. Knowledge of the amounts of radiation within a spacecraft are essential to providing necessary personnel protection with a minimum shielding weight.

In these projects man will be subjected to extensive periods of weightlessness. Very little is known of the effects of prolonged exposure to this condition; the effects of physiological stresses must be re-evaluated in these terms. Further information concerning the emotional reactions and hormonal changes of astronauts under stress during weightlessness is required. The projected lengths of time away from earth require a determination of the type of illness and injuries which might occur during flight and the devising of methods of self treatment including the development of miniaturized equipment for such treatment.

Marked increase in the lifting power of new boosters has placed additional requirements for investigations of acceleration tolerances, the physiological effects of sustained acceleration, and the effects of vibration while the astronaut is in a supine position.

In project Mercury, long term isolation and confinement, cabin volume, and prolonged exposure to artificial atmospheres were not significantly important considerations. However, in the extended flights of Gemini and Apollo, the solution to these problems, as well as the performance problems of the astronauts under the artificial social and physical environment, becomes essential to a successful mission.

EXPLANATION OF FUNDS REQUESTED:

Experimental studies

These studies serve to delineate the characteristics and capabilities of man under the variables of the space environment and space flight equipment. These studies will be conducted during astronaut training, orbital flights including the One-Day mission, and in simulation tests. The studies initiated or continued in fiscal year 1963 and being pursued in fiscal year 1964 include the determination of interaction of protons with various materials, human tolerance to impact and landing accelerations, and investigations of launch, re-entry and abort accelerations.

New experimental studies will be initiated in fiscal year 1964 in tissue radiation damage, emergency medical procedures for radiation exposure, shielding concepts which will reduce weight penalties, and instrumentation to indicate flux, energy, type and directionality of particles. Other experimental studies will be directed toward the effects of vibration in a supine position, development of a self-contained life support and suit ventilation system, and an investigation of atmospheric composition for long duration flights.

Crew systems

This area includes the development and improvement of the systems and components required to support and protect the astronauts such as pressure suits, cabin atmosphere, and survival equipment. Tasks being continued in fiscal year 1964 include the development of a space suit for use inside a spacecraft, an extravehicular space suit, and an automatic pressure suit test console. New studies in fiscal year 1964 include the development of an extravehicular suit maneuvering device, a space garment, miniaturized equipment for in-flight medical care, and food for space flight.

Biomedical in-flight experiments

These experiments are required to maintain current information on the physiological effects of space flight. Orbital flight produces an environment which in many respects cannot be duplicated on earth, such as extended weightlessness.

In fiscal year 1964, new tasks are to be initiated to obtain up-to-date information on the biomedical aspects of weightlessness and to test crucial hypotheses regarding weightlessness effects. The development of an environmental control system for long duration flights is to be continued in fiscal year 1964.

Medical operations

This area includes specific efforts directed toward flight crews, ground support activities, and the analysis of flight medical data. It includes the medical selection of the astronauts, their training in the physiological bases for the life support system, the development and implementation of the medical recovery plan, and the design of in-flight medical experiments. The fiscal year 1964 effort will include new tasks concerned with the identification of hazardous materials and operations at the relevant NASA centers and the development of appropriate safety measures.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

INTEGRATION AND CHECKOUT

OBJECTIVES:

The objectives of this program are to provide overall integration analysis, reliability assessment and checkout for all elements essential to the Apollo project. This includes the launch vehicle, the spacecraft and the ground operational support systems. This effort will be directed toward the objective of insuring that the major system elements of the Apollo project are designed, developed and tested to fit together mechanically, electrically and functionally for systems assembly and compatibility during operations.

SUMMARY OF RESOURCES REQUIREMENTS:

Funds	1962	1963	1964
Integration.....	$ 200,000	$ 6,000,000	$26,000,000
Checkout.....	825,000	26,500,000	101,000,000
Reliability assessment.....	225,000	6,000,000	26,000,000
Subtotal, direct R&D costs...	$1,250,000	$38,500,000	$153,000,000
Personnel costs.....	216,000	1,405,000	1,703,000
Operation of installations.....	279,000	1,929,000	2,675,000
Total costs.....	$1,745,000	$41,834,000	$157,378,000
Personnel			
NASA Headquarters.....	27	130	150
North Eastern Office.....	-	3	4
Total personnel.....	27	133	154

The cognizant Headquarters office responsible for program management is the Office of Manned Space Flight.

PROGRAM JUSTIFICATION :

The requirement for the Integration and Checkout program arises from the unique characteristics of the Apollo project which distinguishes it from other projects. These include (1) the serious consequences of failure as measured in terms of national prestige, human life, and cost; (2) the complexity of the total project in terms of the technology required and the numbers and types of industrial contractors involved; and (3) the long period of operations in the space environment with no significant maintenance or repair possible.

The direct R&D funds associated with the program primarily cover work conducted by the General Electric Company (GE) under contract with NASA. The

contract was executed in February, 1962. Effort from this point until September, 1962, consisted of a study program to analyze the integration and checkout requirements of the Manned Lunar Landing Program. Upon completion of the study phase, GE was authorized to implement portions of the program evolved during the study phase, and is currently expanding its efforts at a rapid pace to meet the requirements of the program. A new division, the Apollo Support Department with Headquarters in Daytona Beach, Florida, was created by GE to handle this contract. GE has established offices at the Manned Spacecraft Center, Marshall Space Flight Center and the Launch Operations Center to better meet the needs of the program as it develops. In the performance of work under the contract with NASA, GE is under the general direction of the Directorate of Integration and Checkout, Office of Manned Space Flight. In each specific area of technical endeavor related to programs conducted at the NASA field centers, however, the NASA Center Directors provide technical and administrative direction to the contractor personnel.

EXPLANATION OF FUNDS REQUESTED:

Integration

Work in the integration area is directed toward identification and documentation of equipment and procedure interfaces within the Apollo project; preparation of an Apollo system description; and studies of integration methods and their application to Apollo including design standards, configuration control, and data handling. Technical support is also provided to the Office of Manned Space Flight and the NASA field centers carrying out manned space flight programs. As a result of this work, numerous technical reports have been published and distributed.

The integration level of effort will rise over the next several years in phase with the growth in the total Apollo project. This buildup is essential so that the documentation and study of the current program can be conducted and decisions reached on future systems and procedures to insure proper systems integration. It is estimated that contractor personnel required for integration will reach 650 man-years in fiscal year 1964, compared with 6 in fiscal year 1962 and 135 in fiscal year 1963.

Funds are also programmed in fiscal years 1963 and 1964 for the use of computers. The large volume of technical data which will be handled necessitates the use of automatic data processing and computation equipment.

Checkout

Work in the checkout area consists of two distinct parts. One portion is a continuation of the engineering study effort to provide NASA with checkout systems analysis; standardization studies; an integrated space vehicle checkout system specification; studies on test procedures; the application of advanced checkout techniques to the Apollo project; and system checkout engineering support at the field centers.

The other portion covers the provision of checkout equipment to be included within the integrated launch control and checkout system. This system will be developed and installed at the Launch Operations Center to support operational manned lunar flights from Launch Complex 39. In fiscal year 1963, funds are required for the initial procurement of hardware items for the system. The fiscal year 1964 estimates also provide for long lead-time procurement of checkout equipment to assure delivery, installation and testing prior to the needed operational date for the system. Requirements for these hardware items are directly tied to Apollo and Saturn production plans and launch schedules.

Contractor man-years for checkout will increase from 23 in fiscal year 1962 to 650 in fiscal year 1963 and 1,800 in fiscal year 1964.

Reliability assessment

The reliability effort consists of assessing overall mission reliability and safety levels; implementing an overall reliability and failure data system; and reviewing reliability and quality procedures and controls. A major portion of this effort will be conducted at the NASA centers through the support of Center reliability assessment programs. Preparation of common definitions and procedures, and compilation of summary data will be accomplished at the GE Daytona location for utilization by the centers. Mission reliability and safety estimates will be used to identify areas where greatest reliability and safety gains are needed, and to establish requirements for redundancy, manpower and testing. Review and improvement of design, manufacturing, test and launch operations reliability and quality procedures and controls will result in improved system hardware reliability levels.

The level of effort for this portion of the program will also increase in fiscal years 1963 and 1964. The funds are related to the contractor manpower required to review reliability and quality procedures and controls in the areas of design, manufacturing, test and launch operations. About 650 man-years will be required in fiscal year 1964, compared with 7 and 180 in fiscal years 1962 and 1963 respectively. Effort is also required to implement at an early date a reliability and failure data system that provides mission reliability and safety estimates which can result in timely and effective improvements. Funds in fiscal years 1963 and 1964 will also be required for computers, since the large volume of data handled necessitates the use of automatic data processing and computation equipment.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

SYSTEMS ENGINEERING

OBJECTIVES:

The objectives of the Systems Engineering program are to provide for centralized systems engineering and study capability for the manned lunar program; for the study of advanced mission concepts; and for the support of Apollo system synthesis, including development of overall reliability and systems test plans and the definition of environmental hazards and scientific mission requirements.

SUMMARY OF RESOURCES REQUIREMENTS:

Funds	1962	1963	1964
Systems Engineering and studies, direct R&D costs	$992,000	$26,500,000	$37,000,000
Personnel costs	$1,846,000	4,133,000	4,760,000
Operation of installations	1,831,000	4,237,000	5,768,000
Total costs	$4,669,000	$34,870,000	$47,528,000
Personnel			
NASA Headquarters	125	197	230
Marshall Space Flight Center	96	150	150
Manned Spacecraft Center	---	40	40
Launch Operations Center	---	13	15
North Eastern Office	---	4	5
Total personnel	221	404	440

The responsibility for the Systems Engineering program is assigned to the Office of Manned Space Flight, NASA Headquarters. The installations working on the program are listed above.

PROGRAM JUSTIFICATION

The goals of the Systems Engineering effort are to provide clear definition of mission objectives for both approved and future manned space flight missions, selection of means by which missions are to be accomplished, orderly review of alternatives prior to decisions, development of broad subsystem specifications, clear delineation of the interface between specified technical areas of responsibility, technical monitoring of the status of these activities, a study capability to provide a basis for resolving technical problems, and planning for backup and future missions.

These activities are accomplished within the Office of Manned Space Flight by the Office of Systems. The organization is divided into two major components; Systems Engineering and Systems Studies. The Systems Engineering activity relates to communications and tracking, flight systems, design performance, design practices and reliability. The Systems Studies group provides the capability for program planning, space science studies, human factors studies and engineering studies. The Office of Systems is supported by Bellcomm, Inc., a subsidiary of the American Telephone and Telegraph Company, which provides supplementary scientific and technical capability needed to undertake engineering studies in depth, conduct technical fact finding and evaluation, and provide analytical support in technological areas related to the manned space flight program. Currently planned technical personnel of Bellcomm, Inc. total 167, reaching that level on about October 30, 1963. Support is also obtained from the Jet Propulsion Laboratory, which provides further effort required in the field of space technology.

Numerous concept study contracts are also planned involving the Apollo mission and such future missions as the manned lunar base, manned space stations and manned planetary explorations together with supporting projects such as the lunar logistics system and the Nova large launch vehicle. Based on these studies determinations will be made on the feasibility of the proposals and the time phasing to incorporate these future programs into the overall national space effort.

EXPLANATION OF FUNDS REQUESTED:

In July 1962, based on studies directed by the Office of Systems, a decision was reached to focus study, planning and procurement efforts for lunar exploration primarily on the Lunar Orbit Rendezvous (LOR) mode. However, studies continued on direct flight and earth orbit rendezvous modes. In October a report was published summarizing the results of these further studies and reaffirming the selection of the LOR mode as the best choice for the mission.

Significant progress has been made toward the development of the Apollo Systems Specifications, scheduled for completion during January, 1963. This document, which must be continually updated, defines the flight missions to be undertaken, delineates the interfaces between subsystems and establishes the requirements to be met by each subsystem.

Studies and effort underway, in addition to that leading to the publication of the Apollo Systems Specifications in January 1963, involve tasks related not only to approved missions but also to possible future missions. The following are typical of the efforts underway: study to identify the critical problems involved in lunar launch; studies to gather available information on the natural environmental hazards to Apollo mission success; and study to define communication and tracking systems requirements in support of the manned lunar landing program.

Many additional studies and tasks are planned for the remainder of fiscal year 1963 and throughout fiscal year 1964. Among these are studies designed to define a lunar logistics system and its possible relationship to the Apollo mission, together with its relationship to an advanced mission for construction of a manned lunar base. Studies will also involve the development of concepts and plans for manned lunar base construction, the scientific and technical role of manned space stations, and the purpose and feasibility of manned planetary explorations of Mars and Venus. The Nova vehicle, which is the largest currently envisioned, is also under study, particularly since it is the next step in increasing payload capability and can provide the escape velocity required for deep space probes by manned spacecraft. Pre-development studies are in process to establish the vehicle configuration. Generally, it is currently described as a two stage to orbit (three stage to escape) launch vehicle about 300 feet in height exclusive of payload. Both liquid and solid propellants are under consideration for the first stage whereas the second and third will probably utilize liquid hydrogen and liquid oxygen propellants. Design of the vehicle will enable use of a nuclear powered third stage when available. The design of the vehicle is being carefully developed to provide flexibility in the delivery of payloads with wide varieties of sizes, shapes, densities and weight distributions.

Fiscal year 1964 funding estimates are based, for the most part, on estimates of currently planned effort contracted with Bellcomm, Inc. and the Jet Propulsion Laboratories, and estimates of specific study contracts in connection with current and advanced mission planning.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

METEOROLOGICAL SATELLITES

OBJECTIVES:

The objectives of the Meteorological Satellites Program are:

(1) To establish and continually improve meteorological satellite capability to provide the meteorologist with world-wide observations of atmospheric conditions and storm systems.

(2) To develop a meteorological satellite system suitable for use on a routine continuing basis in an operational meteorological satellite system.

(3) To provide a capability to explore and understand the structure, temporal and spatial variation, and the dynamic processes of the atmosphere in the region from 30 to 100 kilometers. Further, to determine the interactions of this region with other regions of the atmosphere through the measurement and analysis of the basic meteorological parameters, so that improvements may be made in the capabilities for obtaining operational and research data.

SUMMARY OF RESOURCES REQUIREMENTS:

Funds	1962	1963	1964
Supporting research and technology.....	$3,436,000	$4,500,000	$10,200,000
Flight program.....	30,997,000	52,815,000	53,500,000
Subtotal, direct R&D costs..	$34,433,000	$57,315,000	$63,700,000
Personnel costs.....	2,406,000	3,291,000	4,537,000
Operation of installations....	2,857,000	3,683,000	4,848,000
Total costs.....	$39,696,000	$64,289,000	$73,085,000
Personnel			
NASA Headquarters.....	27	32	38
Langley Research Center.....	2	29	33
Goddard Space Flight Center...	230	243	319
Wallops Station.....	52	60	70
Western Operations Office.....	7	6	5

	1962	1963	1964
Pacific Launch Operations Office.....	---	9	11
Total personnel.....	318	379	476

Primary responsibility for the Meteorological Satellites Program, including both satellites and meteorological sounding rockets, is in the Office of Applications at NASA Headquarters. Implementation of the program is accomplished mainly at Goddard Space Flight Center with further support at the installations listed above.

PROGRAM JUSTIFICATION:

The meteorological satellite is a new observation tool which has already demonstrated its value to the science of meteorology and to the practice of weather forecasting. Satellites will not provide all necessary meteorological information, but they have already supplied tremendous amounts of useful meteorological data not available from conventional observational techniques. Satellites give global coverage of some meteorological parameters, in contrast to the five to ten per cent coverage provided by ordinary methods, and because of their unique vantage point above the atmosphere, make new measurements possible. These data will improve the basic scientific understanding of atmospheric processes, will lead to a more comprehensive knowledge of world and regional climatology, and produce advances in weather forecasting. The data are also used in practical daily forecasting by identifying and tracking significant atmospheric storm systems.

The benefits to be derived from improved capabilities in meteorology include protection of life and property from weather disasters; safeguarding transportation; crop planning, control and protection; industrial planning of weather-dependent products, outdoor enterprises, and heating and cooling loads; convenience in planning personal activities; eventual limited weather modification and control; and improved international cooperation, along with good will, in return for providing current global meteorological data to other nations. The same meteorological data required for world wide civilian needs can, under an overall operational system, with proper handling, also meet special military needs.

The flight program was begun with the successful launchings of TIROS I through VI, and five more R&D TIROS launchings are planned. Operational TIROS launchings, funded by the Weather Bureau, are scheduled and are interspersed with the five R&D launches to give additional data until the flight operations of Nimbus demonstrate that the Nimbus/Nimbus Operational System data can fulfill routine requirements. The Nimbus R&D project encompasses the launch of four progressively more advanced spacecraft, beginning in fiscal year 1964.

The U. S. Weather Bureau, in the Department of Commerce budget submis-

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sions, will request funds for the launch and flight of operational Nimbus spacecraft, which will form the basis of a Nimbus Operational System (NOS). The flights of the operational Nimbus spacecraft will be interspersed with NASA's R&D launches. Although all data gained from the R&D spacecraft will be available for operational purposes, the operational Nimbus will emphasize the application of the data gained for routine weather analyses.

The NOS system will form the development link between the Nimbus R&D project and a fully operational meteorological satellite system. Meanwhile, NASA will continue to pursue fundamental Research and Development objects. The development of improved operational systems depends not only upon specific flight projects but also on sustained programs of supporting research and technology. These programs include effort on techniques relating to the reduction and processing of meteorological satellite data, feasibility and initial design studies of more complex sensory systems, and advanced meteorological satellite configurations and concepts. The programs will also provide improved satellite instrumentation and equipment to measure and interpret critical atmospheric parameters.

The planned satellite flight schedule follows:

Mission R&D	Launch Vehicle	Calendar Year of Launch
TIROS I	Thor-Able	1960) successfully
TIROS II	Thor-Delta	1960) launched
TIROS III	Thor-Delta	1961)
TIROS IV	Thor-Delta	1962)
TIROS V	Thor-Delta	1962)
TIROS VI	Thor-Delta	1962)
TIROS A-52	Thor-Delta	1963
TIROS A-53	Thor-Delta	1963
TIROS A-54	Thor-Delta	1963
TIROS A-55	Thor-Delta	1964
TIROS A-56	Thor-Delta	1964
Nimbus A-4	Thor-Agena	1963
Nimbus A-5	Thor-Agena	1964
Nimbus A-6	Atlas-Agena	1965
Nimbus A-7	Atlas-Agena	1966

Meteorological sounding rockets are at present the only feasible vehicles for acquiring data in the 100,000 foot to 300,000 foot layer of the atmosphere. This layer is above the altitudes normally reached by radiosonde balloons and is not amenable to indirect sensing techniques from satellites, being far below the altitudes where satellites can orbit and make ambient measurements. The samples of data obtained thus far indicate that significant meteorological processes take place at these altitudes. This layer may hold the key to an understanding of how changes in the sun's radiations influence the weather.

Furthermore, these levels may be utilized by future high flying aircraft and are known to be critical for reentering space vehicles. For these reasons, the observation capabilities in the region must be improved.

It is planned to launch about 45 large meteorological sounding rockets in fiscal year 1964 to develop sensors and techniques for measuring the important atmospheric parameters from 200,000 to 300,000 feet and above. Approximately 100 small meteorological sounding rockets are to be launched in fiscal year 1964 to provide data to be used in the development of a meteorological sounding rocket system for use in the 100,000 to 200,000 foot region.

EXPLANATION OF FUNDS REQUIRED:

Supporting research and technology	1962	1963	1964
Synchronous meteorological satellite.....	---	$300,000	$950,000
Advanced meteorological sensor development.....	$800,000	950,000	3,200,000
Meteorological systems research.	2,636,000	1,650,000	2,450,000
Advanced meteorological system component development.....	---	1,600,000	3,600,000
Subtotal, direct R&D costs....	$3,436,000	$4,500,000	$10,200,000
Personnel costs.....	441,000	753,000	1,111,000
Operation of installations.....	501,000	709,000	1,004,000
Total costs.....	$4,378,000	$5,962,000	$12,315,000
Total personnel.....	58	81	115

The objectives of the supporting research and technology effort are: (1) to develop sensors, controls, and data acquisition and handling systems to implement and improve meteorological systems; (2) to study data from previous satellites and sounding rockets to provide broader bases for system improvements; (3) to evaluate further experiments and uses for a given system; and (4) to study for feasibility and value to the program new concepts or applications of meteorological systems, prior to establishing a flight project (e.g. the equatorial orbiting, synchronous, earth-oriented meteorological satellite).

Accomplishments in supporting research and technology provide improvements for current projects and the technical foundation for progress. Some of the most significant areas of activity are discussed below.

Tiros experiments have produced extensive picture and infrared radiation data. While operational use has been made of the picture data, much remains to be done in correlating the pictures with the infrared data.

Further development of such items as radiometers, spectrometers and radi-

ation detectors suitable for inclusion in the Nimbus spacecraft is underway. As these new sensors are developed for Nimbus, a power system of greater and better regulated electrical capacity will be required and must be developed concurrently for the sensors to be of use. More accurate and more reliable control systems and such items as horizon sensors, which are vital to control, will provide improved measurement values commensurate with improved sensors. Techniques and components for these purposes are under study and development.

The present Nimbus solar paddle system with only one degree of freedom restricts the variety of orbits available to the spacecraft and also requires a larger solar panel, due to the loss of efficiency when the sun's rays strike the solar cells at less than the optimum angle. A system with two degrees of freedom is under study.

A tape recorder capable of being read out arbitrarily at several locations with no loss in recorded data and no "dead time" is being developed to record TV and high resolution infrared signals.

Studies have shown it to be desirable to develop techniques and components for adapting the electrostatic tape camera to meteorological satellites. Technically, the electrostatic tape camera is a combination TV camera and tape recorder which eliminates one step in the image transfer process. The electrostatic tape camera will also provide higher resolution pictures and a greater number of gray shades.

The TIROS and Nimbus infrared systems tape recorders are a result of supporting research and technology in the past. Improvements in recorder technology and the development of a digital tape recorder are needed for the transmission of ever increasing volumes of meteorological data from the Nimbus spacecraft series.

New types of TV cameras such as the image orthicon for nighttime viewing will provide better picture data from future meteorological satellites; and since the incoming radiation from the sun profoundly affects the atmosphere, an instrument suitable for measuring and telemetering the solar constant from meteorological satellites is highly desirable.

The presently authorized meteorological satellite projects include only the TIROS project (the original proof-of-feasibility satellite) and Nimbus (the polar orbiting, earth-oriented, first operational satellite). Neither the TIROS, nor the Nimbus, singly, or even together, provide the ultimate capability needed to meet user requirements. Therefore, a study is under way in fiscal year 1963 to identify the critical scientific and engineering problem areas and the advances in technology required to bring the maximum area of the earth under constant observation. An equatorial orbiting, synchronous, earth-oriented satellite is considered a likely configuration. Preliminary work toward determining system and component characteristics will be undertaken in fiscal year 1964.

TIROS

	1962	1963	1964
Spacecraft and subsystems.....	$5,304,000	$5,500,000	$2,000,000
Data acquisition.....	330,000	4,100,000	1,600,000
Engineering utilization of data.	1,041,000	1,400,000	1,300,000
Launch vehicles.....	---	10,200,000	2,300,000
Subtotal, direct R&D costs....	$6,675,000	$21,200,000	$7,200,000
Personnel costs.....	1,255,000	1,192,000	1,616,000
Operation of installations.....	1,526,000	1,364,000	1,759,000
Total costs.....	$9,456,000	$23,756,000	$10,575,000
Total personnel.....	166	151	170

The objectives of the TIROS project are: (1) to prove the engineering and scientific feasibility and desirability of the meteorological satellite; (2) to provide maximum interim operational data for use in weather analysis and forecasting prior to availability of Nimbus data; (3) to provide R&D toward advanced meteorological satellite systems; (4) to measure emitted infrared and reflected solar radiation in selected spectral regions; and (5) to observe cloud cover and patterns, and measure earth-atmosphere heat balance.

TIROS has proved the engineering and scientific feasibility and desirability of the meteorological satellite, and continues to provide significant data toward the accomplishment of all other objectives. All six attempted launches have been successful and operational data have been provided to the extent of the system's capabilities since the launch of TIROS I on April 1, 1960. As of December 1, 1962, approximately 194,000 pictures had been received from the satellites, of which over 70 per cent were meteorologically useful. Discovery, verification, and positioning of a considerable number of major storms has been made possible or confirmed by TIROS data.

A total of five additional R&D TIROS satellites is planned for launch through fiscal year 1965. In order to accommodate the desires of the Weather Bureau to augment continuous operational cloud data coverage at the earliest possible date, additional operational TIROS satellites, funded by the Weather Bureau, are planned for launch in fiscal years 1964 and 1965, interspersed with the five R&D launches. The schedule will be phased to cover the calendar years 1963 and 1964 to provide a regular flow of TIROS data until the Nimbus/NOS data can be relied upon to meet routine meteorological requirements.

In addition to the data used operationally in weather analyses and forecasting, the TIROS series is providing a continuing background of research, development and reliability information on meteorological satellite systems. This background is contributing to the improvement of follow-on satellite systems such as Nimbus; for example, equipment essential for the Nimbus stabil-

ization and control system will be tested using TIROS. Further work under consideration includes a highly eccentric orbit to provide information on the whole disk of the earth for more detailed work on the concept of a synchronous equatorial orbit for a meteorological satellite. TIROS data have been used also in research which showed that certain infrared data can be used for nighttime cloud observations and the approximate determination of cloud top height, and demonstrated that the organization of cloud patterns is far greater than was ever anticipated, particularly the spiral banding noted in storms and a previously unknown convective pattern which is frequently observed over ocean areas.

Additional TIROS will be launched by the Thor-Delta vehicle (TIROS I was launched by the Thor-Able). Delta vehicles for R&D launches will continue to be incrementally funded in fiscal year 1964.

Nimbus

	1962	1963	1964
Spacecraft and subsystems.....	$16,581,000	$21,240,000	$31,550,000
Data acquisition.....	---	2,450,000	4,050,000
Launch vehicles.....	7,300,000	6,600,000	8,200,000
Subtotal, direct R&D costs.....	$23,881,000	$30,290,000	$43,800,000
Personnel costs.....	533,000	992,000	1,421,000
Operation of installations.....	603,000	1,213,000	1,652,000
Total costs.....	$25,017,000	$32,495,000	$46,873,000
Total personnel.....	70	104	146

The objectives of the Nimbus project are: (1) to develop for continuing use a reliable satellite system, including read-out stations, for an eventual operational meteorological satellite system, and provide initial improvements to that system; (2) to provide data from the Nimbus R&D system, together with the satellites furnished through the Nimbus Operational System (NOS) for operational use by the Weather Bureau and other weather services, and for meteorological research; (3) to obtain full global picture coverage of daytime cloud cover, and grosser night cloud cover using IR sensors; and (4) to obtain emitted infrared and reflected solar radiation measurements.

The results of an analysis and study of the requirements of the U. S. Weather Bureau, the Department of Defense, and the Federal Aviation Agency for meteorological data which can be most practically acquired through satellites were applied to the Nimbus Project. The agencies were continually consulted during design and planning. The spacecraft developed under this project are planned as the basic instruments in the operational meteorological satellite system. The user requirements are such that the satellite must have

earth stabilization in order to view the atmosphere continuously. Further, the satellite must be in a near-polar orbit in order that combined views from its orbits will show the entire globe at least once each day in daylight. The satellite design must allow for growth, to permit the inclusion of other or improved sensors as they are developed, without necessitating a costly redesign and complete requalification each time. In this manner user requirements will be met most rapidly at the least cost. Nimbus is planned as the first civilian earth-oriented satellite. (TIROS is space-oriented and consequently can view the earth through only part of any given orbit; for these and other reasons, it cannot adequately satisfy user requirements on a long term basis.)

Nimbus is approximately 10 feet high and 5 feet in diameter at the base and will weigh about 700 pounds. This initial version is limited by currently planned launch vehicle capabilities. The later Nimbus will probably weigh up to 850 or more pounds and utilize the Atlas-Agena launch vehicle. The satellite will have three major subsystems: power, stabilization (consisting of gas jets for coarse control and inertia wheels for fine control), and the sensory system, which will include three vidicon cameras and radiation sensors on the first Nimbus. Later Nimbus spacecraft will include duplicate sets of these sensors for improved useful life and reliability.

It is anticipated that the launch of four Nimbus R&D spacecraft will result in a reliable and sufficiently redundant satellite to assure the weather data user the minimum data that he requires on a continuous basis. The first two research and development satellites will be primarily minimum satellites launched to test out the basic system and the basic configurations. Even their data, however, will be immediately made available for operational weather analysis and forecasting.

The third Nimbus satellite will include sensor redundancy in an elementary form by having duplicate systems, and will require the Atlas-Agena launch vehicle. The fourth research and development satellite will be an integrated redundant system, with the capability of interconnecting individual parts of subsystems in flight on command, in order to provide a system with still longer life.

Since it is recognized that failures may take place during this period which will prevent continuity between R&D launches, Congress has provided the Weather Bureau funds for additional satellite launches--the NOS satellites--to be interleaved with the R&D satellites. The fabrication, launch and operation of these NOS satellites is being managed by NASA with funds transferred by the Weather Bureau.

After the Nimbus R&D series has been completed and the basic operational satellite has been developed, Nimbus type satellites will be funded by the Weather Bureau and launched on a routine, regular basis as part of the continuing NASA responsibility under the operational meteorological satellite system.

Meteorological sounding rocket systems

	1962	1963	1964
Experiments, equipment, and support for large rockets.....	$441,000	$790,000	$1,440,000
Large rockets.....	---	270,000	360,000
Small rocket systems.....	---	265,000	700,000
Subtotal, direct R&D costs....	441,000	$1,325,000	$2,500,000
Personnel costs.....	177,000	354,000	389,000
Operation of installations.....	227,000	397,000	433,000
Total costs.....	$845,000	$2,076,000	$3,322,000
Total personnel.....	24	43	45

The objectives of this project are to develop and improve sensors and techniques for measuring the basic meteorological parameters in the region from 200,000 to 300,000 feet with large rockets; and to develop a reliable, simplified, self-sufficient sounding system (rocket vehicle, sensors, and data acquisition) to provide a capability for routine measurements of the basic meteorological parameters for research and applications in the 100,000 to 200,000 foot region of the atmosphere with small rockets.

In order to determine the magnitude and extent of the dynamic and thermodynamic variations of atmospheric properties in the upper stratosphere and mesosphere, launch sites for large meteorological sounding rockets are distributed at various latitudes to measure the atmospheric structure in the various climatic regimes from the Arctic to the Tropics. NASA plans to launch approximately 45 large meteorological sounding rockets in fiscal year 1964.

Recent research has indicated that the region of the atmosphere explored by small meteorological sounding rockets serves as an important link between the higher regions where solar radiation effects dominate, and the lower regions where convection and air mass mixing control the surface weather. Thus, this region may provide the data leading to the solution of many problems in weather analysis and forecasting.

At present a variety of rockets and sensors are used for studying this region. The integrated system to be developed, consisting of the rocket motor, sensors, and data acquisition equipment, is aimed at providing a standardized flight article which will meet the requirements at an overall minimum cost. Approximately 100 rockets will be launched in fiscal year 1964.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

COMMUNICATIONS SATELLITES

OBJECTIVES:

The objectives of the NASA Communications Satellite Program are to assist in the early establishment of operational communications satellite systems, and to support the continuing development and expansion of such systems through a program of research, development and flight testing of techniques and concepts designed to insure the realization of the full capabilities of communications satellites.

SUMMARY OF RESOURCES REQUIREMENTS:

Funds	1962	1963	1964
Supporting research and technology	$ 7,478,000	$12,976,000	$ 5,000,000
Flight program	25,627,000	30,739,000	46,100,000
Subtotal, direct R&D costs	$33,105,000	$43,715,000	$51,100,000
Personnel costs	1,179,000	2,644,000	2,293,000
Operation of installations	1,307,000	2,690,000	2,378,000
Total costs	$35,591,000	$49,049,000	$55,771,000

Personnel			
NASA Headquarters	27	32	38
Goddard Space Flight Center	95	213	168
Langley Research Center	23	24	19
Western Operations Office	1	1	-
Wallops Station	8	9	8
North Eastern Office	-	1	1
Total number of personnel related to program	154	280	234

Primary responsibility for the Communications Satellite Program is in the Office of Applications at NASA Headquarters. Project management responsibility has been assigned for each of the current projects to Goddard Space Flight Center. Support for the program is accomplished at the locations listed above.

PROGRAM JUSTIFICATION:

The effective conduct of the Nation's affairs depends on rapid and reliable communications over great distances on the earth. High-frequency radio, used in many of the present worldwide communications systems, and the existing transoceanic telephone cables are rapidly being overburdened. The anticipated future expansion of communications requirements necessitates the development of new, more reliable, and more economical techniques of greater capability than existing systems. Communications satellites make it possible to establish microwave communication over long distances by providing relay stations at altitudes where they can be viewed simultaneously from many points on the earth's surface. With their use all types of telecommunications can be extended to the entire earth. NASA will support the continuing improvement, development and expansion of the uses of communications satellite systems through research, development and flight tests. NASA will not only play a primary role in support of the Space Communications Corporation in accordance with the policy of the Communications Satellite Act of 1962, but will also support all industries supplying components for future communications satellite systems.

NASA exchanges information with the Department of Defense (DOD), and insures that NASA's program will meet DOD requirements to the maximum extent possible, through a Technical Committee for Communications Satellites, made up of program and project level representatives from NASA and Defense agencies, reporting to the Unmanned Spacecraft Panel of the Aeronautics and Astronautics Coordinating Board.

The NASA Communications Satellite program consists of supporting research and development of components and techniques required for future spacecraft, as well as a flight program to design, develop, test feasibility, test reliability, and determine the useful life of communications satellites. The flight program will pursue the development and flight testing of both active repeater and passive satellites. The active repeater satellite projects include Relay, Syncom, and the advanced synchronous satellite development. Echo is a passive satellite project.

The communications satellite flight schedule is as follows:

Mission	Launch Vehicle	Calendar Year of Launch	Launch Location
Echo-II (rigidized sphere passive reflector)			
Suborbital test (2 flights)	Thor	1962	AMR
Orbital test	Thor-Agena	1963	PMR
Relay (low altitude wideband active repeater)			
1 flight	Thor-Delta	1962	AMR
2 flights	Thor-Delta	1963	AMR

Mission	Launch Vehicle	Calendar Year of Launch	Launch Location
Syncom (24-hour orbit, narrow band active repeater)			
3 flights	Thor-Delta	1963	AMR
Advanced Synchronous Communications Satellite (24-hour orbit, wideband active repeater)			
2 flights	Atlas-Agena	1965	AMR
2 flights	Atlas-Agena	1966	AMR

The Communications Satellite program will use ground stations for transmitting and receiving signals for communications, command-control, and telemetry. NASA will lease or build ground stations, telemetry-command stations, and special ground equipment for some of its communications projects. A number of the communications experiments will be conducted jointly with other participants, such as the DOD and certain foreign governments, which will utilize their own ground stations.

EXPLANATION OF FUNDS REQUESTED:

Supporting Research and technology	1962	1963	1964
Advanced synchronous satellite studies.....	$ 1,000,000	$ 5,000,000	$ ---
High gain reflective structures.....	126,000	450,000	200,000
Advanced passive satellite studies.....	4,113,000	2,750,000	1,200,000
Intermediate altitude satellite studies.....	---	2,000,000	2,000,000
Electronically steerable antennas.....	---	234,000	100,000
Isotope thermoelectric power supply studies.....	---	100,000	200,000
Technical and operational studies.....	2,239,000	2,442,000	1,300,000
Subtotal, direct R&D costs..	$ 7,478,000	$12,976,000	$ 5,000,000
Personnel costs.....	146,000	1,130,000	745,000
Operation of installations....	172,000	1,178,000	785,000
Total costs.....	$ 7,796,000	$15,284,000	$ 6,530,000
Total personnel.....	19	118	75

These estimates provide support for advanced communications satellites and new system concepts. The program consists of comprehensive studies, theoretical studies and investigations, and subsystem-system feasibility and development. Comprehensive studies provide a basis for program direction and embrace several efforts which are concerned with the technological, operational and economic problems of communications satellites. Theoretical studies and investigations determine areas of worthwhile hardware development. The results of such studies lead to feasibility demonstrations and developments applicable to future communications satellite systems.

Advanced passive satellite technology work is being undertaken to develop a number of passive structures having improved radio cross section-to-weight ratios and reduced susceptibility to solar pressure. The target for this improved radio cross section is a structure with ten times the Echo A-12 cross section but of substantially the same weight. An improvement of this magnitude is necessary to reduce the ground station complexity and cost required to establish useful communication channel capabilities. Effort will be devoted to materials improvement, structures development, and ground testing of the various approaches.

The fiscal year 1963 program includes major effort on advanced synchronous orbit satellite studies, and feasibility research on intermediate altitude communications spacecraft. Such studies allow a thorough analysis and evaluation of complex advanced systems problems before the placement of extensive development contracts.

Fiscal year 1964 funds will be used to continue research on hi-gain reflective structures, directivity patterns for antennas and measurement of radio transmission losses due to scattering objects, development of satellite materials and components, and attitude stabilization techniques. The effort will include continuing study on intermediate altitude, advanced passive, and multiple access communications spacecraft, and research directed toward the demonstration of feasibility of isotopic thermoelectric power supplies. Studies will be initiated on large solar collectors and propagation characteristics.

The Hughes Aircraft Company, Culver City, California, was awarded a contract for a preliminary design of an advanced synchronous altitude satellite spacecraft, including the design and development of a traveling wave tube, a transponder, an electronically steerable phased array antenna, a hot gas reaction jet control system, and specifications for the spacecraft and the on-board electronics. The Central Radio Propagation Laboratory, National Bureau of Standards, Boulder, Colorado, is engaged in research on directivity patterns for antennas and measurements of radio transmission losses due to scattering objects.

Flight program

Echo (rigidized sphere)	1962	1963	1964
Thor launch vehicle (one ballistic flight).....	$1,000,000	$ ---	$ ---
Thor-Agena launch vehicle (one orbital flight).....	4,800,000	---	---
Sphere development and procurement.....	75,000	306,000	---
Canisters and spacecraft environmental tests.....	65,000	400,000	---
Beacons.....	163,000	245,000	---
Test, evaluation and documentation services.....	---	34,000	---
Data reduction and analysis...	---	450,000	200,000
Subtotal, direct R&D costs..	$6,103,000	1,435,000	$ 200,000
Personnel costs.....	542,000	597,000	407,000
Operation of installations....	560,000	553,000	377,000
Total costs.....	$7,205,000	$2,585,000	$ 984,000
Total personnel.....	71	66	44

Project Echo covers development and flight-testing of a passive communications satellite which will be spherical, 135 feet in diameter, weigh about 500 pounds, and be constructed of an aluminum-mylar laminate. The project includes two ballistic flights from which took place in January and July, 1962, and one orbital launch scheduled from the Pacific Missile Range in the last half of fiscal year 1963. The ballistic flights, using Thor DM-21 launch vehicles with TV equipment and a recoveriable film camera, tested satellite ejection and inflation. In the first ballistic flight (AVT-1) the canister opening and sphere ejection was successful, but the sphere ruptured and tore apart. The second ballistic flight (AVT-2) resulted in successful ejection and deployment of the sphere, although radar data indicated that the inflation process may not have been complete. Excellent quality TV signals from the Thor were received and recorded at AMR, and in both ballistic tests the recovered film data capsules yielded excellent film.

The orbital launch, utilizing a Thor-Agena launch vehicle, will place the satellite in a circular orbit of about 700 nautical miles altitude. The major objective of the orbital flight is to test the useful life of the rigidized sphere and its practicality as a reliable reflector of radio waves. The major contractors for this project are G. T. Schjeldahl Co. of

Minnesota for the spheres; Aero-Geo-Astro of Virginia for beacons; Grumman Aircraft Engineering Co., Bethpage, L.I., New York, for canisters; Geophysics Corporation of America, Viron Div., in Minnesota for inflation system; Douglas Aircraft of California, for the ballistic launch vehicles and the booster stage for the orbital launch vehicles; and Lockheed Missile & Space Co. of California, for the Agena B stage of the orbital launch vehicle.

Spacecraft development and procurement, launch vehicles and launch support were provided for with prior year funds. Fiscal year 1964 funds are required to permit continued observation of the satellite in the post launch period, and for data reduction and analysis.

Relay	1962	1963	1964
Spacecraft	$3,409,000	$3,000,000	$ ---
Ground station equipment	376,000	1,603,000	---
Radiation experiments	245,000	115,000	---
Ground station operations	833,000	1,680,000	1,150,000
Command and control stations	2,049,000	1,085,000	---
Coordination planning and documentation	---	1,210,000	350,000
Communications rentals	---	100,000	175,000
Data reduction and analysis	---	275,000	225,000
Thor-Delta launch vehicles* (2 orbital flights and 1 backup)	---	---	---
Subtotal, direct R&D costs	$6,912,000	$9,068,000	$1,900,000
*Funded in FY 1961			
Personnel costs	361,000	567,000	298,000
Operation of installations	426,000	594,000	318,000
Total costs	$7,699,000	$10,229,000	$2,516,000
Total personnel	47	59	30

The mission of Relay is to accomplish experimental wideband communications between widely separated ground stations by means of a low-altitude active communications satellite; to measure the effects of the space environment on the Relay satellite; and to determine the reliable active life of the Relay spacecraft.

Project Relay covers development and flight testing of an experimental wideband, low orbit, active repeater communications satellite. The spin-stablized spacecraft is an 8-sided prism, 29 inches in maximum width and weighing about 168 pounds, with a degree of attitude control through use of a magnetic coil. The spacecraft contains two complete and separate communi-

cations transponders, each capable of relaying a standard TV channel or equivalent high speed data. Only one transponder is operated at any time; the other is for backup. The spacecraft also has the capability of multi-channel two-way telephone service between selected ground stations. It contains a radiation experiment for monitoring the radiation levels encountered by the satellite and measuring radiation damage to selected solid-state devices. In addition, the satellite includes a solar cell/nickel-cadmium battery power supply, solar attitude sensors, and command-telemetry equipment.

Communications experiments with the Relay spacecraft demonstrating a U. S.-Europe link will be conducted between the AT&T ground station at Andover, Maine (services of which are being contracted for by NASA) and European ground stations at Goonhilly, England; Pleumeur-Bodou, France; Fucino, Italy; and Raisting, West Germany. Experiments demonstrating a U. S.-South America link will be conducted between the IT&T ground station at Nutley, New Jersey (which is being contracted for by NASA) and a South American station at Rio de Janeiro, Brazil. In addition to the communications ground stations, NASA is utilizing two ground stations to test the functioning of the Relay spacecraft. These stations will be located at Nutley, New Jersey, and Mojave, California. Relay spacecraft will be launched from AMR into elliptical orbit with 4,000 nautical mile apogee, 700 nautical mile perigee, and 47° inclination. The first launch tock place on December 14, 1962, using a Delta vehicle.

The major contractors are STL of California for a spacecraft design study and coordination, planning and documentation; Astro-Electronics Division of RCA of New Jersey for spacecraft development; Philco Corporation of California for the Mojave ground antenna; AT&T of New York and IT&T of New York for ground station operations; and Douglas Aircraft Corporation of California for the launch vehicles.

Prior year funds have been used for spacecraft development, ground station operations equipment, command and control stations, and radiation experiments. The funds also provided for initiation of coordination, planning and documentation, communications rentals, and data reduction and analysis.

Funding for fiscal year 1964 will cover continuation of ground station operations of AT&T and IT&T, coordination, planning and documentation, communication rentals, and data reduction and analysis.

Syncom	1962	1963	1964
Thor-Delta launch vehicles (two orbital flights and one backup).....	$2,500,000	$5,000,000	$ ---
Apogee motor development (JPL)	475,000	250,000	---
Backup traveling wave tube....	132,000	50,000	---
Spacecraft.....	6,668,000	3,445,000	500,000

	1962	1963	1964
Range and range rate equipment.....	$1,571,000	$ 785,000	$ 410,000
Ground station support and environmental test.....	1,066,000	3,881,000	2,215,000
Communication rentals.....	---	330,000	---
Data reduction and analysis...	---	865,000	875,000
Subtotal, direct R&D costs..	$12,412,000	$14,606,000	$4,000,000
Personnel costs.....	130,000	350,000	288,000
Operation of installations....	149,000	365,000	308,000
Total costs.....	$12,691,000	$15,321,000	$4,596,000
Total personnal.....	17	37	29

The objectives of Syncom are to provide experience in using communications satellites in a 24-hour orbit at the earliest possible time; to flight test a new and simple approach to satellite attitude and period control; to develop transportable ground facilities which can be readily deployed in useful areas; to develop the capability of launching satellites into the 24-hour orbit, using existing launch vehicles plus apogee kick rockets; and to test the life of communications satellites components at the 24-hour orbit altitude.

The Syncom spacecraft will be a narrow band active repeater communications satellite. The spacecraft will be 28-inches in diameter, weigh about 145 pounds, and contain a communications transponder capable of accommodating one two-way radio telephone channel. It will also contain the apogee-kick rocket motor, hydrogen peroxide jets and nitrogen gas jets for attitude and position control, solar attitude sensors, solar cell/nickel cadmium battery power supply, and telemetry and control equipment. A Delta vehicle will be used to launch the spacecraft into a highly eccentric orbit with apogee at synchronous altitude. When apogee is reached, the apogee-kick rocket motor will be fired and will provide sufficient additional velocity to inject the satellite into a circular near 24-hour orbit inclined 33° to the equator.

This project commenced in fiscal year 1962. Major contracts initiated were with Hughes Aircraft of California for spacecraft and telemetry and command equipment; STL of California for range and range rate equipment; Watkins-Johnson of California for a traveling wave tube backup; and Douglas Aircraft of California for the Thor-Delta launch vehicles.

The ground stations (except for the telemetry and command, and range and range rate equipment) will be furnished by the DOD through the U.S. Army

Satellite Communications Agency. The main ground station contractor to the DOD is Bendix Aviation of Towson, Maryland. Each ground station contains equipment for (1) communications and (2) functions concerned with the control of the spacecraft and reception of telemetry. Overall ground station design and provision of the basic communications ground station is the responsibility of the DOD. However, NASA will provide all of the equipment required for the second function above.

Prior year funds were used for spacecraft development; range and range rate equipment; backup traveling wave tube; apogee motor development; ground station support and environmental test; and full payment for three Thor-Delta launch vehicles. Fiscal year 1963 funds provided for communications rentals, and the initiation of data reduction and analysis.

Funds for fiscal year 1964 are required to continue ground station support, spacecraft and range and range rate equipment procurement and data reduction and analysis.

Advanced synchronous communications satellites	1962	1963	1964
Atlas-Agena launch vehicles (three orbital flights and one backup).....	$200,000	$2,200,000	$12,500,000
Spacecraft.....	---	2,330,000	16,640,000
Equipment for ground stations.	---	1,100,000	4,960,000
Ground station operations.....	---	---	1,000,000
Reliability studies.....	---	---	500,000
Switching circuit.....	---	---	300,000
Telemetry and command stations	---	---	600,000
Range and range rate equipment.....	---	---	2,000,000
Services and rentals.....	---	---	500,000
Data reduction and analysis.....	---	---	1,000,000
Subtotal, direct R&D costs..	$200,000	$5,630,000	$40,000,000
Personnel costs.....	---	---	555,000
Operation of installations....	---	---	590,000
Total costs.....	$200,000	$5,630,000	$41,145,000
Total personnel.....	1/	1/	56

1/ Personnel assigned to supporting research and technology in 1962 and 1963.

The objectives of this project are to develop and flight test an advanced active communications satellite in a 24-hour orbit. This satellite

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will be compatible with all current types of common carrier traffic, including voice communications, teletype, monochrome and color television in quality consistent with international standards. Numerous ground stations will be readily accommodated, and each station will be able to communicate with any or all other stations. The spacecraft communications electronics plan provides for four satellite transponders, each of them in duplicate. Each transponder will have the capacity of 600 two-way voice channels or one monochrome or color television channel with some margin over international standards, when used with 85-foot dish antennas or equivalent horn-type antennas. The satellite will represent the logical extension of the Syncom satellite to a wideband capability and will use similar techniques for achieving orbit, and maintaining position and orientation. Launch will be from the Atlantic Missile Range into a 24-hour circular equatorial orbit (22,300 miles altitude). In this orbit the satellite will appear stationary to an observer on earth, and can serve as a link between suitably equipped ground stations within its view.

Fiscal year 1962 funds provided for the initial incremental funding of Atlas-Agena launch vehicles. Fiscal year 1963 funds cover spacecraft development, scheduled to commence in the latter half of the year, initial procurement of equipment for ground stations, and the second increment of funding for Atlas-Agena launch vehicles.

Fiscal year 1964 funds are required for spacecraft development; operational support; ground station operations; reliability studies; switching circuit; telemetry and command stations; equipment for ground stations; range and range rate equipment; services and rentals; data reduction and analysis; and incremental funding for Atlas-Agena launch vehicles.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

ADVANCED APPLICATIONS SATELLITES

OBJECTIVES:

The Advanced Applications Satellite program is intended to examine possible new applications of satellites, determine the feasibility of such applications, and develop systems to meet established requirements.

SUMMARY OF RESOURCES REQUIREMENTS:

Funds	1962	1963	1964
Supporting research and technology	--	$800,000	$1,000,000
Subtotal, direct R&D costs.....	--	$800,000	$1,000,000
Personnel costs.....	32,000	85,000	232,000
Operation of installations.....	41,000	118,000	372,000
Total costs.....	$73,000	$1,003,000	$1,604,000

Personnel	1962	1963	1964
NASA Headquarters.....	4	8	21
Total personnel.....	4	8	21

Responsibility for the Advanced Applications Satellites program is in the Office of Applications at NASA Headquarters. As the program develops, assignments to centers will be made.

JUSTIFICATION AND EXPLANATION OF FUNDS REQUESTED:

Under this program, NASA conducts a continuing review of new practical and desirable non-military satellite applications to establish feasibility and need. This program is designed to realize the maximum utilization of space.

Fiscal year 1964 effort will emphasize studies in two areas of possible civilian satellite applications. In the first of these, the navigational satellite, NASA's effort will reflect the interest of such groups as the International Meeting on Marine Aids to Navigation, the Radio Technical Commission for Aeronautics, the National Academy of Sciences, the U.S. Maritime Administration and the Federal Aviation Agency. All of these organizations have recognized the need for greater navigational accuracy for nonmilitary craft. Several have recommended that research be conducted to establish the requirements for a practical civilian navigational satellite system.

Since the Navy is engaged in development of the Transit system for military navigation needs, NASA will conduct a thorough evaluation of the possibilities of meeting civilian requirements through that system. But because of the differences between military and civilian requirements, the present high cost of Transit ground equipment, and the technological advances made since inauguration of Transit development, other techniques will also be investigated to determine the need for an advanced civilian system.

Fiscal year 1964 effort will also concentrate on determining the feasibility of a satellite designed to collect data from widely scattered locations throughout the world, including floating buoys, meteorological balloons, and remote, automatic ground stations. The satellite envisioned would be capable of collecting seismic data, meteorological data near the surface of the earth, oceanographic data, cosmic ray information at high levels of the atmosphere, and geomagnetic data from the 71% of the earth's surface covered by water and from inaccessible land areas such as polar regions or deserts. The program contemplated for fiscal year 1964 will include contracts to identify technical requirements and incorporate recent technical advances into feasibility and preliminary design studies of possible satellite configurations.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

INDUSTRIAL APPLICATIONS

OBJECTIVE:

The objective of the Industrial Applications program is to promote the early and effective utilization of the technological advances evolving from the NASA research and development activities by industry.

SUMMARY OF RESOURCES REQUIREMENTS :

Funds	1962	1963	1964
Industrial Applications, direct R&D costs	$300,000	$2,370,000	$3,500,000
Personnel costs	288,000	675,000	1,180,000
Operation of installations	289,000	715,000	1,419,000
Total costs	$877,000	$3,760,000	$6,099,000
Personnel			
NASA Headquarters	19	39	62
Flight Research Center	1	1	1
Lewis Research Center	8	7	8
Manned Spacecraft Center	2	3	3
Marshall Space Flight Center	6	8	13
Ames Research Center	--	3	4
Langley Research Center	--	4	4
Wallops Station	--	1	2
Western Operations Office	--	1	2
North Eastern Office	--	1	2
Goddard Space Flight Center	--	--	11
Total personnel	36	68	112

Primary responsibility for the program is in the Office of Applications at NASA Headquarters. All of the locations listed above are an integral part of the program and will provide support.

PROGRAM JUSTIFICATION:

In the National Aeronautics and Space Act of 1958, Congress charged NASA to apply the scientific and technical knowledge from its vast research and development program for the benefit of all mankind. One segment of the overall NASA program which has been established to satisfy this requirement is the Industrial Applications program. This program identifies and disseminates to industry new ideas and innovations arising in the course of conducting the

space program. The industrial community will translate these ideas and innovations into new products, processes, techniques, devices, and materials for the benefit of the national community.

EXPLANATION OF FUNDS REQUESTED :

A procedure has been established to identify and document innovations and ideas with industrial potential at NASA Centers and NASA contractors. This information is then evaluated technically to determine the industrial potential. The final step in the procedure is disseminating the information to the industrial community.

In fiscal year 1963, efforts were concentrated on identifying, documenting, and evaluating potential applications. Industrial Applications Officers were designated at each NASA Center and at each operating office to establish and manage the procedures by which personnel identify and document their innovations on special reports.

At NASA Headquarters these reports are evaluated to determine their industrial potential. Non-profit organizations, such as regional research institutes and universities, aid in the evaluation process. These organizations, located across the United States, work with the field Centers and contractors in getting first-hand information on the innovation or idea.

The potential applications, having been identified and evaluated, are disseminated to the industrial community. The initial dissemination method has consisted of briefings to industry, outlining the potential applications. The meetings which were held in a number of midwestern cities in fiscal year 1963 have been well received by the industrial community, and contacts made in the course of these meetings are being followed up.

Other dissemination methods are being considered. Information will be released through existing publications, in one version for management and a second more detailed version for engineers and scientists. Information will be processed through the Office of Scientific and Technical Information in NASA Headquarters to trade journals, professional societies, trade associations, and other government agencies, such as the Small Business Administration and the Office of Technical Services within the Department of Commerce. Educational institutions will also be used in disseminating information to the industrial community.

Studies have already been initiated with industrial concerns to obtain management advice on how best to retrieve innovations and ideas from NASA's industrial contractors.

The funds requested for fiscal year 1964 will be used to expand these pilot programs to encompass a greater proportion of NASA's effort, and to investigate new dissemination techniques which will insure that industry has the information on a timely basis.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

GEOPHYSICS AND ASTRONOMY

OBJECTIVES:

The fundamental objective of the Geophysics and the Astronomy program is to extend our knowledge and understanding of the earth, the sun, and the universe. The major projects, planned and underway, to accomplish this fundamental objective can be grouped into the following disciplines:

GEOPHYSICS

The earth's upper atmosphere, ionosphere, and magnetosphere and the near region of interplanetary space will be explored with the objective of determining the natural environment and to understand the geophysical phenomena involved. These studies provide a scientific basis for meteorological investigations, radio propagation studies, exploration of other planets, and determination of effects on manned and instrumented space flight. Measurements will be made to determine the shape, size, and gravitational field of the earth and the interaction of the earth with the gravitational fields of nearby celestial bodies. In addition to its value as basic scientific data this data is necessary for orbit and trajectory calculations.

SOLAR PHYSICS

A comprehensive study of the sun will be made from above the obscuring and distorting influence of the earth's atmosphere with the objective of understanding its structure, composition, and dynamics as a typical star and to determine its influence on the earth and other planets. Since the sun is the dynamo which drives the solar system, understanding the nature of solar radiation and its fluctuations is necessary to understand the other phenomena involved in geophysics. This study includes not only the measurement of the more conventional electromagnetic radiation, such as visible and ultraviolet radiation and x-rays, but also the solar protons emitted during solar flares. Knowledge of the flux of these particles is required to assess the hazard to manned space flight.

ASTRONOMY

Astronomical observations will be made from above the earth's atmosphere to increase our understanding of the nature, evolution, and natural laws of the universe and to study the behavior of matter and energy.

In addition to these fundamental scientific and technical objectives, the program also has the objective of furthering our international cooperation in the exploration of space.

SUMMARY OF RESOURCES REQUIREMENTS:

Funds	1962	1963	1964
Supporting research and technology	$ 5,200,000	$ 13,700,000	$ 15,200,000
Flight projects	92,575,000	130,800,000	179,200,000
Subtotals, direct R&D costs	$97,775,000	$144,500,000	$194,400,000
Personnel costs	10,091,000	14,566,000	19,033,000
Operation of installations	11,905,000	15,143,000	19,191,000
Total costs	$119,771,000	$174,209,000	$232,624,000
Personnel			
NASA Headquarters	103	119	136
Flight Research Center	1	1	3
Goddard Space Flight Center	1,141	1,297	1,606
Wallops Station	79	90	117
Ames Research Center	---	30	50
Lewis Research Center	---	7	7
Langley Research Center	---	35	35
Pacific Launch Operations Office	---	6	11
North Eastern Office	---	3	3
Total personnel	1,324	1,588	1,968

Primary responsibility for the Geophysics and Astronomy program is in the Office of Space Sciences at NASA Headquarters. The Goddard Space Flight Center is responsible for management of the individual flight projects. Launch vehicle support is provided by Goddard Space Flight Center, Langley Research Center, Marshall Space Flight Center, and the Lewis Research Center. Wallops Station provides support for sounding rocket and Scout launchings. Some of the smaller spacecraft are developed at the Goddard Space Flight Center with much of the subsystem design and almost all of the manufacturing contracted to industry. The larger spacecraft are developed by industrial contractors with the assistance of the NASA laboratories.

About 70 organizations in 26 states including NASA centers, universities and other government and non-government research organizations are now participating in the program by providing scientific experiments and conducting supporting research. The program thus provides a means by which qualified scientists throughout the nation can participate in the exploration of space. It also provides a means whereby student scientists and engineers can participate in the program, gaining training and developing interest in space exploration.

PROGRAM JUSTIFICATION:

The Geophysics and Astronomy program is a logical continuation of a highly successful program of geophysical and astronomical research which this Nation has conducted over several decades. As technology has progressed this program has successively used airplanes, balloons, sounding rockets, and small spin stabilized satellites to carry instrumentation farther and farther from the surface of the earth, and for longer and longer periods of time. Larger, stabilized spacecraft are now being used to conduct the interdisciplinary experiments required to understand the aurora, trapped radiation, and the processes which determine the structure and dynamics of the upper atmosphere. Small satellites are still very useful, and will continue to be used for monitoring and for unique experiments which cannot be carried on the larger observatories.

The sun, as the center of our solar system and the primary source of terrestrial energy, has a profound effect on our existence. It controls the weather and disrupts communications. A major hazard to Apollo stems from the high energy particles ejected from solar flares. As a typical star, the sun offers an opportunity to study at relatively close range the characteristics of bodies which are a principal constituent of the universe. Spacecraft offer a unique opportunity for this study because they overcome the limitations on observation inherent in the earth's atmosphere.

Successively larger ground based telescopes have been used for astronomical studies in order to improve the resolution and increase the range of observation. However, telescopes have always been limited to a very narrow optical region, and by atmospheric turbulence in the resolution which they could obtain. With the increase in payload capability brought about by the large boosters and the development of technology required to produce a large spacecraft such as the Orbiting Astronomical Observatory, capable of pointing a large telescope with great accuracy, both of these fundamental limitations on astronomy will be removed.

Ultimately, as the technology is developed, the techniques of manned flight will be used for the more complex experiments which require the presence of man.

The basic justification for this program is to increase our knowledge and understanding of the universe. The perennial quest for knowledge and control of environment is a natural inclination of man. The space program provides a new and challenging opportunity to satisfy this motivation.

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The Geophysics and Astronomy flight schedule is as follows:

Mission	Launch Vehicle	Launch Location	First Launch
Geophysics			
Explorers & Monitors	Scout/Delta	AMR/PMR	1959
Geophysical Observatories			
Eccentric Orbit	Atlas Agena	AMR	1963
Polar Orbit	Thor Agena	PMR	1964
Geodesy	Delta	AMR	1964
Solar Physics			
OSO	Delta	AMR	1962
Astronomy			
OAO	Atlas Agena	AMR	1965
International			
Ariel (UK #1)	Delta	AMR	1962
United Kingdom #2	Scout	AMR	1963
Allouette (Canada)	Thor Agena	PMR	1962
Polar Ionosphere Beacon	Scout	PMR	1963
Follow-on Program	Scout	AMR/PMR	1964

EXPLANATION OF FUNDS REQUESTED:

Supporting research and technology	1962	1963	1964
Geophysics	$ 3,615,000	$10,161,000	$ 9,500,000
Solar physics	405,000	1,335,000	2,000,000
Astronomy	449,000	1,429,000	3,000,000
Interdisciplinary space sciences	731,000	775,000	700,000
Subtotal, direct R&D costs ...	$ 5,200,000	$13,700,000	$15,200,000
Personnel costs	2,815,000	2,690,000	3,120,000
Operation of installations	3,280,000	2,661,000	2,898,000
Total costs	$11,295,000	$19,051,000	$21,218,000
Total personnel	368	284	322

The supporting research and technology efforts are conducted by universities, NASA installations, and other government and non-government research organizations under the scientific and administrative coordination of the Office of Space Sciences in NASA Headquarters. The program includes theoretical and laboratory research and development of laboratory models of flight experiments. Experiments are not selected for flight projects until their feasibility has been demonstrated to a degree that will give a high probability of successful development of a flight experiment to meet a given flight date. This area of effort also includes the development of experiments to be flown in balloons and aircraft and advanced work on scientific instruments for the manned space flight program. Data which has been obtained from various flight projects and ground based observation is correlated under this program to take advantage of all available information in arriving at conclusions.

The fiscal year 1963 program includes 130 research tasks in 39 universities, 4 NASA Centers and 26 other research organizations. The fiscal year 1964 program will increase the number of these efforts and will bring additional universities into the program. The program has been developed primarily on the basis of unsolicited proposals, which are evaluated for the research idea and the competence of the scientific research team involved. This approach not only encourages initiative on the part of scientists throughout the country, but also results in a higher quality of research, since the scientists are working in the areas of their highest interest and competence. Major elements in the direction of the program include consultation between NASA program scientists and the research scientists involved and participation by representative scientists from outside NASA in the planning of the program.

Flight projects

Geophysics

Explorers and monitors	1962	1963	1964
Spacecraft.....	$4,483,000	$9,300,000	$11,800,000
Launch vehicles.....	---	11,200,000	8,800,000
Orbiting geophysical observatories			
Spacecraft.....	20,629,000	27,500,000	39,600,000
Launch vehicles.....	5,100,000	11,000,000	22,200,000
Geodesy			
Spacecraft.....	---	---	3,400,000
Launch vehicles.....	---	---	2,800,000
Subtotal, direct R&D costs.....	$30,212,000	$59,000,000	$88,600,000

Flight projects (continued)	1962	1963	1964
Personnel costs.....	3,379,000	5,373,000	6,939,000
Operation of installations..	3,943,000	5,605,000	7,119,000
Total costs.....	$37,534,000	$69,978,000	$102,658,000
Total personnel.....	442	562	710

Explorers and monitors

Explorers are smaller satellites designed to carry a specific group of experiments into orbits especially selected for the experiments involved. They have the advantage of a comparatively short development leadtime and can be launched by Delta and Scout launch vehicles. These satellites have demonstrated that some measurements must be repeated over an extended period of time to monitor variations in the phenomena and their relationships to the solar cycle. For this purpose Monitors are being developed, which will fly a relatively standard set of instruments in a standard spacecraft. These will be launched by Delta launch vehicles.

Explorer satellites flown to date have provided a substantial amount of information on cosmic radiation, the great radiation belt, the earth's magnetic field, and the effects of solar events on the environment of the earth. Explorer XII, developed by the Goddard Space Flight Center and launched on August 15, 1961 by a Delta vehicle, traversed the earth's magnetosphere at altitudes ranging 180 miles to 47,800 miles. Each orbit lasted about 26 hours. Since this spacecraft operated prior to the high altitude nuclear tests which produced the artificial radiation belts, it provided a good basis for assessing the changes produced by those tests.

Explorer XIV, which is similar to Explorer XII, was launched on October 2, 1962. It traverses the earth's magnetosphere out to about 61,000 miles. Each orbit lasts about 36 hours. Preliminary results from this spacecraft indicate that the Van Allen radiation belt is essentially unchanged by the high altitude nuclear explosions except in the areas within 3,000 miles of the earth. These results also indicate that, for spacecraft operating at altitudes between 200 and 1,000 miles, solar cells should be shielded to prevent power deterioration due to radiation damage.

Explorer XV was launched on October 27, 1962, specifically to study further the man made radiation belts created by the high altitude nuclear tests. Incorporating experiments designed for Explorer XIV, Telstar, and Relay, this satellite was launched into an orbit of 194 to 10,900 statute miles and circles the earth every 5 1/4 hours.

Data taken by Explorer VII and balloon flights have shown that at certain times, such as during the solar proton events of November 1960, an unprotected astronaut would have received a lethal radiation dosage of about 3,000 R. These data, together with information available from other solar

events, have shown that the design of shielding from solar protons is a major problem area in the Apollo program. Theoretical studies and analysis of the arrival times of solar protons at the earth have shown that the configuration of the interplanetary magnetic field can affect the duration, intensity, and angular distribution of a solar proton event.

In order to provide the data needed for Apollo and to extend our research on energetic particles and magnetic fields into interplanetary space, development of a series of Interplanetary Monitor satellites has been initiated by the Goddard Space Flight Center. The first of the series is scheduled to be launched in the latter part of 1963. It will be sent on a highly eccentric orbit reaching an altitude of about 173,000 statute miles, only 48,600 miles away from the position at which the moon comes closest to the earth. The satellite's structural design is taken directly from the highly successful Explorer XII, XIV and XV series of satellites. It will weigh about 125 pounds, be spin stabilized, and initially powered by solar cell arrays charging silver cadmium batteries. The system has sufficient transmitter power that even at 173,000 miles from earth the data can be received by the NASA minitrack stations. The Interplanetary Monitors will be launched by Delta vehicles at intervals which will provide for continuous monitoring.

An isotopic power supply is being considered for the third spacecraft of the Interplanetary Monitor series. The system would weigh about the same as the solar paddles and batteries which it would replace. It has been used successfully on the Navy's Transit 4A satellite. The isotopic power supply is expected to extend the useful lifetime of the satellite and provide a more reliable source of power.

Measurements of density, composition, pressure, and temperature of the earth's upper atmosphere have been made with sounding rockets and by tracking inflated sphere satellites (Explorer IX and Echo I). The first atmospheric structures satellite designed to measure these properties by means of gauges and spectrometers will be launched early in 1963. By orbiting such instruments in a satellite we will be able to study the variations of these properties with altitude, latitude, and time of day. This Explorer, developed by the Goddard Space Flight Center, is a spherical spacecraft with a 35 inch diameter and weighs about 400 pounds. It will be launched by a Delta vehicle into an orbit ranging from 160 to 700 statute miles and covering the equatorial and temperate latitudes. A second identical spacecraft is scheduled for launch late in 1963 or early 1964 to continue these measurements.

Development of an Atmosphere Monitor is being undertaken in fiscal year 1964 for initial launching in 1965. It will be launched by an improved Delta vehicle capable of putting it in a polar or near a polar orbit. This will make it possible to monitor the atmosphere at all latitudes. The design of the spacecraft will be based on the design of the atmospheric structures Explorer, but it will incorporate sensors, spectrometers, and a power supply designed for long life and reliability. Additional Atmosphere Monitor spacecraft will be scheduled to provide for continuous monitoring of the atmosphere over a complete solar cycle.

Direct measurements of ion and electron temperature and density in the earth's ionosphere have been made with sounding rockets, Scout probes, and the Explorer VIII satellite. The Canadian Allouette is currently sounding the ionosphere from above using a swept frequency technique to examine the structure of the top side of the ionosphere, estimate the cosmic noise level, and measure electron density in the vicinity of the satellite.

Two Explorer satellites will be launched in 1963 and 1964 to continue these measurements using a fixed frequency technique for sounding which will give a higher information rate although the resolution will not be as high. These satellites, developed under NASA sponsorship by the Central Radio Propagation Laboratory of the National Bureau of Standards and the Airborne Instruments Laboratory, will be launched into nearly circular polar orbits of about 600 miles altitude by Scout vehicles.

Measurements made to date have made it possible to initiate the design of an Ionosphere Monitor which will incorporate the best features of the earlier satellites and probes into a standard spacecraft design for continuous monitoring of the ionosphere over a complete solar cycle. The spacecraft will have a sounder for monitoring the topside of the ionosphere, beacons for transmission of signals which can be received on the ground for ionospheric propagation research, and instruments for direct measurements in the vicinity of the satellite. The first of these Monitors will be launched in 1965 by a Delta vehicle.

Orbiting geophysical observatories

The Orbiting Geophysical Observatories (OGO), which are being developed by the Space Technology Laboratory under the management of the Goddard Space Flight Center, are designed to carry large numbers of diversified experiments for obtaining correlated scientific and technological measurements within the earth's atmosphere, the magnetosphere, and cislunar space to obtain a better understanding of the earth-sun relationship and the earth as a planet. The data acquired will be utilized to evaluate the hazards of space to manned and unmanned space flight, as well as to provide a portion of the scientific base required to understand the complex phenomena associated with our solar system, our galaxy, and the universe.

The spacecraft consists of a basic box-shaped body, approximately two and one-half feet square by five and one-half feet long. The "box" provides space for scientific experiments and the subsystems required to control the attitude and temperature of the spacecraft, transmit the acquired data to the ground, control the observatory from the ground, and supply the power. In addition, the "box" supports the solar paddles utilized for power generation and various booms which carry experiments, antennas, and gas jets. The attitude of the observatory is controlled to fulfill the experiment requirements for pointing at the earth, space, the sun, and along the orbital plane. The weight of the observatory is approximately 1,000 pounds.

The first OGO, an Eccentric Orbiting Geophysical Observatory (EGC), will be launched in 1963 by an Atlas-Agena vehicle into a highly eccentric orbit passing through the Van Allen radiation belt. Over a year ago, twenty experiments were chosen for this mission to study solar and galactic radiation, the Van Allen radiation belt, the earth's magnetic field, the ionosphere, the upper atmosphere, micrometeoroids, and radio noise associated with the galaxy.

The second OGO, a Polar Orbiting Geophysical Observatory (POGO), is scheduled for launch in 1964 by a Thor-Agena vehicle. POGO will fly over the polar regions at relatively low altitudes to obtain data in the upper atmosphere and ionosphere. Twenty experiments have been chosen for this mission to obtain information similar to that which will be obtained from EGO. Since the data will be acquired in the region close to the earth, most of the POGO experiments are associated with solar-terrestrial relationships.

It is now planned to continue the OGO missions through a complete solar cycle in order to obtain continuous scientific data concerning the earth-sun relationships. Certain experiment types will be standard aboard each flight, while others will be dependent upon the requirements for information concerning new discoveries. The spacecraft will be updated to the state-of-the-art and modified to provide special capabilities. Initially, the Atlas-Agena and Thor-Agena vehicles will produce the desired orbits, but as heavier payloads and more power consuming orbits are required, boosters with increased capability will be needed.

Geodesy

The first geodetic satellite, ANNA, has been successfully launched. The data from this satellite will improve our knowledge of the earth's gravitation field and the location of points on the surface of the earth. In order to specify the gravitational field of the earth to the accuracy required for placing a communication satellite in geostationary orbit, additional geodetic satellites must be launched at different inclinations and at different altitudes from that of ANNA; these satellites will also be necessary for calibrating our satellites and space probe tracking techniques. Additional geodetic satellites with radio and optical tracking aids will be launched with Delta vehicles beginning in 1964.

Solar physics

Orbiting solar observatory	1962	1963	1964
Spacecraft	$3,242,000	$ 8,650,000	$12,600,000
Launch vehicles	2,500,000	2,700,000	4,800,000
Subtotal, direct R&D costs	$5,742,000	$11,350,000	$17,400,000

	1962	1963	1964
Personnel costs.....	$512,000	$736,000	$1,626,000
Operation of installations...	597,000	759,000	1,623,000
Total costs.....	$6,851,000	$12,845,000	$20,649,000
Total personnel.....	67	77	166

Ground based solar observations and experiments from rockets have shown that the ultra-violet and soft X-ray portion of the solar radiation varies with solar activity. In order to study this phenomenon it was necessary to develop a spacecraft capable of pointing experiments at the sun for long periods of time and telemetering the energy input in certain spectral regions. The Orbiting Solar Observary (OSO) was developed to do this.

The first solar observatory, OSO I, was launched into orbit around the earth in April 1962 by a Delta launch vehicle. It was developed by Ball Brothers Research Laboratory, Boulder, Colorado. The spacecraft consists of a spinning "wheel" for gyroscopically stabilizing the spacecraft in orbit, and a section capable of pointing experiments at the sun within one minute of arc. This means that the instruments are pointed at the center of the sun with an accuracy equal to 1/30 of the sun's diameter. Experiments are also carried in the spinning "wheel" in such a manner that they look at the sun during each revolution of the wheel and compare the radiations from the sun with radiation from other parts of the sky. The experiments carried on OSO I have provided our most comprehensive information to date on the mechanisms in the solar atmosphere at the time of a solar flare.

While the first OSO pointed its experiments only at the center of the sun making possible spectral measurements as a function of time, it was not possible to relate fluctuations in the spectrum to particular sunspots or active regions on the sun. The next OSO which will be able to scan the sun's surface, will accomplish this objective. One of the major experiments on OSO II will incorporate an occulting disk which will obscure the main body of the sun from the instrument field of view so that studies can be made of the sun's corona or outer atmosphere. This spacecraft will be launched in the first half of 1963. Additional flights are planned with the OSO type spacecraft at approximately six month intervals to continue the studies of the phenomena on the surface of the sun and to monitor solar activity.

Although OSO I has already provided and OSO II will provide a major advance in our understanding of solar physics, they have limited payload capability and pointing accuracy and cannot be trained on a particular region on the sun. In order to understand the mechanisms responsible for a solar flare, and help to provide a warning of an impending increase in the radiation level to an Apollo astronaut, a satellite is needed which can point a heavier set of experiments at a very small region on the sun.

Study contracts have been let with three firms which will lead to the development of an Advanced OSO that will have a capability of pointing all of its experiments at the sun. The spacecraft will carry larger and more complex experiments and point them with an accuracy of five seconds of arc or about 1/360th of the sun's diameter. With offset pointing and scan capability it will be able to concentrate its instruments on individual areas of the sun small enough to make detailed studies of individual solar flares. This should make possible a comprehensive study of that part of the sun which can be seen from the plane of the earth's orbit. Plans call for launching this spacecraft into a polar orbit with an Atlas-Agena launch vehicle. Additional study of this system and its experiments will be conducted throughout 1963. In addition, preliminary design of the spacecraft and the "breadboarding" of long lead-time subsystems will be initiated during 1964.

In addition to electromagnetic radiation, the sun also emits charged particles. These can be divided into (1) a relatively constant flux of very low energy protons and electrons (the solar wind) and (2) much more energetic protons, emitted during the large solar flares, which constitute a major hazard to manned space flight. In order to understand these phenomena and to be able to predict the onset, duration, and intensity of a solar proton event, it is necessary to monitor simultaneously the optical flux from the sun, the solar wind, the magnetic field, and the flux of the energetic protons. The OSO spacecraft will provide data correlated in time with that of two other spacecraft to accomplish this. The details of the Interplanetary monitor, which will make measurements in the vicinity of the earth, are described in the Geophysics flight program.

Astronomy	1962	1963	1964
Orbiting astronomical observatory			
Spacecraft.....	$34,821,000	$31,800,000	$37,800,000
Launch vehicles.....	3,400,000	4,300,000	15,100,000
Subtotal, direct R&D costs	$38,221,000	$36,100,000	$52,900,000
Personnel costs.....	489,000	1,615,000	2,859,000
Operation of installations....	571,000	1,665,000	2,846,000
Total costs.....	$39,281,000	$39,380,000	$58,605,000
Total personnel.....	64	209	292

The objective of the Orbiting Astronomical Observatory (OAO) is to provide a stabilized platform in space for making observations of the stars, planets, nebulae, and interplanetary and interstellar media in the relatively unexplored infra-red, ultraviolet, X-ray, and gamma ray regions of the electromagnetic spectrum. This spacecraft, which is ten feet in diameter,

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ten feet long, and weighs about 3600 pounds, is being developed by the Grumman Aircraft Engineering Corporation. The first OAO, which will be launched in 1965, will have a "coarse" control system capable of pointing the spacecraft in any desired direction with an accuracy of one minute of arc. Subsequent spacecraft will have an additional capability of "fine" pointing the primary instrument with an accuracy of one second of arc. The first OAO will carry two major experiments, one looking from each end of the spacecraft. The Smithsonian Astrophysical Observatory is preparing an instrument which will use four 12-inch telescopes with a broad band television ultraviolet photometer. It will map the sky and record the brightness of 200,000 stars. The University of Wisconsin is preparing the other major experiment for the first spacecraft. It will use four 8-inch telescopes, a 16-inch telescope, and 2 spectrometers to study the energy distribution of individual stars and nebulae over a wide enough range of the ultraviolet region of the spectrum to provide information on the structure and properties of several hundred of the brightest stars and nebulae.

The second OAO spacecraft, to be launched in 1965, will carry a 36-inch Cassegrain telescope with a large aperture spectrophotometer. Using the fine pointing control, this instrument can be focused on several thousand selected stars and nebulae to provide detailed data on temperature, pressure, density, and chemical composition.

Princeton University has been selected to prepare the major experiment for the third spacecraft which is schedule for launch early in 1966. The experiment will be designed to make quantitative observations of the absorption spectrum of interstellar gas in the ultraviolet region of the spectrum. From these data information is provided on the chemical composition of interstellar gas and dust, the pressure and temperature, its state of ionization, velocity, position and relative proportion of occurrences in space.

Work on additional experiments will be initiated in fiscal year 1964. Astronomical instrumentation is being flown on sounding rockets to determine the best combination of instruments to give the greatest amount of information when flown on the OAO. The launch vehicle for the OAO will be the Atlas-Agena modified to accommodate the ten foot diameter and 3600 pound weight of the spacecraft.

International satellites	1962	1963	1964
Spacecraft.....	$3,285,000	$2,300,000	$1,500,000
Launch vehicles.....	7,350,000	10,550,000	5,500,000
Subtotal, direct R&D costs.	$10,635,000	$12,850,000	$7,000,000
Personnel costs.....	954,000	1,445,000	1,493,000
Operation of installations...	1,120,000	1,457,000	1,387,000
Total costs.....	$12,709,000	$15,752,000	$9,880,000
Total personnel.....	125	157	157

A number of international cooperative space exploration efforts have been undertaken under this program. These include the Ariel satellite for which the United Kingdom furnished the experiments and NASA furnished the spacecraft and launch vehicle. A second United Kingdom satellite under similar arrangements is now under development. It is expected that the United Kingdom will construct a third satellite for which NASA will provide the launch vehicle and support services. The successful Canadian-built Allouette satellite had test and support service and the launch vehicle provided by NASA. NASA is also participating in the acquisition, reduction and analysis of data from these satellites.

A Polar Ionosphere Beacon satellite is being developed by the Applied Physics Laboratory of the Johns Hopkins University under NASA sponsorship. Widespread international participation has been arranged using the beacon for ionospheric propagation research from ground based stations.

The Italian Project was conceived to place an Italian-built satellite into an equatorial orbit utilizing a Scout launch vehicle. This satellite will make both a density and ionospheric measurement and will be launched from a mobile platform located on or near the equator. The Geophysics and Astronomy program is planned so that the scientific results of these international efforts complement the NASA projects and the scientific data is made available to U.S. scientists. Each country finances its own efforts in these cooperative projects.

Sounding rockets and geoprobes	1962	1963	1964
Sounding rockets and geoprobes, subtotal, direct R&D costs...	$7,765,000	$11,500,000	$13,300,000
Personnel costs.....	1,942,000	2,707,000	2,996,000
Operation of installations.....	2,394,000	2,996,000	3,318,000
Total costs.....	$12,101,000	$17,203,000	$19,614,000
Total personnel.....	258	299	321

During the past year NASA has continued to conduct vertical soundings in many scientific areas. Nike Cajun, Nike Apache, Aerobee, Javelin, and Journeyman rockets have and will continue to be used for this purpose.

Significant progress has been made using spectrometers in measuring the atomic and molecular mass composition of the upper atmosphere. Coordinated studies of wind shears, turbulence, and temperatures in the upper atmosphere have been conducted from sites in northern and temperate latitudes and in the southern hemisphere using chemical releases and grenades. NASA, the Air Force, and Sweden have cooperated in an experiment to sample noctilucent clouds-very high, fast moving, luminous clouds-that occur only in certain regions of the auroral zone.

Ionosphere probes have been launched during 1962 containing Japanese designed radio frequency resonance experiments and U.S. designed Langmiur probes. These probes measured simultaneously electron density and temperature using the two independent techniques.

Sounding rocket flights have studied the behavior of liquid hydrogen under the weightless conditions of space. This information is of importance to the Centaur and Saturn vehicle development programs.

The first successful launching of a low frequency radio astronomy receiver was accomplished on a sounding rocket in 1962. The experiment provided data on the low frequency radio waves in the Milky Way. Analysis of these data is expected to provide information on the evolution of our galaxy and on the radio background noise against which communications between space vehicles must be made.

Emphasis in fiscal years 1963 and 1964 is being placed on preparation of experiments to be conducted during the Internation Year of the Quiet Sun (1964-65). Ionospheric studies and studies on the structure, dynamics, and absorption characteristics of the atmosphere will be made during this period and correlated with solar observation to describe the earth's environment during a period in which it is least affected by solar activity.

In July 1963, an eclipse of the sun will be observed from the vicinity of Fort Churchill, Canada, where sounding rockets will be launched to measure both electron temperature and density, and airglow during the eclipse.

Increased emphasis will be placed on the use of sounding rockets for solar and galactic astronomy experiments. In addition to providing very useful astronomical data on the sun, the stars, and the planets these flights will check out instruments for later flights on the more expensive astronomical observatories.

Javelin and Journeyman vehicles will be used to launch geoprobes which will carry combinations of instruments to make coordinated verticle profiles of the atmosphere and ionosphere.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

LUNAR AND PLANETARY EXPLORATION

OBJECTIVES:

The primary objective of the Lunar and Planetary Exploration Program is the exploration of the solar system. An immediate objective of the program is to obtain scientific information and design data required for manned spaceflight systems development, particularly for the manned lunar landing program.

Effort supporting these basic objectives consists of two broad categories: science and technology. The scientific effort includes studies of the sun, moon, planets, and interplanetary space. The technological work includes the development of space vehicle systems, particularly spacecraft, necessary to carry scientific payloads to the moon and planets, and to accomplish landings on these bodies.

Lunar program

A principal scientific objective of the lunar program is the exploration of the moon and its environs for information on the history of the earth-moon system and on the origin of planetary bodies in the solar system. Experiments to be performed are intended to provide information on the surface structure, physical properties of the surface, and origin of the surface features.

Unmanned lunar exploration is an essentail step in preparing for a successful, safe, manned landing on the moon. Visual observations made at some distance from the moon's surface will play an important part. However, in the final analysis, only observations made on the surface can measure the bearing strength of the surface and the contours of surface irregularities. Such information is necessary before manned lunar landings can be attempted with adequate confidence.

Planetary and interplanetary programs

The basic objective of the planetary and interplanetary programs is the exploration of the sun, interplanetary space, the planets and their satellites, comets, and asteroids.

The accomplishment of these objectives will be initiated by unmanned fly-by missions to Mars and Venus because such missions are, by comparison, easier to accomplish and provide the greatest assurance of returning significant data. Fly-by missions will be followed by capsule landings, and finally planet-orbiting spacecraft with large landing capsules which can carry out detailed study of the planetary surfaces.

The experiments and objectives of these flights to the planets parallel those described for the lunar program except that greater emphasis will be placed initially on the determination of atmospheric characteristics and on the detection of life or life forms.

SUMMARY OF RESOURCE REQUIREMENTS:

Funds	1962	1963	1964
Supporting research and technology.....	$10,843,000	$20,244,000	$20,000,000
Flight program:			
Ranger.....	63,430,000	78,970,000	90,000,000
Surveyor:			
Lander.....	37,938,000	59,996,000	69,300,000
Orbiter.....	1,196,000	1,700,000	28,200,000
Mariner:			
Mariner A.....	5,726,000	---	---
Mariner Venues fly-by....	30,226,000	9,096,000	---
Mariner Mars fly-by.....	---	29,400,000	47,000,000
Venus/Mars lander.....	12,425,000	18,273,000	53,100,000
Pioneer.....	---	3,500,000	15,000,000
Subtotal, direct R&D costs.....	$161,784,000	$221,179,000	$322,600,000
Personnel costs.....	1,446,000	2,830,000	4,757,000
Operation of installations...	1,401,000	2,383,000	3,913,000
Total costs.....	$164,631,000	$226,392,000	$331,270,000
Personnel			
NASA Headquarters.....	83	101	113
Goddard Space Flight Center..	34	21	86
Western Operations Office....	76	129	135
Ames Research Center.....	-	83	133
Wallops Station.....	-	2	4
North Eastern Office.....	-	3	3
Total personnel.....	193	339	474

Primary cognizance of the lunar and planetary programs is in the Office of Space Sciences in NASA Headquarters. Responsibility for the conduct of the major portions of the technical program rests with the Jet Propulsion Laboratory and the Ames Research Center. Contributions are also made by the installations listed above.

PROGRAM JUSTIFICATION:

The exploration of the moon is important to science because its surface has not been subjected to the erosion of winds and water, and therefore may preserve a record of the early history of the solar system. This record may well be lost forever on the earth, Mars, or Venus. The possibility exists that the moon may also have on or near its surface organic molecules which will provide a clue to the development of physical life on the earth.

Exploration of the planets presents a different type of attraction, because they all differ markedly from the earth. In these very differences may lie clues to the nature, origin, and evolution of the solar system. The study of other planets will certainly provide better knowledge of the earth. The expected discovery of organic molecules and life forms may have tremendous implications not only in basic chemistry and biology but even in medicine. The scientific study of solar and interplanetary space will strengthen the understanding of the sun-earth relationships on which not only our comfprt but our life cycle itself so intimately depend. Vital information will be gathered on potential hazards which await future space travelers. Included in this category are lethal solar radiation streams, lunar and planetary terrains, and even planetary meteorological conditions. Knowledge may be uncovered to permit utilization of natural resources at these distant destinations.

A fundamental prerequisite to the exploration of the solar system is the development of spacecraft capable of performing the desired missions. This achievement requires the perfection and integration of many technologies, including attitude sensing and control; midcourse navigation (radio-command techniques for lunar missions and self-contained celestial navigation for distant planetary missions); terminal guidance and spacecraft propulsion; long-range communications; precise orientation of spacecraft-borne components such as antennas, sensors, and radiators; long-term power gneration sources and systems; control of internal and surface temperatures under widely varying conditions; design of extremely efficient structures capable of functioning under the wide range of environmental conditions to which the spacecraft will be exposed; the solution of the problems of entry into planetary atmospheres; and the development of automatic or remotely-controlled devices for transporting instrumentation over the planetary surface, gathering samples of planetary matter, analyzing them and transmitting the data to earth.

Lunar and planetary projects are planned to evolve to utilize the full capabilities of new launch vehicles as they become operational. Spacecraft and instrumentation development are phased to this capability. The lunar and planetary exploration program has been planned to avoid duplication and to promote reliability in the spacecraft development area. Every effort has been made to minimize the number of types of spacecraft and to maximize the number of uses for each type. Wherever possible, the same basic subsystems or their advanced derivatives will be employed in successive spacecraft series. This will result in the evolutionary development of a

family of unmanned exploration spacecraft, wherein the relatively simple systems and limited capabilities of early spacecraft will be extended and refined as launch vehicle weightlifting capability is increased. This building-block concept will permit exploitation of early unmanned scientific and technological missions as part of an orderly flight-qualification sequence prior to undertaking manned exploration activities.

The Lunar and Planetary Exploration flight schedule is as follows:

Mission	Launch Vehicle	Calendar Year of First Launch	Launch Location
Ranger			
Test	Atlas-Agena	1961	AMR
Capsule	Atlas-Agena	1962	AMR
TV Package	Atlas-Agena	1963	AMR
Surveyor			
Lander	Atlas-Centaur	1964	AMR
Orbiter	Atlas-Centaur	1965	AMR
Mariner			
Venus	Atlas-Agena	1962	AMR
Mars	Atlas-Agena	1964	AMR
Lander	Atlas-Centaur	1965	AMR
Pioneer	Thor-Delta	1964	AMR

EXPLANATION OF FUNDS REQUESTED:

Supporting research and technology	1962	1963	1964
Lunar.....	$2,873,000	$4,504,000	$3,895,000
Planetary and interplanetary.	7,970,000	15,740,000	16,105,000
Subtotal, direct R&D costs.	$10,843,000	$20,244,000	$20,000,000
Personnel costs.....	410,000	953,000	1,739,000
Operation of installations...	479,000	816,000	1,512,000
Total costs.....	$11,732,000	$22,013,000	$23,251,000
Total personnel.....	53	106	180

Supporting research and technology effort falls into three major categories: science, technology, and advanced studies.

The goal of the science portion of supporting research is the acquisition of knowledge about the moon, the planets, and interplanetary space by means of ground-based observation and study efforts aimed at predicting and simulating extraterrestrial environments. These efforts are essential for the proper design of scientific instrumentation and to provide standards against which later flight data can be compared. There is a particularly urgent need in this area to provide scientific information vital to the manned space flight missions.

Lunar studies will continue by telescopic observations, analysis of lunar photographs, construction of topographic charts, and interpretation of the information to gain geological data. Research is underway in the simulation of lunar surfaces, the effect of hypervelocity impact of small particles on these surfaces, and the analysis of meteoritic and tektitic materials. In the interplanetary area, support is provided for land-based and balloon-borne studies of the composition of space, including particulate matter from the sun and from interstelllar space; magnetic and electrical fields, including gravitational fields; and instrumentation for studies by spacecraft. Concerning the planets themselves, use is made of physical techniques such as optical, radio, and radar astronomy, to acquire specific information about the atmospheric composition of the planets, including ionospheres, if present. Research is also being supported in the simulation of planetary atmospheres and related theoretical areas. Since the research in many instances depends upon the adequacy of the physical instruments used in these studies, instrument development is supported where necessary to assure availability of adequate equipment.

Work in the area of technology is directed toward advancing the engineering of spacecraft hardware in support of current and planned lunar and planetary flight projects. It consists of investifation and verification of new concepts. Discoveries which are derived from basic research are translated into engineering practices thereby enabling the development of actual flight hardware of improved performance capability. This effort also supports follow-on versions of current projects as well as the planning of future misssons to the moon, planets, sun, and out-of-the-ecliptic destinations, both for scientific exploration and as preludes to manned space flight.

The cost of obtaining scientific data from space increases with the total weight of the payloads boosted, and decreases as the useful life and the performance level are increased. Therefore, ways are being sought to reduce the weight of the structure to allow more scientific instruments aboard, while at the same time increasing both the reliability and the level of performance, thus reducing the cost per item of scientific data obtained. Techniques will be developed for ejecting capsules from passing spacecraft, to enter the atmosphere and land on a planetary surface, transmitting scientific data during the descent and after landing. Since spacecraft that land on Mars and Venus must be biologically sterile, spacecraft components which will not deteriorate when sterilized are required. Communication systems which will operate reliably over long distances must

be developed, as well as improvements in on-board processing of data which will enable more scientific data to be handled per unit of time.

The work will be done at the Jet Propulsion Laboratory (JPL), at various NASA Centers, and by contract with private concerns and universities. Many of the individual tasks to be performed by JPL and by NASA Centers are continuations of work initiated in previous years. Funding requirements for these tasks, and for new tasks, are based on experience for comparable work previously conducted. Estimates for contracts are based on projected needs and upon the exploitation of promising proposals made to NASA.

Work during fiscal year 1964 is part of a continuing program to support flight programs projected for the next several years. Due to its nature, the technology effort must be started early to allow time for re-orienting effort to exploit break-throughs or promising avenues not initially apparent, for overcoming unexpected difficulties, and for examining alternate techniques before selecting the best one.

Studies of advanced systems are conducted to support planning of current and future programs, and to assist in obtaining the best program for current projects.

Advanced studies fall into two categories: studies of a general nature, such as space flight mechanics and planetary trajectories, which support all lunar and planetary projects; and studies of potential future spacecraft systems to determine their need, feasibility and general configuration. These studies are generally conducted at NASA Centers; however, some studies are conducted by industry under NASA contract. Supporting studies of advanced lunar and planetary systems have been conducted since the beginning of NASA. Out of this activity several projects have been modified and new ones have emerged.

Flight Projects

Ranger	1962	1963	1964
Spacecraft.....	$32,530,000	$44,170,000	$48,300,000
Launch vehicles.....	30,900,000	34,800,000	41,700,000
Subtotal, direct R&D costs.	$63,430,000	$78,970,000	$90,000,000
Personnel costs.....	380,000	467,000	581,000
Operation of installations...	354,000	382,000	392,000
Total costs.....	$64,164,000	$79,819,000	$90,973,000
Total personnel.....	51	60	55

The mission of the Ranger project is to obtain basic scientific data required to understand the origin and nature of the moon and to obtain the information required for adequate design of spacecraft for the manned space flight program.

The Ranger spacecraft consists of a basic hexagonal structure, or bus, which is capable of carrying various payloads. Equipment required for attitude control, communications, electrical power, and spacecraft environmental control is common to the bus for any of the scientific missions which Ranger might be called upon to perform. An Atlas-Agena launch vehicle is used to place the 800-pound Ranger on its desired trajectory.

Of the five flights attempted to date, two spacecraft were placed in close earth orbit, two into orbits about the sun after flying by the moon, and one impacted on the far side of the moon.

The primary mission of the first two Ranger flights, which were made in 1961, was to provide engineering tests of the spacecraft system. A secondary objective was to measure significant characteristics of the interplanetary medium along a 700,000 mile highly elliptical earth orbit. The second stage of the launch vehicle failed to perform as planned during both flights, resulting in the spacecraft being placed in a near earth orbit. The spacecraft appeared to function normally.

The next three Rangers, launched in 1962, were designed to perform a lunar rough landing mission. The spacecraft carried equipment to send back about 100 television pictures of the lunar surface, to measure the gamma ray activity in space and at the surface of the moon, and to furnish data on the radar reflectivity characteristics of the lunar surface. In addition, a major mission objective was to hard land on the lunar surface a 56-pound survivable capsule containing a highly sensitive seismometer. A launch vehicle malfunction resulted in the Ranger III passing ahead of the moon. The spacecraft functioned normally until an attempt to obtain pictures during fly-by. The launch vehicle performed properly for Rangers IV and V but the spacecraft malfunctioned.

The engineering data obtained from these five flights have been used to advantage in both the Ranger and Mariner programs. For example, the Mariner II solar panels were enlarged based on Ranger III data; and the Mariner central computer and sequencer was provided with redundant capability as a result of the failure of this component on Ranger IV.

The mission for the next Ranger flight, scheduled in calendar year 1963, will be to ob ain high resolution television pictures of the lunar surface. The spacecraft will be basically the same as for earlier Rangers except that the landing capsule will be replaced by a cluster of six television cameras fixed to the bus. The television system will begin operation at a distance above the lunar surface which will provide pictures of a quality equivalent to present earth-based telescopic photographs. Coverage will continue until impact, with the quality of the last picture sufficient to identify an object a few feet in diameter. In addition to the television equipment, several experiments for studying the space environment during flight will be included.

Additional flights in calendar years 1964 and 1965 are planned. The payloads that will be flown on these flights will be determined based on data obtained from previous shots. Several worthwhile payloads, including the type unsuccessfully flown on Rangers III, IV, and V are under consideration.

Payloads also being considered for these flights include a seismometer hard-landing capsule similar to the one flown on Rangers III-V or the television package which will be flown on Rangers VI-IX. Another payload now undergoing preliminary development is the hard-landing photo-reconaissance capsule. This capsule, upon landing on the lunar surface, will take a 360° panoramic picture of the landscape with sufficient detail to identify objects two-tenths of an inch in size in the immediate vicinity of the capsule.

Among the major subcontractors incolved, the Aeronutronics Division of Ford Motor Company supplied the hard landing capsules for Rangers III, IV, and V, and the Radio Corporation of America will furnish the high-resoultion television package scheduled for flight on the next four Rangers.

Surveyor

	1962	1963	1964
Lander	$35,629,000	$48,296,000	$37,500,000
Orbiter	1,196,000	1,700,000	18,000,000
Launch vehicles	2,309,000	11,700,000	42,000,000
Subtotal, direct R&D costs	$39,134,000	$61,696,000	$97,500,000
Personnel costs	294,000	516,000	740,000
Operation of installations	250,000	420,000	500,000
Total costs	$39,678,000	$62,632,000	$98,740,000
Total personnel	40	67	70

Lander

The Surveyor lander spacecraft is being developed to accomplish the first soft landings on the moon. The successful development of this spacecraft will make significant contributions to the technology of spacecraft capable of performing complex precision maneuvers in space. The first objective of the Surveyor project is, therefore, to demonstrate a soft alnding on the moon. Once safely down on the lunar surface, the lander will serve as a remote observation post for surveying the lunar topography and examining the surface texture. It will also function as a stationary laboratory for measuring the physical and chemical characteristics of the lunar surface and subsurface, and the environmental conditions on the moon. Typical of the data to be obtained by Surveyor are high-resolution television pictures of the terrain in the vicinity of the landing site, measurements of the lunar surface hardness and other physical characteristics, its chemical and minerological composition,

seismic activity, and the rate of meteorite particles striking the moon.

In addition to its scientific function as a lunar research laboratory, the lander will provide essential data in support of the Apollo manned lunar landing program. Specifically, it will test and verify the suitability of various landing sites for Apollo landings and will provide essential statistical data on the meteoroid hazard on the lunar surface, which are required for the proper design of protective shielding in the outer skin of the Apollo spacecraft and in the astronauts' space suits.

The lander spacecraft system is currently under development by the Hughes Aircraft Company. Major subcontractors are Thiokol-Elkton for the main retrorocket, Thiokol Reaction Motors Division for the vernier propulsion system, and Ryan Electronics for the altitude and velocity radars. The responsibility for management has been assigned to the Jet Propulsion Laboratory.

During fiscal years 1961 and 1962, the lander effort was directed largely toward engineering design, and component and subsystem development and testing. Also during fiscal year 1962, the fabrication of the proof-test model of the spacecraft was begun. Significant tests, such as main retro-and vernier-engine propulsion tests, laboratory drop tests to study landing dynamics, and free-fall drop tests of the terminal-descent sequence from a tethered balloon were started. The activities in fiscal year 1964 will be concentrated primarily on extensive system tests of the proof-test spacecraft and the production of the first flight units. These system tests will include thermal-vacuum tests, shock tests, tethered tests with the propulsion system operative, simulation of the entire mission profile in the environmental chamber, and field tests in the California desert where the spacecraft will be operated by radio command and data retrieved as though it were on the moon. Also in fiscal year 1964, a number of tests of critical lander subsystems will be conducted on Centaur development flights. These comparatively inexpensive tests will check out spacecraft separation, structural dynamics, the vernier engines and the radars, the attitude-control system and the midcourse maneuver, and other vital functions.

Orbiter

The Surveyor orbiter is to be our first lunar orbiting satellite. It will be a derivative of the Surveyor lander and will use many lander components and subsystems.

The orbiter is being designed to be launched into close orbits about the moon, where it will serve as a lunar reconnaissance syatem, long-lifetime environmental monitor, and selenodetic satellite. Its stereo television cameras will provide broad area surveys of the lunar surface and a basis for the initial selection of landing sites for later unmanned and manned spacecraft. The pictures obtained will provide basic data for photo-geological interpretations of large areas of the lunar surface, the construction of photomosaics and topographic maps. From these data it should be possible to select likely landing areas for on-site examination by Surveyor landers.

From precise tracking data and analysis of the changes in the spacecraft's orbit over a period of time, it should be possible to obtain greatly improved knowledge of the figure of the moon; i.e., the characterisitics of its gravitational field, its size, shape, and mass distribution. Such data are not only of great scientific interest as they relate to the moon's internal structure, its history, and process of formation, but are essential for precision guidance of spacecraft in the vicinity of the moon, e.g., the Apollo lunar-orbital rendezvous maneuver and the ascent guidance for the return to earth.

As a long-life monitor of the environmental conditions near the moon, the orbiter will provide vital data on the radiation and meteoroid hazards close to the lunar surface which will be of value of the Apollo program.

The orbiter and lander will serve as an operational team to select and verify the suitability of sites for future manned landings. TV imagery from the orbiter will be used as a basis for preliminary selection of sites; the preliminary selections will then be verified by sending landers to make detailed surveys of the local terrain and test the surface to insure satisfactory bearing strength and stability for manned landings.

Early feasibility studies of theorbiter television system were performed in 1960 and 1961. Preliminary design studies of the spacecraft configuration were started by the Hughes Aircraft Company in fiscal year 1962. Fiscal year 1963 funds are being used to procure spacecraft design studies, including the engineering optimization of subsystems and modes of operation, and to fund the design and breadboard development of the visual instrumentation subsystem (VIS) and the multi-camera television package to provide the stereo and high-resolution imagery of the lunar surface.

Fiscal year 1964 funding will permit the spacecraft hardware development phase to start, with development of the proof-test spacecraft. The VIS development will be synchronized so that its proof-test model can join the spacecraft for system tests beginning in early calendar year 1964. This schedule will permit an orderly but expeditious test and evaluation program to be carried out prior to the first orbiter mission, currently planned for mid-calendar year 1965.

Project management responsibility for the orbiter has been assigned to the Jet Propulsion Laboratory.

Mariner	1962	1963	1964
Mariner A.....	$5,726,000	---	---
Venus fly-by.....	13,226,000	$9,096,000	---
Mars fly-by.....	---	24,300,000	$31,400,000
Venus/Mars landers.....	12,425,000	18,273,000	43,400,000

Mariner (continued)	1962	1963	1964
Launch vehicles:			
Atlas-Agena.....	$17,000,000	$5,100,000	$15,600,000
Centaur.....	---	---	9,700,000
Subtotal, direct R&D costs.....	$48,377,000	$56,769,000	$100,100,000
Personnel costs.....	362,000	575,000	1,260,000
Operation of installations.	318,000	514,000	1,155,000
Total costs.....	$49,057,000	$57,858,000	$102,515,000
Total personnel.....	49	71	123

The central objective of the Mariner is development and utilization of the technology necessary for fly-by and capsule landing missions to Mars and Venus. From the standpoint of both technical spacecraft developments and launch vehicle availability, the objectives will be accomplished in two phases.

In the first phase, which is already underway, the technology for the fly-by portion of the mission will be developed and demonstrated using the Atlas-Agena launch vehicle. The Mariner II, which flew within approximately 21,000 miles of Venus on December 14, 1962, was part of this first phase. Because of the success of Mariner II this mission will not be repeated at the time of the Venus opportunity in 1964; instead resources will be concentrated on the Mars mission late in 1964 and on later missions with larger spacecraft to both Mars and Venus.

In the second phase, during a period from 1963 to approximately 1967, the technology necessary for planetary atmospheric entry, descent and landing will be developed resulting in a heavier spacecraft to be flown on the Atlas-Centaur launch vehicle. In this manner, by 1967 both the delivery system and the entry-lander system will have been developed. In addition, the delivery system will have been demonstrated and refined on both the Agena and Centaur fly-by-capsule missions, and the entry-lander system will have been demonstrated on the Centaur missions. Thus, during the period 1962 to 1967, Mariner spacecraft will perform the initial scientific exploration of Venus and Mars; and by 1967, developments in spacecraft technology will have set the stage for a continuation of this effort by the larger and more versatile Voyager spacecraft.

The choice of scientific instruments to be carried on Mariner is governed both by the basic scientific objectives and by the fact that the fly-bys are preludes to more thorough investigations with orbiters and landers. During the course of the Mariner project, 1962 to 1967, the instruments will gradually change. As more knowledge is gained, their purposes will become more specific and their desired ranges more clearly defined.

For Venus, items of initial interest are the nature of the atmosphere, the surface temperature, the rotation rate, spin axis, orientation, and magnetic field and particle measurements. The structure of the atmosphere of Venus is of great scientific interest. Knowledge of its pressure, temperature profile and consitituents is of immediate importance in planning a long-range planetary program. If current estimates of the surface temperature and pressure are confirmed, designing a spacecraft that can survive entry and landing will be a difficult task. The strength of the magnetic field of Venus is also important to the understanding of the science of the solar system and to the engineering of spacecraft. If the magnetic field is exceptionally strong, trapped radiation similar to the earth's radiation belts may present communication problems. If, on the other hand, the field is very weak, it is possible that the planet could sustain a very dense ionized layer which would account for the high temperature of 600°F detected from earth with microwave telescopes.

Some of these questions may be answered as the valuable data, which were obtained by Mariner II during its historic pass by Venus, are reduced. The microwave and infrared radiometers on Mariner II were flown to measure the temperature of the surface and atmosphere, and to examine the nature of the cloud cover. Data from the planet and interplanetary space were obtained from the magnetometer, the plasma probe, the energetic particles package, and the cosmic dust detector. Findings based on analysis of these data will determine experiments to be flown on future Venus missions.

For Mars, the basic question is the existence of life. Earth experiments will, therefore, be oriented toward this detection problem. An infrared spectrograph will be carried to determine the existence and location of organic molecules. The upper atmosphere should be examined for ozone to determine whether or not the surface of the planet is protected from ultraviolet radiation which in large doses is damaging to life as it is known on earth.

A Mars mission may include such experiments as an ultraviolet spectroscope, a magnetometer, and an infrared spectrometer which would search for organic molecules on the Martian surface. In addition, since the Martian atmosphere is clear, the spacecraft would carry an optical system capable of taking and transmitting photographs of the terrain.

For the later Centaur launched missions, the capsule which leaves the spacecraft to enter the planetary atmosphere would carry pressure-accelerometer instrumentation, experiments to determine the nature of the atmosphere, and instruments to detect the existence of life.

Responsibility for Mariner management has been assigned to the Jet Propulsion Laboratory. Vehicle systems management for Atlas-Centaur and for Atlas-Agena is at Lewis Research Center. Spacecraft subsystems are being developed both in and out-of-house with an increasing out-of-house trend.

Fiscal year 1963 funding provided for the final check out and test at the Atlantic Missile Range, launch and space flight operations, and data reduction and analysis for Mariners I and II. Fiscal year 1963 funding also provides for the initiation of activities leading toward the two calendar year 1964 flights to Venus. These activities included design review of the 1962 equipment and initiation of procurements for long lead time items for test models of the 1964 spacecraft. Upon cancellation of the program the effort was redirected to the Mariner Mars fly-by missions scheduled for flight in calendar year 1964.

For the Mariner fly-by mission to Mars, fiscal year 1963 funds will provide for engineering design, development on the required new and modified subsystems, purchase of spacecraft and GSE equipment for proof test, type approval test, and life tests. Although all subsystems have basically the same design approach as those of the Venus spacecraft, modifications and, in certain cases, new items are required. In addition, a number of simplifications and improvements will be phased to obtain the necessary increase in reliability. For example, the attitude control system must change over from an earth seeker to a star (Canopus) seeker, transmitter power must increase and frequency must change, the midcourse system requires a "two burn" capability, and the power system must be modified for the increased solar distance.

Fiscal year 1964 funding will provide for systems assembly and tests; purchase of hardware for the flight spacecraft and spares; initiation of checkout of flight hardware; and purchase, assembly and checkout of GSE.

At the start of fiscal year 1962 plans for the larger capsule-carrying version of Mariner provided for flights to Venus and Mars in calendar year 1964. As a result of a program reorientation, the calendar year 1964 Venus flights were replaced by the lighter Agena-sized Mariner, and the Mars flights in 1964 were also replaced. Design and subsystem development, which had started in fiscal year 1962, had to be reoriented appreciably; although basic design phiosophy for the Centaur launched Mariner remains the same, namely to provide capability for missions to both Mars and Venus delivering entry capsules.

With 1963 funds, subsystem development activities started and procurement of long lead-time items for proof test and type approval will be continued.

Fiscal year 1964 funding will provide for the purchase of spacecraft and ground support equipment for proof test, type approval test, and life test; the assembly of the proof test model and type approval equipment; the conduct of tests and analysis of results; and the start of procurement of flight hardware.

Pioneer	1962	1963	1964
Spacecraft.....	---	$3,500,000	$10,000,000
Launch vehicles.....	---	---	5,000,000
Subtotal, direct R&D costs.....	---	$3,500,000	$15,000,000
Personnel costs.....	---	319,000	437,000
Operation of installations.....	---	251,000	354,000
Total costs.....	---	$4,070,000	$15,791,000
Total personnel.....	---	35	46

The Pioneer missions form an essential part of a broad program to measure the characteristics of solar fields and radiation in both space and time which began with early Explorer satellites and the Pioneer V. Broad program objectives are to provide knowledge of the origin of the sun; its dynamics, composition, and effect on the earth's environment; and the relation between solar flares and radiation hazards to manned space flight, with the hope of predicting these hazards in advance.

Pioneer will be a series of 100-120 pound space probes to monitor the interplanetary environment near the orbit of the earth. The Thor Delta launches will be scheduled at six month intervals with the first launch scheduled for the last half of 1964. The spacecraft will be injected with energy just above that required for escape from the earth in a trajectory that would provide a separation distance between earth and spacecraft of 30 million miles after 6 months. Scientific information from Pioneer in conjunction with that from presently scheduled Mariners, will provide simultaneous measurements at widely separated points in interplanetary space. In addition, the Pioneer flights will provide backup for the interplanetary portion of the Mariner missions.

The relatively simple subsystems intended for use on Pioneer should result in great reliability. This aspect is extremely important since a failure of the Mariners would otherwise completely eliminate the possibility of any interplanetary observations during the International Quiet Sun Year, which is a period crucial to the scientific program and to the Apollo program.

Project and spacecraft systems management is at the Ames Research Center. Data acquisition management is at the Jet Propulsion Laboratory, and Delta systems management is at the Goddard Space Flight Center. Spacecraft development and hardware preparation will be by contract with industry. It is planned to award the contract early in calendar year 1963.

Related work in the past with similar systems includes that done on the Pioneer V, Explorer's VI, X and XII and the Interplanetary Monitor Probe (IMP) series. Pioneer represents an extension of these earlier developments and of Pioneer V in particular. The flight of Pioneer V was an extremely successful

one. It produced several discoveries of major significance in our study of the sun and interplanetary space. Improvements planned for the new Pioneer, plus the vastly improved NASA data acquisition facilities represented by the deep space network, should combine to provide an even more valuable contribution to the interplanetary sciences.

Funding in fiscal year 1963 will provide for spacecraft design, subsystem development, and procurement of long lead time items for test models.

In fiscal year 1964 the requested funding is for assembly and test of prototype equipment, and for procurement and assembly of flight equipment.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

BIOSCIENCE

OBJECTIVES:

The bioscience program of the NASA is being developed to provide this country with biological knowledge that can be gained only in the environment of space, and with the basic biological knowledge pertinent to space exploration and operations. Research is being conducted and planned on matters such as the detection and study of extraterrestrial life and its impact on evolutionary theories, and the effects of the space environments on the behavior and functioning of living organisms.

SUMMARY OF RESOURCES REQUIREMENTS:

Funds	1962	1963	1964
Supporting research and technology	$2,915,000	$10,050,000	$10,800,000
Flight program	133,000	10,950,000	24,400,000
Subtotal, direct R&D costs	$3,048,000	$21,000,000	$35,200,000
Personnel costs	519,000	2,486,000	3,628,000
Operation of installations	515,000	1,626,000	2,511,000
Total costs	$4,082,000	$25,112,000	$41,339,000
Personnel			
NASA Headquarters	32	40	47
Ames Research Center	32	239	329
Wallops Station	1	4	15
North Eastern Office	-	-	2
Total personnel	65	283	393

Primary responsibility for the Bioscience program is in the Office of Space Sciences at NASA Headquarters. Conduct of the major portion of the technical program rests with the Ames Research Center. Contributions to the program are made by other NASA installations, and by the scientific community.

PROGRAM JUSTIFICATION:

Biological studies are an integral part of the national space program from several standpoints. Experiments to further biological knowledge are conducted in the unique environment of space to determine the effects on living organisms of weightlessness, radiation, and stresses produced by as yet unidentified altered ambient conditions and by the modification or absence of the diurnal cycle. Studies are undertaken to search for and examine extraterrestrial life and determine the impact of the knowledge gained on the origin and evolution of life as we know it.

All of these studies are pertinent to and support future manned exploration of space by developing a better knowledge of life's biological and physiological processes as affected by space flight and operational environments. The Biosciences Subcommittee of the Space Sciences Steering Committee serves as the vehicle by which the cooperation and participation of the Department of Defense and the scientific community in the NASA Bioscience Program is elicited.

The planned flight schedule of the Bioscience program is as follows:

Mission	Launch Vehicle	Calendar Year of First Launch	Launch Location
Biosatellite	Atlas-Agena	1964	Pacific Missile Range

EXPLANATION OF FUNDS REQUESTED:

Supporting research and technology	1962	1963	1964
Direct R&D costs.....	$2,915,000	$10,050,000	$10,800,000
Personnel costs.....	504,000	1,529,000	2,647,000
Operation of installations.....	495,000	1,008,000	1,858,000
Total costs.....	$3,914,000	$12,587,000	$15,305,000
Total personnel.....	63	174	287

The broad spectrum of biological and medical phenomena to be investigated in the space environment and the search for extraterrestrial life necessitate a firm and substantial background of theoretical and laboratory research. The successful interpretation of space flight data depends upon a thorough knowledge and understanding of the phenomena studied, gleaned many months prior to the actual space flight mission. Research is also necessary to define and delineate the experiments to be carried out in space, and to devise techniques and instruments for successful studies. The supporting research and technology program makes use of the facilities of NASA Centers,

universities, industry, and other government agencies. Of research projects currently sponsored for execution outside the NASA organization, about 50 per cent are conducted by universities, 30 per cent by industry, and 20 per cent by other government agencies.

In the search for extraterrestrial life, an understanding of primitive and early terrestrial life must be gained for "control" comparisons with the organisms or organic particles of matter which may be found in space or on other astral bodies. Among the organizations engaged in research of this nature is the University of Wisconsin, studying the cyto-chemical characteristics of planetary micro-organisms through the use of simulated planetary environments. The Shell Development Company of California is undertaking studies of hydrocarbon analysis of meteorites as a means of detecting life in space, while the Jet Propulsion Laboratory is developing devices for future unmanned space probes which will be able to detect life on other planets through the use of biological reactions, as well as physical and chemical processes.

Studies of the influence of planetary environments on life processes will continue at Ames through the use of simulated planetary atmospheric and environmental models. The Ames Research Center is also responsible for an effort designed to obtain high resolution infra-red observations of Mars, Venus, and the moon by means of a balloon-borne telescope lifted to 80,000 feet, above that portion of the atmosphere which blocks out the wave lengths to be observed. The instrument to be used is the Stratoscope II telescope, jointly funded and developed by NASA, the National Science Foundation and the Office of Naval Research. It is a 36 inch reflecting telescope, designed to be suspended from a large polyethylene balloon with attachments to make possible precise pointing by remote control.

In the field of environmental biology, ground-based research at Ames includes studies of the behavioral effects of rotation and acceleration on cellular systems; the effects of high energy radiation on biological systems; neuro-muscular reactions to radiation damage; and the effects of gravity on vestibular mechanisms.

The fiscal year 1964 fund estimates support the continuation of projects initiated with fiscal year 1962 and 1963 funds, with the expansion of the program in areas where earlier studies have pointed out a need for further knowledge.

FLIGHT PROGRAM

Biosatellite	1962	1963	1964
Spacecraft.....	$133,000	$ 8,750,000	$11,700,000
Launch vehicles.....	---	2,200,000	12,700,000
Subtotal, direct R&D costs....	$133,000	$10,950,000	$24,400,000

	1962	1963	1964
Personnel costs.....	15,000	957,000	981,000
Operation of installations.....	20,000	618,000	653,000
Total costs.....	$168,000	$12,525,000	$26,034,000
Total personnel.....	2	109	106

The Biosatellite project's two objectives are to investigate the biological effects of decreased gravity and weightlessness, with additional studies on the effects of high energy heavy particle cosmic radiation, and the effects on biological rhythms of removal from the earth's rotation.

Some of the unique space environmental factors of obvious biological importance which differ quantitatively and even qualitatively from those which obtain on earth are: decreased gravity and weightlessness or zero g, an environment disconnected from the earth's rotation, high energy heavy particle cosmic radiation, and high vacuum. Other environmental factors of space such as decreased magnetism, lower energy proton radiation, and changes in temperature and electromagnetic fields can be simulated in the laboratory, and such studies are underway.

Laboratory studies have shown that many species of living organisms have remarkably sensitive gravitational receptors indicating the effect of gravity at the cellular and perhaps lower level. Experiments have been designed to investigate the validity of several alternative hypotheses. These range from the study of behavior of molecules in physical non-living systems to the behavior of the complex nervous systems of primates.

The Biosatellite is being developed to provide a self-contained laboratory for performing a variety of experiments in flight. These experiments will be selected from a large number of proposals to form an integrated, mutually compatible and complementary group of experimental observations.

The spacecraft will be of a size and weight class to be launched by an Atlas-Agena class vehicle. It will include a recovery system and is designed to permit insertion of a life-cell and life-support system. The spacecraft will be stabilized during flight and subsequently positioned for retrofire and reentry.

The life support system will be a further development and refinement of a life support system previously funded. It will include a life-cell, an environmental control system, biomedical instrumentation, telemetry equipment, and metabolic support including two-gas sea level atmosphere. The life support system will be designed with sufficient flexibility to accommodate a variety of experimental subjects. It will be of sufficient size and capacity to support several monkeys in orbit for periods of about two weeks.

The tracking network will provide a collection system capable of allowing frequent evaluation of the response of the payload to the environment, and will permit commands as required to maintain control of the experiments and to initiate recovery.

The Ames Research Center has been designated project manager for the biosatellite program.

Fiscal year 1963 funding provided for initiation of the project, including design and initiation of test and flight hardware fabrication. Funding for fiscal year 1964 will support continued fabrication and environmental testing of flight articles, and incremental financing of launch vehicles, for a first launch in late calendar year 1964.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

LAUNCH VEHICLE DEVELOPMENT

OBJECTIVES:

The objectives of this program are to provide reliable and economical launch vehicles for: (1) the unmanned earth orbital, lunar, planetary, and interplanetary missions for scientific experimentation; (2) meteorological, communications, and supporting research and technology flight missions; and (3) the acquisition of engineering data from unmanned flights to support manned space exploration.

SUMMARY OF RESOURCES REQUIREMENTS:

Funds	1962	1963	1964
Supporting research and technology	---	$2,000,000	$5,000,000
Scout development	$4,700,000	4,200,000	---
Delta development	5,255,000	---	---
Centaur development	73,791,000	92,900,000	110,700,000
Operational support	1,915,000	8,900,000	15,000,000
Subtotal, direct R&D costs	$85,661,000	$108,000,000	$130,700,000
Personnel costs	8,617,000	7,694,000	10,615,000
Operation of installations	6,580,000	5,801,000	8,217,000
Total costs	$100,858,000	$121,495,000	$149,532,000
Personnel			
NASA Headquarters	69	83	96
Langley Research Center	140	98	119
Goddard Space Flight Center	61	75	73
Wallops Station	65	74	59
Marshall Space Flight Center	651	-	-
Launch Operations Center	32	93	118
Western Operations Office	6	28	34
Lewis Research Center	-	471	618
Total personnel	1,024	922	1,117

Primary responsibility for the Launch Vehicle Development program is in the Office of Space Sciences at NASA Headquarters. Technical direction and support of the program is accomplished at the locations cited above.

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PROGRAM JUSTIFICATION:

The present group of launch vehicles being utilized for unmanned scientific space exploration includes the Scout, Delta, Thor-Agena, and Atlas-Agena. Development of the Scout was completed in fiscal year 1963 and Delta in fiscal year 1962. Thor-Agena and Atlas-Agena were developed by the Air Force.

Although development of these vehicles is completed, their continued use during this decade makes it essential that effort be provided to increase their reliability and capability to support unmanned scientific missions. The increasing investment in both spacecraft and launch vehicles stresses the need for greater probability of success than has been achieved so far. Therefore, under the operational support category, funds are requested for product improvement for the Scout, Delta, Thor-Agena, Atlas-Agena, Centaur and for certain support services and facilities not directly chargeable to operational missions.

Closely associated with product improvement is the need to correct system deficiencies in existing vehicles and to improve the design criteria for future vehicle systems. Funds are requested under supporting research and technology to meet these requirements.

Development of the Centaur will continue in fiscal year 1964, with the first operational mission planned for late calendar year 1964.

EXPLANATION OF FUNDS REQUESTED:

	1962	1963	1964
Supporting research and technology.....	$ ---	$2,000,000	$5,000,000
Personnel costs.....	---	1/	1/
Operation of installations..	---	1/	1/
Total costs.....	$ ---	$2,000,000	$5,000,000
Total personnel...	---	1/	1/

The supporting research and technology effort for light and medium-class vehicles is necessary to minimize and reduce system deficiencies in existing vehicle systems and to improve their design criteria.

During fiscal year 1963 studies are being initiated on adapting the Titan-II vehicle to the Centaur upper stage. Also, other vehicle combinations are being investigated for possible application to fulfill scientific mission requirements beyond existing capabilities.

1/ Personnel and operations included in other projects within program.

In fiscal year 1964, applied research will be initiated in the area of component development. The scope of work will consist of effort in solid state technology as related to space environments, propulsion fuel systems, thrust chamber dynamics, high energy propellant systems, operational analysis of vehicle systems, guidance system and control requirements, vehicle structural dynamics, standardized stages, launch procedure criteria, and other related launch vehicle research support.

Centaur development	1962	1963	1964
Vehicle development	$48,010,000	$82,317,000	$93,618,000
Engine development	19,011,000	2,729,000	5,070,000
Support services	6,770,000	7,854,000	12,012,000
Subtotal, direct R&D costs	$73,791,000	$92,900,000	$110,700,000
Personnel costs	3,251,000	2,779,000	3,737,000
Operation of installations	2,080,000	1,300,000	1,765,000
Total costs	$79,122,000	$96,979,000	$116,202,000
Total personnel	369	338	388

The purpose of the Centaur development program is to provide a high performance launch vehicle for NASA unmanned lunar and planetary exploration projects which are beyond the capabilities of the presently available Atlas-Agena launch vehicle. Later missions for Centaur will include placing communications, meteorological, and scientific satellites into high earth orbits, as well as launching of additional interplanetary probes.

Centaur itself is a high energy upper stage using liquid hydrogen and liquid oxygen. This represents the first practical usage of liquid hydrogen for launch vehicles in the United States. The first stage is a modified Atlas with cylindrical tankage required to mate with the ten-foot diameter Centaur upper stage. The Centaur development program will produce a very light weight high performance upper stage to exploit the full potential of liquid hydrogen performance capabilities. Because of the requirement for high performance from the stage, the program also includes the development of a light weight inertial guidance system and other light weight subsystems required by Centaur to perform its extended duration, difficult space flight missions.

The major industrial contractors involved in the Centaur program include General Dynamics/Astronautics, San Diego, California, as the overall system contractor; Pratt & Whitney Aircraft Corporation of East Hartford, Connecticut, and West Palm Beach, Florida, as an associate contractor for the development and fabrication of the 15,000 lb. thrust liquid hydrogen engine (RL-10-A-3), which are also used in the Saturn S-IV stage; and Minneapolis-Honeywell of St. Petersburg, Florida, as the principal subcontractor to General Dynamics for development of the Centaur guidance system.

The Centaur development project is under the direction of the Lewis Research Center at Cleveland, Ohio, which has complete project management responsibility for NASA. The RL-10-A-3 engine development is under the direction of the Marshall Space Flight Center since these engines are also used for Saturn, but the integration of these engines into Centaur is under the direction of the Lewis Research Center. The Atlas vehicles which are modified for the first stage of Atlas-Centaur are purchased through the U. S. Air Force.

The Centaur project was established under the Advanced Research Projects Agency of the Department of Defense in 1958 as a relatively small scale development project directed toward liquid hydrogen launch vehicle technology. The project was transferred to NASA in mid-1959, and has been gradually modified and increased in scope until it is now a major vehicle development program.

The first development launching of Centaur occurred on 8 May 1962, and resulted in a vehicle failure after approximately 54 seconds of flight. After the first flight, the program underwent an intensive investigation by the Marshall Space Flight Center, which then had project management responsibility. The results of this investigation indicated that additional technical effort on the part of both the contractors and NASA was required. In order to provide this effort without interfering with the vitally important Saturn development program at Marshall, project management responsibility was shifted to the Lewis Research Center in October 1962.

Additional funds were provided during fiscal year 1963 by reprogramming within NASA in order to increase the ground test program and the reliability and quality assurance efforts, which review of the program had indicated were required. During calendar year 1962, the prime contractor's effort was changed into a project team type of organization, and both NASA and the prime contractor are now organized on a project basis for an intensified effort on Centaur development.

At the present time, Centaur is at the peak of its development effort. The redesigns indicated by the first flight failure and the subsequent investigations are under way; and an intensified ground test program has

been approved and is being implemented. The fiscal year 1964 funds will cover the continuation of engineering and design effort, additional ground test programs, flight tests, and the procurement of development vehicle hardware necessary for the complete development effort.

Based upon the results of the first launch and subsequent studies, the major technical decisions concerning the vehicle configuration have been made. The next flight date is scheduled for mid-1963, with additional flight tests scheduled on a regular basis thereafter. By early calendar year 1964, the operational configuration will be flight tested, and by late calendar year 1964 or early 1965 the vehicle will be capable of operational flights.

During fiscal year 1964, the major emphasis in the vehicle development area will be on a greatly intensified reliability and quality assurance program, additional ground testing effort including dynamic and structural vehicle tests, and tests of flight vehicles and major subsystems under simulated space conditions. Also, effort will be directed at optimizing the tank materials and tank fabrication techniques to increase the structural margin of safety of Centaur under flight conditions. A number of flight tests will also be conducted during this period.

Engine development effort carried out with fiscal year 1964 funding will be primarily directed to the continuation of the engine throttling program at the Lewis Research Center. Successful completion of this development will greatly increase the flexibility and capability of the Centaur vehicle for lunar missions.

Support services during fiscal year 1964 will include the continuation of Atlas procurement in support of the flight test program, and propulsion testing of flight-configured vehicles at the Sycamore Canyon, California site of General Dynamics, as well as the Edwards Air Force Base, California test site. Additional test services will be provided by the Lewis Research Center for the dynamic test of the complete Atlas-Centaur vehicle and tests under simulated space conditions. Some specialized industrial support will be funded in certain areas of special reliability control and in some technical support areas.

Operational Support	1962	1963	1964
Product improvements and production testing.....	---	$7,700,000	$10,900,000
Maintenance of ground support equipment.....	$1,915,000	1,200,000	2,100,000
System engineering.....	---	---	2,000,000
Subtotal, direct R&D costs	$1,915,000	$8,900,000	$15,000,000

	1962	1963	1964
Personnel costs.....	$4,267,000	$4,225,000	$6,725,000
Operation of installations....	3,433,000	3,639,000	6,233,000
Total costs.....	$9,615,000	$16,764,000	$27,958,000
Total personnel.....	508	499	711

The objective of this effort is to provide adequate support of launch vehicles which have progressed beyond development to performance of operational flight missions. Continuing support of an operational vehicle is critical when service uncovers deficiencies and problem areas which require additional effort. In addition, there is a continuing need for improving the present vehicles, requiring incorporation of better methods of production, fabrication and engineering improvements.

Product improvements and production testing

Improvements to existing vehicles based on operating experience have been indicated. Many of these are highly desirable and in the best interest of gaining optimum performance from operational vehicles. However, to assure that only proper changes are made, it is necessary that proposed system improvements be reviewed and qualified. These system improvements consist of such items as providing more flexible systems for arming solid propellant motors, more accurate gyros for inertial reference packages, changes to propellant utilization systems, improved horizon sensors, and improved accommodation of various payloads on operational vehicles.

Funds are also required to complete a Centaur combined-system static test stand at the prime contractor's plant at San Diego, California, which will be initiated in fiscal year 1963. This test stand, compatible with that at the launch complex at the Atlantic Missile Range, will provide for a more thorough check-out at the contractor's plant and thus effectively reduce the time on the launch stand.

Maintenance of ground support equipment

These funds will provide for the periodic routine maintenance, modification and replacement of damaged or worn out equipment at NASA launch complexes necessary to maintain the launch capability for operational vehicles. Also provided is the acquisition of catastrophic spares, and ground handling and check-out equipment to insure against lengthy launch complex non-availability in case of a catastrophic vehicle failure. This "insurance" is necessary to avoid delays due to long lead time procurements for ground support equipment.

System engineering

This activity provides for an engineering capability in contractors' and sub-contractors' organizations. This capability is necessary throughout the operational life-time of a vehicle system and is obtained by contracting for a quantity of engineering man-hours on an annual basis. Otherwise, the system coordination and reliability efforts would not receive satisfactory attention. This item also includes the effort necessary to review and analyze all system failures in whatever depth necessary. Many ground and flight test failures are of a unique or unusually obscure nature and require detailed investigation and analysis.

Projects for which no direct R&D costs are anticipated for fiscal year 1964

Scout development	1962	1963	1964
Direct R&D costs.....	$4,700,000	$4,200,000	$ ---
Personnel costs.....	1,050,000	690,000	153,000
Operation of installations....	1,037,000	862,000	219,000
Total costs.....	$6,787,000	$5,752,000	$372,000
Total personnel.....	140	85	18

Delta development			
Direct R&D costs.....	$5,255,000	$ ---	$ ---
Personnel costs.....	49,000	---	---
Operation of installations....	30,000	---	---
Total costs.....	$5,334,000	$ ---	$ ---
Total personnel.....	7	---	---

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

FACILITY, TRAINING, AND RESEARCH GRANTS

OBJECTIVES:

The Facility, Training, and Research Grants program is a planned, coordinated effort of institutional liaison to establish and maintain direct scientist-to-scientist communication between NASA and the university research community. The purpose and scope of this program are to augment and complement sponsored research and in-house activities in support of NASA's mission through the use of facilities grants to help universities provide facilities urgently needed for space research; training grants for the purpose of increasing the future supply of scientists and engineers required in space-related science and technology; and research grants to enable universities to increase their role in support of NASA's program through encouragement of creative multidisciplinary investigations, development of new capabilities, and consolidation of activities.

SUMMARY OF RESOURCES REQUIREMENTS:

Funds	1962	1963	1964
Facilities grants.....	$6,000,000	$10,000,000	$18,000,000
Training grants.....	1,972,000	15,000,000	25,000,000
Research grants.....	4,389,000	5,600,000	12,000,000
Subtotal, direct R&D costs..	$12,961,000	$30,600,000	$55,000,000
Personnel costs.....	256,000	447,000	553,000
Operation of installations....	330,000	619,000	885,000
Total costs.....	$13,547,000	$31,666,000	$56,438,000

Personnel			
NASA Headquarters.....	32	42	50
Total personnel.....	32	42	50

Responsibility for this program resides in the Office of Grants and Research Contracts in the Office of Space Sciences at NASA Headquarters.

PROGRAM JUSTIFICATION:

The success or failure of the national space program rests directly on the skill and training of the people who undertake the effort. Success will be contingent not only upon NASA, but also on the effort of other government agencies, industry, universities, and the scientific community in general. It is imperative that NASA utilize all capabilities in its intensive scientific effort designed to probe the boundaries of present knowledge. In the development of this capability, the universities have a special role.

NASA has supported and continues to support substantial amounts of research in universities, which contributes significantly to the national space effort. With the decision to expand and accelerate this effort, it became apparent that the existing sponsored research program alone could not utilize fully the ability of our universities to preserve and advance the role of the United States as a world leader in aeronautics, space sciences and technology. Accordingly, a program was initiated in FY 1962 to enlarge university participation in aeronautics, space sciences and technology and to complement the sponsored research activity of NASA. Only through an accelerated NASA-oriented university program can the supply of scientific talent and the development of significant research activity meet the demands of the rapidly expanding space program.

The greatest source of scientific research talent in the country resides in the university community. Many of the ideas on which various aspects of the space program are based have originated there. NASA's methods of operation are designed to secure maximum direct assistance to the space program and at the same time to help strengthen the established academic framework. NASA's objectives to work within the existing university structure rather than foster activities tending to weaken the university, or to pull the university researcher away from teaching. On the other hand, universities must bear their share of responsibility for our Nation's success in space and allocate an appropriate portion of their material and human resources to that end. In such a partnership, NASA expects to help support research, help in the production of trained talent and assist in the provision of buildings and other research facilities.

The three main aspects of this program are supplementary to the sponsored research supported by NASA. Training produces the skilled manpower: research scientists, technicians, and instructors. The quality and quantity of the research accomplished by this highly trained manpower and the ideas generated in the course of their work, are the chief determinants of the success of the Nation's space effort. Adequate facilities are obviously essential to a viable program of this kind.

Research training will increase the supply of highly trained scientists and engineers in space-related science and technology. NASA has established the goal of training about 4,000 graduate students, in 150 qualified universities, yielding an output of about 1,000 Ph.D's in science

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and engineering per year.

New research facilities, supported by NASA, are required to provide adequate working space for the growing scientific research and training in space-related work at those universities heavily engaged in such efforts. It is estimated that in the next 5 to 7 years a total of some 60-75 universities will have such needs. Only through a program of this magnitude will the universities be in a position to undertake the work of which they are capable and which is required if the national goals in space are to be realized.

Research support which enables universities to develop and increase their capabilities of satisfying the growing demands of the national space effort is already required. Emphasis will be placed on broad research endeavors of relevance to NASA, promotion of the consolidation of projects into coherent interdisciplinary groups, and encouragement of new work to fill existing research gaps. The establishment of research programs within currently competent but non-participating groups will also be stimulated. Simultaneously, NASA will continue and substantially expand its sponsored research in universities in direct response to programmatic needs.

The relative magnitude of NASA's support to these aspects of the program has been balanced in an attempt to ensure the most efficient use of the nation's research and academic capabilities. Diminution of support in any of these areas would damage the program as a whole and would limit the rate of growth of the space effort. Initially, maximum emphasis has been placed on the training of scientists and engineers, for it is in this critical area that the demands of the space program will be most severe during the next decade. Support of research and the construction of necessary facilities are phased into this program in order to utilize this manpower most efficiently. Thus, all three aspects of the program are inextricably related and require balanced effort and support in order to accomplish the objectives of the national space effort.

EXPLANATION OF FUNDS REQUESTED

Facility grants

An important deterrent to supporting research and training in space related science and technology at non-profit scientific and educational institutions is a lack of adequate laboratory space, which makes it difficult or impossible for scientists to produce their best work.

In 1961, laboratories used for research in colleges and universities were occupied by the equivalent of about 80,000 full-time personnel. This total included faculty and staff holding doctor's degrees in science and engineering; professional scientists and engineers; post-doctoral, and graduate students compensated for research; research fellows and graduate students not directly compensated for research; and supporting technicians,

machinists, and other non-professional assistants. This figure is expected to become 150,000 in 1970 in accordance with projections of the increased granting of doctoral degrees.

Some research scientists confine their attention to theoretical studies and may literally need only a blackboard, well-stocked book shelves, and a desk in a quiet room suitable for concentration. More and more frequently, however, scientists are requiring the use of elaborate research equipment, such as computers, reactors, and flight simulators. Sufficient space must be provided not only for the equipment required, but also for the faculty, and research work of graduate students.

Accordingly, where additional laboratory facilities are urgently needed to conduct such research, and the institution involved has demonstrated its intent to seek ways in which the benefits of the research can be applied to the social, business, and economic structure of the United States, NASA will provide funds for the acquisition of facilities. NASA's enabling legislation and subsequent appropriation acts reflect a clear understanding of the need for such activities. NASA must be assured, before facilities grants are made, however, that the agency's assistance is required in order to develop and expand the national resource of research laboratories located in the universities. Other sources of funds, such as university endowments, philanthropic organizations, individual bequests and state appropriations have not kept pace with the rapidly increasing demands for adequate laboratory space in which to conduct scientific research. The contributions of other Government agencies to facilities engaged in scientific research have been notable. Such contributions, however, have frequently not been of direct value to NASA-oriented research.

These facilities will help relieve the critical shortage of working space for groups now heavily involved in research pertinent to the NASA mission. They will also make possible the establishment and development of new multidisciplinary research groups relevant to the objectives of NASA. Funds are provided in amounts determined by NASA to be appropriate in each instance, up to the full cost of the proposed building including a reasonable amount for fixed equipment.

A major criterion for selecting the recipients of facilities grants is the relative importance to the national space program of the particular field or combination of fields of research for which the laboratories will be used. The urgency of the university's needs for the building, based on the extent of its present research and training program of interest to NASA, is also taken into consideration, as are the demonstrable competence, achievements, and potential for further contribution to the space program of its scientific staff. The nature and extent of the university's commitment to work in the space sciences is another relevant factor.

In September 1962, NASA awarded its first facilities grants to five universities to provide research laboratories housing multidisciplinary activities in space related sciences and technology. The five grants totaled

$6.4 million of fiscal year 1962 funds. These first facilities will begin to become operational in 1965.

Training grants

A rapidly growing space program will place increasingly severe demands on the already limited supply of highly trained scientists and engineers. The demand will be of two general kinds, those technical personnel required to participate directly in current space activities to solve immediate problems; and those required to conduct basic research of a long-range nature, to teach new students in order to replenish the manpower pool, and to evaluate and organize the vast amounts of scientific data acquired through increasing space experimentation into coherent intellectual frameworks.

The main element of the training program provides three-year pre-doctoral training opportunities to selected graduate students at universities offering Ph.D. degrees in space-related areas. As recipients of these traineeships, young, high-calibre scientists and engineers will conduct research in space-related fields, while acquiring a high level of competence. At the end of this training, the student may remain at a university, carrying out long-range basic research and teaching the "next generation", or he may participate directly in current research activities of immediate importance to the space program either at the university, in industry, or within NASA. Those universities which participate in the program are selected by NASA on the basis of proposals which they submit. Individual candidates are selected by senior members of the faculty who know their capabilities and who may supervise the research training of the student. The stipends granted are competitive with those offered by other sources, including other Federal agencies. Thus, the grants will not draw students away from other departments of the institutions, if they would normally have chosen advanced education in other areas.

Specialized training for selected students offers several advantages over and above the usual fellowships granted in general areas. First, it offers the students direct identification with NASA's goals and problems and involves them directly in the new programs of the space age. In many cases, the students' professors are directly engaged in research activity supported by NASA. The students thus have a direct relationship to NASA through contact with scientists and scientific experiments generated by senior investigators. Such close ties with NASA will provide the trainee with additional motivation for the continuation of studies in this area and for direct participation in the space program. A second advantage of these traineeships is the incentive they provide for undergraduates, since successful contenders are prepared for active participation in many areas of the space program. When the trainees have completed their academic work, they may choose employment with NASA or another Government research activity, the university, or industry.

During the summer of 1962, the National Academy of Sciences assembled a group of senior scientists and engineers from universities, government, and industry, for a six-week study of the space sciences. This group gave

wholehearted endorsement to the NASA research training program and indicated that NASA should set as a minimum goal the training of one thousand Ph.D's annually. Such a rate requires about 4,000 students in training at a given time. This goal constitutes the basis for NASA's planning in this area, and present plans call for its attainment during the 1966-67 school year.

That a program of this magnitude is necessary and entirely reasonable has been strongly reinforced by a report of the President's Scientific Advisory Committee. This Committee has just completed a study which indicates that qualified students are available who cannot enter graduate research training unless new opportunities are available and that an increase of 3,500 to 5,000 annual "new starts" should be made in the number of federally assisted graduate students. Thus, in this context, it is reasonable to expect that NASA, whose R&D appropriation is about one-fourth of the Federal R&D appropriations, would support approximately one-fourth of these new starts. Further, this report has been studied by and given the unqualified endorsement of, the Federal Council of Science and Technology.

NASA initiated its graduate training program in the spring of 1962 with grants to ten universities for the support of ten graduate students at each university for a period of three years. The total cost of this program was approximately two million dollars. In the fall of 1963, NASA increased this program significantly to include approximately 800 trainees at about 90 universities, at a total cost of 15 million dollars. Thus, by the fall of 1963, 900 students will be in training.

With the addition of about 1,250 students in the fall of 1964, and 1,333 in 1965, about 3,383 students will be in training. Current plans indicate that the program will be stabilized at a figure of about 4,000 students in training.

It should be noted that the first group of trainees will not complete their tenure until the spring of 1965. Because of this three-year lead time, the program is being given heavy emphasis in FY 1963 and FY 1964 in order to establish the desired level as soon as possible. Even with this emphasis in FY 1963 and 1964, the level of 4,000 students will not be reached until 1966, and the goal of 1,000 students graduating per year will not be reached until the spring of 1967.

The selection of recipients of traineeships is the responsibility of the universities receiving NASA predoctoral training grants. No amount of the stipend is contingent upon or represents payment for teaching, research, or other services in the nature of part-time employment on the part of the recipient graduate student, unless such activities are required by the university of all degree candidates whether or not recipients of stipends or similar awards. Recipients of traineeships under these grants shall not be permitted to accept concurrently other educational assistance in the form of grants, fellowships, or assistantships.

The awards are made to predoctoral graduate students of unusual promise who have an interest in the space sciences. The awards may be made either to graduate students already engaged in a course of study leading to the doctorate or to students about to undertake such a course of study. In making awards, every effort is made to choose individuals who show promise of being able to complete the doctorate within a three-year period.

In selecting trainees, the university is expected to consider the candidate's academic records, personal qualifications, and research and study plan for the training period. Recipients in most cases will be citizens of the United States. However, in exceptional cases when the interest of NASA will be served and after prior approval from NASA, non-citizens may receive awards. Individuals receiving support under these grants do not incur thereby a formal obligation to the Government of the United States. However, since the objectives of this program will be best served if such individuals engage in research and teaching in science or engineering following completion of their training, they will be encouraged to do so.

An essential aspect of this program is the continuity of support accorded the trainees. Although the traineeships will be reviewed each year by the institution and awarded on an annual basis, it is anticipated that a student who qualifies as a NASA trainee may look forward to renewal of his traineeship for a second and third year if his qualifications are maintained at a level acceptable to the university. Only in exceptional cases and after approval by NASA may awards be made to the same individual for more than three years. In case a trainee fails to qualify for a second or third year extension and another individual is awarded a traineeship in his stead, the new student is apprized at the outset that the duration of his traineeship may be less than the customary three years.

The grant includes an annual stipend to the student of $2,400 for a full year of graduate study. In addition, the trainee may receive an additional allowance of up to $1,000 per year, mainly for dependency and escalation, to be administered by the university in accordance with its established policy. The university also receives an allowance to cover tuition and reasonable expenses directly related to training, such as laboratory fees, small items of equipment, specialized course content improvement, and an appropriate share of faculty augmentation.

Research grants

A more flexible program of research support than that of the project-type research is required to respond to the demands of broad NASA research requirements which overlap or fall outside the scope of specific program interests. In order to enable universities to be more responsive to such broad requirements, a specific program was established to assist those universities desiring to make the most efficient use of their research capabilities. This program is intended to support the consolidation of related research projects into unified multidisciplinary activities, encourage new investigations to fill existing gaps, and stimulate the participation of new

embryonic groups of high potential. This program will operate along with and as an adjunct to the sponsored research support provided by other program offices of NASA.

For those institutions not currently participating in space research, this program aims to encourage the development of promising work which, because of the institution's youth or lack of publicized ability in specific areas of interest, has not received previous support. Such support can increase the number of universities interested in investigating some of the fundamental problems facing NASA's scientific programs and can broaden the base of the nation's university space research capability.

The support of programs at currently non-participating institutions will provide the incentive for scientists to remain there and will reduce the movement of skilled manpower to those few universities with heavily supported programs. Such support will also obviate the necessity for a young scientist to leave his university in order to participate in a space program.

The university already engaged in space-related research is afforded the opportunity of making the most efficient use of its research and training potential. It is becoming more apparent that research in space science and technology requires a combination of many traditional disciplines. Over the past twenty years many new problems in fields such as aeronautics, materials, and the life sciences have been successfully investigated through the multidisciplinary approach. However, in no area has the need for a multidisciplinary view been clearer than in space research. The problems facing NASA require the full efforts of biologists, geologists, physicists, chemists, electronic specialists, metallurgists, engineers, and many others.

At present, most of the nation's universities are traditionally organized along specific educational lines into departments which teach the usual scientific disciplines. Many universities are at present undergoing changes in structure in order to attack properly the fundamental problems of nature as they are now recognized. Important areas of fundamental research with a direct bearing upon critical problems, but of long range duration or lack of specificity, often suffer from lack of recognition and support. As a result, many fertile areas of promising research lie fallow and gaps appear which do not receive proper attention in the university. Specific project support tends to overlook these opportunities because of more constraining mission requirements. This program is able to fill the gaps created between discrete projects and gives the nation's space program the benefit of research which fits the total problem and is not artificially distorted by administrative constraints.

If fundamental research is to be conducted in the most efficient and productive manner, the institution and the scientific investigator must be assured of long-term financial support. Such support permits the participants to plan programs in depth and devote their full attention to their work. It is NASA's policy to provide continuity of research support where possible and practical.

The research grants program offers a mechanism through which NASA can specifically devote attention to proposals from universities for research which take full advantage of their imagination and their entire capabilities. NASA encourages multidisciplinary approaches utilizing all the flexibility and inventiveness that an entire university can exercise.

In fiscal year 1962, $4.4 million was allocated to this program for a number of investigations of the type described above. In fiscal year 1963, $1.8 million has been allocated to continue the work funded in fiscal year 1962, and $3.8 million will be used to support additional multidisciplinary activities and to initiate programs involving new research groups. For fiscal year 1964, $12 million will be required to provide continuity to programs initiated in the preceding years and to assure an orderly growth of the entire program in keeping with NASA's growing research requirements.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

SPACE VEHICLE SYSTEMS

OBJECTIVES:

The objective of the Space Vehicle Systems program is to identify and solve critical technical problems bearing on present generation space vehicles as well as to advance the state-of-the-art to enable the development of more advanced space vehicles for future space missions.

SUMMARY OF RESOURCES REQUIREMENTS:

Funds	1962	1963	1964
Supporting research and technology	$12,620,000	$25,277,000	$37,762,000
Flight projects	8,142,000	20,654,000	24,200,000
Subtotal, direct R&D costs	$20,762,000	$45,931,000	$61,962,000
Personnel costs	22,821,000	28,699,000	32,644,000
Operation of installations	15,286,000	15,128,000	16,801,000
Total costs	$58,869,000	$89,758,000	$111,407,000

Personnel			
NASA Headquarters	70	81	104
Ames Research Center	647	641	671
Lewis Research Center	345	374	408
Langley Research Center	1,660	1,802	1,950
Flight Research Center	22	22	36
Wallops Station	61	54	60
Marshall Space Flight Center	139	222	228
Western Operations Office	1	6	6
Goddard Space Flight Center	---	82	93
Manned Spacecraft Center	---	1	10
North Eastern Operations Office	---	2	3
Total personnel	2,945	3,287	3,569

Primary responsibility for the direction of the Space Vehicle Systems program is in the Office of Advanced Research and Technology in NASA Headquarters. Program accomplishment is carried out in-house at the locations listed above and through contractors, including the Jet Propulsion Laboratory.

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PROGRAM JUSTIFICATION:

The increased complexities of the advanced space vehicle systems that will be required to accomplish National space objectives for the next two decades attest to the need for a broad, thorough research program to establish an adequate technology. Space vehicle research and technology must not only extend knowledge to enable development of the more advanced vehicles required for future missions, but also identify and solve many critical technical problems of current space vehicles. Such a program has many facets. It begins with conceptual studies of missions and related launch vehicles and spacecraft in order to evaluate their feasibility, to identify major problems, and to provide guidance and perspective for ongoing research and technology programs. Manned missions to the planets, manned orbital space stations, and nuclear earth-moon ferries are but a few examples of such mission studies.

Next, knowledge is required of the environments of the atmosphere and space and their effects on the vehicle. Winds and atmospheric turbulence create many control and structures problems. The harsh space environment with its many hazards to the spacecraft must also be thoroughly understood. High-energy radiation, meteoroid impacts, thermal radiation from the sun, weightlessness, and hard-vacuum must all be defined and their effects studied. Other important environmental effects on spacecraft which must be defined include conditions of spacecraft reentry into the atmosphere, recovery, and landing.

Better systems for entry into the atmosphere and recovery of spacecraft must be devised, as well as economical and reliable methods for recovering and reusing large and expensive launch vehicles. Aerodynamic characteristics of new and unusual space vehicle configurations must be studied to establish stability, control, and performance characteristics. Extreme heating conditions at the base of large multi-engined launch vehicles, as well as effects of aerodynamic heating on spacecraft during entry into various atmospheres, such as those of the earth or the planets, must also be investigated.

Space vehicle structures will become larger and heavier, and they will be required to operate for longer periods of time to perform the advanced missions that will follow presently approved programs. Aggressive research activities are required to maintain the weights of these structures at reasonable levels and at the same time to ensure reliability under the severe environments and complex loading conditions which they will experience. This research begins with basic studies of materials, such as polymers, ceramics, refractory metals and alloys, superalloys, coatings, ablators, materials for containment of cryogenic fuels, lubricants for use in space, and many others.

Closely related to the basic materials research is research designed to determine how to apply the more promising new materials in structures.

Studies will be conducted on the unique structural configurations required for future space vehicles, including arrangements which can be erected in space, and others designed to perform specific functions, such as protection against meteoroids, high-energy radiation, and heat. We must define more accurately the many loads or forces that act on space vehicle structures. Among such forces are those due to ground handling, transportation, erection, winds on the launch pad and in flight, buffeting, acoustic vibration caused by rocket engines, landing impact, and many others. The structural properties of these new and advanced space vehicle systems must be thoroughly investigated to determine their strength for all important modes of structural failure. A most important and very complicated program area concerns space vehicle dynamics. The dynamic response characteristics of the entire space vehicle system to the various loads imposed upon it must be established along with the changes in these loadings which result from the structural deformation of the vehicle.

This many-faceted research program embraces both fundamental and applied research, and, in special cases, engineering developmental activities to provide data for vehicle refinements and improvement or for correction of design deficiencies. While much of this effort is devoted to improvement in theoretical and analytical techniques, practical limitations of theoretical methods make it essential that a large number of detailed experimental investigations be conducted in the many ground-based test facilities at various NASA Centers. However, the demands for rapid technological progress are such that at times neither theoretical analyses nor experimental investigations conducted in ground-based facilities can be relied upon to provide timely answers to all of the important problems. Consequently, as a complement to these ground-based programs, a series of carefully selected flight experiments has been planned to provide urgently needed data. In some cases the answers to important problems can be obtained only by flight experiments. The determination of the nature and extent of the meteoroid hazard is a specific example of such a research problem.

An important responsibility of those concerned with obtaining the new technological information is to insure early application of the more promising results of research activities in space vehicle design. This responsibility is discharged in part by reporting the results of research promptly to all concerned. The information resulting from research must also, however, be formulated into design criteria to insure application to vehicle design of the latest state-of-the-art in an acceptable and uniform manner. Accordingly, as a part of the space vehicle systems research program, uniform guidelines and criteria for space vehicle design will be prepared and kept up to date.

While most of the activities in the space vehicle research and technology program are general in nature, the results of these activities are applicable to all NASA space vehicles and missions, and in many cases, to military space vehicles as well.

EXPLANATION OF FUNDS REQUESTED:

Supporting research and technology

	1962	1963	1964
Advanced concepts.....	$1,480,000	$2,425,000	$4,120,000
Spacecraft aerothermo-dynamics.....	3,570,000	4,830,000	5,850,000
Spacecraft loads and structures.....	1,670,000	4,383,000	6,144,000
Space vehicle environmental factors.....	2,473,000	5,055,000	9,560,000
Launch vehicle aerothermo-dynamics.....	1,550,000	3,590,000	4,440,000
Launch vehicle loads and structures.....	1,877,000	4,494,000	6,148,000
Space vehicle design criteria.....	---	500,000	1,500,000
Subtotal, direct R&D costs..	$12,620,000	$25,277,000	$37,762,000
Personnel costs.....	19,724,000	24,154,000	27,115,000
Operation of installations....	13,061,000	12,523,000	13,879,000
Total costs.....	$45,405,000	$61,954,000	$78,756,000
Total personnel.....	2,536	2,759	2,952

Advanced concepts

In order to use supporting research and technology funds wisely, NASA's research programs must be based on a realistic appraisal of future space flight missions. The operational aspects of these missions along with spacecraft and launch vehicle concepts must be studied in breadth and depth. The results of such advanced conceptual studies will have an important effect on the future plans of all supporting research and technology programs. In fiscal year 1963, the major effort by both NASA laboratories and industrial contractors is being spent on broad preliminary studies in four major areas: manned orbiting space laboratories, advanced earth or orbit transportation systems utilizing vehicles capable of recovery, advanced earth-moon transportation systems utilizing nuclear propulsion, and manned and unmanned planetary missions. The fiscal year 1963 studies will help prepare the way for preliminary program decisions on manned orbiting space laboratories. The fiscal year 1964 study effort will be concentrated on more detailed analysis of the vehicle designs and the basic technological advances required for extending NASA's capability of operating more effectively in space through the use of space laboratories, operating more reliably and economically in earth-orbit and earth-moon missions through the use of

recoverable vehicle systems, and man's eventual exploration of the planets. The additional funds required are indicative of the greater effort needed as the problems under study are examined in greater detail.

Spacecraft aerothermodynamics

Past research in the field of spacecraft aerothermodynamics has produced a major part of the technology on which projects Mercury, Gemini, and Apollo spacecraft and the Air Force's X-20 (Dynasoar) are based. The major objectives of the research program are to develop the technology for successful and efficient entry into the earth's atmosphere for manned flight at interplanetary speeds and unmanned and manned spacecraft entry into the atmospheres of the other planets. A further objective is the provision of greater flexibility of operations both in earth orbiting flight and in deep space missions through advanced configurations having lifting ability, improved control, improved heat rejection ability, good volumetric efficiency, and growth potential. Inherent in these objectives is a greatly improved capacity for safe and reliable landing both on the earth and on other planets.

The aerothermodynamics effort encompasses a broad activity ranging from the most fundamental study of high-temperature plasmas to applied research on the heating and performance of promising spacecraft configurations. It is supported by theory, experiments in advanced laboratory facilities, and by carefully selected flight experiments such as project Fire. It is carried out primarily at the Langley and Ames Research Centers, with additional support from selected university and industrial contracts.

During fiscal year 1964, emphasis will be placed on research at the extreme velocities (45,000 feet per second and greater) associated with interplanetary flight. Studies will be continued on configurations designed to minimize radiative heating to spacecraft from the intensely hot gas cap at these speeds. Research will also be expanded in the area of entry into the atmospheres of other planets, with particular emphasis on those of Mars and Venus. Based on present estimates of the compositions of these atmospheres, preliminary experiments made during the past year indicate a more hostile heating environment than exists for the earth. Theoretical and experimental research will be pursued to provide improved fundamental and quantitative understanding of the physical processes involved in high-temperature atmospheric gases. To this end studies are being carried out to determine the radiation properties and atomic molecular collision interactions in shock-heated gases, and from these to determine the basic gas properties, such as thermal and electrical conductivity and viscosity, essential to the accurate prediction of ultra high-speed flows and heat transfer.

Emphasis will continue in applied research toward further investigation of recently developed concepts for "lifting body" entry vehicles which appear to offer important future advantages in flexibility of operations and growth potential for a variety of missions.

Landing and recovery research will be continued on all promising devices such as steerable parachutes, paragliders, rotors, retrorockets, and various combinations of these and other techniques. Effort will be extended

on the use of variable geometry in the form of inflatable afterbodies and extendable wings to provide the low-speed characterisitcs required for horizontal landing of compact lifting-body spacecraft. These efforts will be augmented by flight research on simplified manned vehicles to devise means of providing acceptable flying qualities of such craft.

Spacecraft loads and structures

The Mercury project conclusively demonstrated our ability to design spacecraft structures which can place a man in earth orbit and protect him from hostile environmental conditions for a brief period and assure his safe return. While the technology gained from this program has been of immeasurable value in working toward the more ambitious mission objectives of Gemini and Apollo, it has also revealed serious technological inadequacies in areas considered vital to the design of subsequent manned and unmanned spacecraft.

Most of these inadequacies are a direct result of more stringent mission requirements, which include increased payloads, higher performance, and longer operating times in the space environment. Particular emphasis is now placed on obtaining new research and technological information required to provide significant advances in ablative and other forms of thermal protection which can assure survival of future generations of spacecraft under the extreme thermal conditions of lifting and higher speed entry into earth and planetary atmospheres. In addition, information is required on the effects of prolonged exposure to environmental hazards.

Since reliable and efficient performance of spacecraft is mandatory, the rational design of future more complex vehicles requires that both the structural arrangement and materials used be tailored to meet more specific and exacting requirements. In order for the materials scientist to be prepared to tailor materials to a presently unforeseen requirement, vigorous research in the structure of matter at the atomic level is essential. Research is being expanded in solid mechanics to assure the availability of appropriate methods of analysis in time to exploit fully the structural ramifications offered by new and improved materials. Implementation of new research to accomplish these objectives will require a significant increase in the research and technology effort on spacecraft structures.

Space vehicle environmental factors

Vehicles for future space missions must be designed to cope with the hostile environment of free space. Such design becomes increasingly difficult for future missions primarily because of the longer duration of exposure to environments which are only partially defined and whose effects on the space vehicles are only known to a limited degree. Such environmental factors include high-energy particle radiation, meteoroid impact, zero gravity effects, hard vacuum, and the effects of thermal radiation.

All space vehicles will, to some degree, be exposed to high-energy radiation fields in space (e.g. Van Allen belts, solar protons, and galactic cosmic rays), with the hazard of the radiation environment depending on the mission. While the problem of protecting man and equipment from the effects of this hazard is important for any long duration mission, it is most severe for vehicles which spend a significant period of time in the trapped radiation belts. If such manned missions are to be conducted, large shielding thicknesses will be involved. Consequently, studies in such areas as secondary radiation, efficient use of on-board mass as shielding, shield optimization, methods for dose calculation and for exploration of active electromagnetic shielding concepts will be continued. Also, studies of radiation effects on particularly susceptible components and materials must be accomplished on a continuing basis in support of both unmanned and manned missions.

The hazard of collision with space debris will increase with mission duration. This debris, in the form of meteors, has been studied by astronomers for many years but there remains a fundamental uncertainty as to the magnitude of the associated hazard to spacecraft. Direct measurements by special satellites in space are required to determine the flux and physical characteristics of the meteoroids and their penetrating ability; further discussion of these experiments is included under the flight projects. Laboratory experiments in high-speed particle impact have produced a limited understanding of impact phenomena. However, true meteoroid velocities and masses have not yet been obtained in the laboratory, and a continued effort will be made to simulate natural meteoroid characteristics to obtain a fuller understanding of impact phenomena in order to devise optimum protection.

Knowledge of the effects of near perfect space vacuum on material properties is not readily obtained in present vacuum test chambers. In order to improve vacuum technology, techniques for reaching, maintaining and measuring the extremely low densities related to the space environment will be supported.

The effects of weightlessness during unpowered space flight pose problems for liquid fueld handling and storage. The major problem is that of positioning the fluid in the tanks so as to accomplish proper venting, as well as proper pumping on engine restart. Gratifying progress has been made during the past year, using small-scale drop tower experiments, in understanding the effects of fluid properties and tank geometry on the configuration of the liquid-vapor interface. It appears that techniques with considerable promise for the control of fluid position have been discovered. Continuing research is required on the behavior of fluids when subjected to such disturbances as accelerations, pumping, and venting, and on heat transfer from tank walls to cryogenic fluids such as liquid hydrogen. A number of these experiments, especially those involving heat transfer, require longer weightless times to insure equilibrium than can be obtained in ground facilities and thus can be practically accomplished only in free-flight.

Spacecraft, both unmanned and manned, must operate within relatively narrow temperature limits. This is complicated by the fact that the vehicles are absorbing radiation from the sun, and radiating heat to the extreme cold of surrounding space at the same time. Interplanetary trajectories will encompass immense ellipses which pass well inside the earth's orbit in the direction of the sun at one time, and then far outside the earth's orbit at another time, resulting in a wide variation in the radiation received from the sun and, hence, a complex problem in temperature control. The characteristics of space vehicle coatings, both in space and in space simulators, will be studied as will mechanical or electronic techniques for altering the heat balance of space vehicles. Methods for more accurately simulating the solar spectrum and for using models to reduce the need for full-scale ground testing will be investigated.

Launch vehicle aerothermodynamics

The primary objective of this effort is to supply the technical knowledge required for the development of the more highly advanced, larger, and more efficient launch vehicles required in the future space program. The configuration aspects of the research will emphasize analytical and experimental investigations of trajectories and staging, loads and forces on spacecraft fairing and transition areas between rocket stages of differing diameters, launch vehicle dynamic and static stability, overall vehicle aerodynamic loads and forces, hinge moments of gimballed rocket nozzles, and flow phenomena in regions of the rocket base. Studies will be continued to determine arrangements of clustered engine nozzles to minimize base heating. The characterisitcs of rocket motor jet plumes will be studied in simulated space pressures, with particular reference to vehicle stability and flight behavior during staging.

Venting flow studies will be continued to determine methods of assuring that the gaseous fuel products will not collect in areas where dangerous explosions could occur during operation of launch vehicle upper stages.

Studies of launch vehicle landing and recovery technology are continuing. With the advent of very large launch vehicles, it may be advantageous to employ wings and possibly some type of propulsion for returning the booster to its launch area. Studies will be initiated to examine the aerothermodynamic problems of such concepts.

The noise generated by large rocket engines is a severe problem, both from the effect on the space vehicle and the launch area. Studies of the noise field around the Kiwi nuclear rocket were initiated this year. Analytical and experimental studies on the generation and propagation of noise from both chemical and nuclear rockets will be continued.

With the large size boosters anticipated in the coming years, launch vehicle aerothermodynamics technology must be expanded as a basis for design of Nova class vehicles. A major portion of this program will be carried out at the Marshall Space Flight Center with support from the Langley, Ames, and Lewis Research Centers.

Launch vehicle loads and structures

The primary goal is to provide the information necessary for the successful, reliable, and efficient performance of structures for future launch vehicles. Future launch vehicles of primary concern will differ substantially from those currently in use or under development. In particular, they will be much larger, and more expensive, which will make impractical the scheduling of a large number of experimental test flights. Accordingly, greater accuracy will be required in predicting structural behavior in the design stage. Research on the application of small-scale dynamic model data to large flight vehicles is one of the studies directed toward achieving this objective. Increases in size and performance of launch vehicles require a substantially greater research effort to obtain information applicable to structural design in such areas as advanced configurations, use of new materials, protection against space hazards, high-temperature conditions, determination of the critical loads acting on the vehicle, and the dynamic response of the structure. Structural components of future launch vehicles will be subjected also to environmental effects on which more detailed information is required. In addition to more information on the effects of the space environment, more detailed and accurate information is required on the effects of atmospheric winds and turbulence on the launch vehicle structure. The fiscal year 1964 budget represents an increase in level of effort commensurate with the shift of emphasis to problems associated with the larger, more complex launch vehicles which will be required to meet future space flight mission requirements.

Space vehicle design criteria

This activity is an engineering effort to enhance the flight worthiness and reliability of future NASA space vehicles. The general design criteria and basic guidelines to be evolved are to provide the designers of NASA space vehicles with a basic and uniform set of conditions for use in designing launch vehicles, spacecraft, and reentry vehicles, as well as integrated space vehicles. Included within this activity is the complilation, correlation, and assessment of state-of-the-art research and technology and the preparation, documentation and updating of general design criteria, standards, and basic guidelines. The effort encompasses the establishment of standard models of the environment within which space vehicles operate and of criteria for the design of the structure, propulsion system, and guidance and control system. The work is being primarily accomplished in-house by the field Centers through a steering committee with working subordinate subcommittees and ad hoc groups. As the criteria activity was proposed and approved late in fiscal year 1962, the activity was just getting underway at the close of the calendar year. The method of intermixing both advanced research and technology oriented and space flight oriented professionals from the various Centers on the steering committee, subcommittees, and groups insures that the knowledge gained from research and technology activities applicable to space vehicles and from flight experience is available to evolve, expand, and update the criteria. The funds requested in fiscal year 1964 will provide

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for the cost of utilizing outside organizations, through contracts, to assist in the preparation of the criteria. The first rough or skeleton NASA criteria, which is planned for completion in fiscal year 1964, and the follow-on expansion and updating as the technology changes will be coordinated with other interested federal departments and with the aerospace industry.

FLIGHT PROJECTS:	1962	1963	1964
Scout reentry heating			
Spacecraft and support services	$(815,000)1/	$ 400,000	$ 500,000
Launch vehicle.....	3,000,000	1,000,000	1,000,000
Subtotal, direct R&D costs	$3,000,000	$1,400,000	$1,500,000
Personnel costs.....	$ 736,000	$ 830,000	$ 906,000
Operation of installations.....	518,000	494,000	495,000
Total costs.....	$4,254,000	$2,724,000	$2,901,000
Total personnel.....	97	98	103

1/ $815,000 was funded in fiscal year 1962 "Operation of installation".

Flight Schedule

Mission	Launch vehicle	Calendar year of launch	Launch location
Materials test	Scout	1963	Wallops Station
Radiative heating	Scout	1963	Wallops Station
Total heating	Scout	1964	Wallops Station

These flight experiments are an essential part of the advanced research and technology program on spacecraft reentry heating. Ground facilities are able at present to provide only partial simulation of the environment for bodies reentering the atmosphere at velocities higher than ICBM reentry speeds. Flight tests are required to verify and extend the theoretical analyses and to provide correlations for ground facilities. The objectives of this series of experiments are to measure, at speeds of about 28,000 feet per second, total heat transfer to the instrumented spacecraft, radiative heat transfer from the hot gas cap, and determine thermal effectiveness and structural integrity of charring ablators and other high-temperature materials. The first experiment to measure total heating was launched from Wallops Station on March 1, 1962, and achieved 23,000 feet per second. The second, launched August 31, 1962, designed to measure radiative heating, was a failure due to malfunction of the launch vehicle. Preparations for the third experiment are about completed, with the launch schedule

delayed to allow corrective modifications to be made on the Scout launch vehicle. Preparations for the fourth experiment are under way. The funds requested in fiscal year 1964 are to provide an additional experiment to measure total heating at velocities approaching 30,000 feet per second.

FIRE	1962	1963	1964
Reentry vehicle and support services	$1,346,000	$5,500,000	$3,400,000
Terminal velocity vehicle..	223,000	2,500,000	600,000
Launch vehicle.....	2,400,000	4,000,000	---
Subtotal, direct R&D costs	$3,969,000	$12,000,000	$4,000,000
Personnel costs.....	$ 809,000	$ 1,362,000	$1,319,000
Operation of installations.	519,000	693,000	597,000
Total costs.....	$5,297,000	$14,055,000	$5,916,000
Total personnel.....	106	159	149

Flight Schedule

Mission	Launch vehicle	Calendar year of launches	Launch location
Measure heating at lunar return velocities (37,000 feet per second)	Atlas plus Antares	1963-1964	AMR

The reentry heating of spacecraft becomes rapidly more severe and less predictable as reentry speeds approach and exceed the speeds involved in return from a lunar space flight. For blunt spacecraft, such as Apollo, at these speeds the air becomes so hot that it radiates substantial heat to the spacecraft. There exist, at present, large uncertainties as to the magnitude of this radiative heating and its effect on spacecraft. Although the most modern ground-based facilities are brought to bear on investigating the heating problem, no single facility either existing or under construction within the country can simulate all the important factors affecting aerodynamic heating (for instance correct velocities, proper heating rates and total heat input values, correct time-heating histories, true atmospheric density variations during reentry flight, and sufficient model size) for a sizeable spacecraft reentering the earth's atmosphere at speeds corresponding to return from a lunar flight. Data from several different facilities must be pieced together and grossly extrapolated with judgement based on available theories to arrive at aerodynamic heating estimates for spacecraft like Apollo.

The primary technical objective of project FIRE is to investigate the heating environment and heating effects around a blunt vehicle having a shape similar to Apollo, during an actual reentry flight at 37,000 feet per second to provide critical anchor points for improving confidence in the limited laboratory test facilities as well as to provide guidance for the application of the experimental and theoretical reentry data generated by laboratory research. The results will also have significance in considering the heating problem which would be encountered in the event of an emergency reentry of Apollo at a steeper entry angle than planned.

Project FIRE, at 37,000 feet per second, is an extension of the Scout reentry research project described above. Project FIRE uses an Atlas D to boost the spacecraft along an ICBM trajectory over the Atlantic Missile Range. The spacecraft consists of a terminal velocity vehicle to impart the necessary reentry velocity, and a reentry vehicle.

General Dynamics/Astronautics is responsible for providing the Atlas D booster and for performing overall system integration functions. Republic Aviation Corp. is the principal contractor on the reentry vehicle, and Change Vought/Astronautics on the terminal velocity vehicle. The Langley Research Center is responsible for overall Project FIRE management; the Marshall Space Flight Center for the Atlas procurement; and the Marshall Space Flight Center together with the Launch Operations Center for launch of the space vehicles. Project FIRE consists of two flight articles plus one additional prototype spacecraft for development testing.

The project was approved in December 1961. The launch vehicle, reentry vehicle and terminal velocity vehicle contracts were awarded during March, May and June of 1962, respectively. The reentry and terminal velocity vehicles reached the approximate 95 percent design point by November 1, 1962 and initial fabrication was well under way. The fiscal year 1964 effort will be largely for final fabrication and assembly, check out, launch and data reduction for the two flights.

Advanced FIRE	1962	1963	1964
Spacecraft and support services	$ ---	$ ---	$5,600,000
Velocity package	---	---	1,200,000
Launch vehicle	---	---	1,700,000
Subtotal, direct R&D costs	$ ---	$ ---	$8,500,000
Personnel costs	---	---	292,000
Operation of installations	---	---	134,000
Total costs	$ ---	$ ---	$8,926,000
Total personnel	---	---	33

Flight Schedule

Mission	Launch vehicle	Calendar year of launches	Launch location
Radiative heating at planetary return velocities	Atlas Agena	1965-1967	AMR

This project will extend the data from project FIRE at 37,000 feet per second (lunar return velocity) to 45,000 feet per second (interplanetary return velocity). Data from this project also will have an imporant bearing on unmanned flights at about the same speed in the atmosphere of Venus, which are now planned for the 1965-1970 time period.

It is expected that the heat radiated by the hot gas cap surrounding the spacecraft during interplanetary return will be many times greater than in the case of the lunar return, and will be accompanied by a critical change in the materials response to heat input. Measurements in flight using the Atlas-Agena vehicle are required to validate theoretical analyses and to provide data for correlation with very limited data from ground facilities.

The Langley Research Center will be assigned management responsibility as a follow-on to project FIRE.

Scout-launched meteoroid satellites	1962	1963	1964
Spacecraft and support services	$ 78,000	$1,620,000	$450,000
Launch vehicle	800,000	1,500,000	500,000
Subtotal, direct R&D costs	$878,000	$3,120,000	$950,000
Personnel costs	250,000	338,000	166,000
Operation of installations	183,000	217,000	130,000
Total costs	$1,311,000	$3,675,000	$1,246,000
Total personnel	33	40	19

Flight Schedule

Mission	Launch vehicle	Calendar year of launches	Launch location
Meteoroid penetration experiments	Scout	1962-1964	Wallops Station

This project is an extension of the advanced research and technology program for study of space environmental factors. The current status of knowledge concerning the meteoroid hazard is such that the uncertainty in weight of material required for protection of spacecraft is represented by a factor of twenty. Flight experiments will provide directly applicable engineering information on meteoroid penetration even in the absence of knowledge of meteoroid velocity and density, or of an understanding of the phenomena of penetration.

The primary objective of this series of satellites is to determine the frequency of meteoroid penetrations through metal sheets from one to five-thousandths of an inch in thicknesses of aluminum and steel.

These satellites are the first approach to obtain data to reduce the large uncertainty which exists at present concerning the probability of penetration of a spacecraft by meteoroids. Since the satellites are limited in weight, only a limited area of material can be exposed to meteoroids, and thus they are likely to encounter in significant numbers only meteoroids capable of penetrating relatively thin materials. To obtain data on material thicknesses approaching those used in actual spacecraft, and to obtain more accurate data essential to predict the probability of penetration for flights of long duration, additional experiments will be necessary.

These spacecraft, launched by the Scout rocket, are about two feet in diameter by six feet long with a total sensor area of about 25 square feet. Orbital life is one year. Project management responsibility is at the Langley Research Center. One satellite was launched in August 1961, but remained in orbit only 2½ days due to an injection error. The life-time was too brief for any penetrations to be recorded.

Saturn-launched meteoroid experiments	1962	1963	1964
Spacecraft and support.....	$ ---	$2,430,000	$4,250,000
Personnel costs.....	---	427,000	442,000
Operation of installations....	---	231,000	252,000
Total costs.....	$ ---	$3,088,000	$4,944,000
Total personnel.....	---	44	44

Flight Schedule

Mission	Launch vehicle	Calendar year of launches	Launch location
Meteoroid Experiment	Saturn	1964	AMR

By 1964, the Scout-launched meteoroid satellites will have provided data on the frequency of penetration of very thin metal skins, and will have provided statistics on the meteoroid hazard to spacecraft. There will remain, however, a significant uncertainty concerning the frequency of penetration of metal skins thicker than 0.005 inches in the near-earth environment.

This project, which will be launched on development Saturns, will expose to meteoroid penetration almost 100 times more area than the Scout-launched series. In addition, this experiment will provide data on penetrations into material thicknesses approaching nominal vehicle wall thickness, such as would be found in the Apollo tanks, SNAP-8 radiators, and other propellant tanks.

The experiment will consist of either a umbrella-type or wing-like structure which will be erected in orbit. About 200 square meters of surface will be exposed to penetration. The spacecraft will contain the normal guidance, control, power and telemetry systems. Its expected weight is about 4,000 pounds, and its life time in orbit will be about one year.

The experiment will be launched by two development Saturn vehicles, as a secondary experiment to Apollo tests, and will replace the ballast normally carried on these tests.

Space vehicle recovery	1962	1963	1964
Flight vehicles and support services	$ ---	$ ---	$950,000
Personnel costs	---	---	280,000
Operation of installations	---	---	136,000
Total costs	$ ---	$ ---	$1,366,000
Total personnel	---	---	31

Laboratory experimental and analytical studies indicate great promise for lifting-body type spacecraft for manned space flight applications. Such vehicles are conceived as having a moderate amount of lift capability at hypersonic speeds to ease the reentry problem (lift/drag ratios between 1.0 and 1.5) and sufficient lift capability at subsonic speeds to permit a horizontal airport-type landing. Although wind tunnel and flight simulator studies provide some indication of the piloting characteristics of the wingless configurations, manned flight tests of a few selected configuration types are required to permit a satisfactory evaluation of their subsonic flying qualities. The overall aerodynamic, structural mass distribution and flight control systems characterisitcs are considerably different from those of aircraft configurations in which flight test data are available.

The lifting body configurations to be constructed and flown are being selected on the basis of extensive laboratory wind tunnel and analytical studies. The relatively inexpensive large scale vehicles are unpowered; they will be towed at low speeds by ground vehicles and aircraft. Upon release at selected altitudes, research flight test pilots will fly the instrumented vehicles back to earth. In addition to the towed tests, consideration will be given to air drop tests from large aircraft. Information will be obtained on general piloting qualities of the vehicles, on flight control system characteristics, and on landing characteristics of such type spacecraft. Sufficient flights will be made to assess the operational procedures and potential of the lifting body class of manned spacecraft. The Flight Research Center will conduct the flight tests.

Secondary environmental experiments	1962	1963	1964
Experiments and support services	$ ---	$ ---	$550,000
Personnel costs	---	---	440,000
Operation of installations	---	---	182,00
Total costs	$ ---	$ ---	$1,172,000
Total personnel	---	---	50

These will be secondary experiments flown on launch vehicles or spacecraft funded elsewhere. The size, weight, and data-transmission requirement characteristics of experiments for testing of materials in the space environment are such that these experiments can often be carried on spacecraft having other primary objectives, permitting the materials experiment to be accomplished without the full cost of a separate launch. For example, a secondary experiment carried aboard the Orbiting Solar Observatory has provided useful data on the emissivity characteristics of several spacecraft materials as affected by continued exposure to the space environment. These data differed in certain important respects from data previously obtained in ground facilities, revealing that all of the factors in the space environment which affect the emissivity of materials have not yet been adequately simulated in the ground facilities used for such tests.

The funds requested for fiscal year 1964 will permit secondary experiments to establish the effects of the several factors in the space environment on the physical characterisitcs of a wide variety of important spacecraft materials.

Launch schedules are not detailed since they are secondary experiments to be flown on launch vehicles or spacecraft funded in other programs.

Small space vehicle flight experiments	1962	1963	1964
Behavior and handling of cryogenic propellants at zero g.....	$ ---	$ 800,000	$1,650,000
Wind shear measurements.....	---	114,000	600,000
Meteor simulation.....	---	600,000	600,000
Trailblazer reentry project...	---	100,000	200,000
Meteoroid penetration probe...	295,000	90,000	450,000
Subtotal, direct R&D costs..	$295,000 1/	$1,704,000	$3,500,000
Personnel costs.....	$1,302,000	1,588,000	1,684,000
Operation of installations....	1,005,000	970,000	996,000
Total costs.....	$2,602,000	$4,262,000	$6,180,000
Total personnel.....	173	187	188

1/ In addition, $925,000 was provided from fiscal year 1962 Operation of installations funds.

This project provides a number of carefully selected ballistic trajectory flight experiments using small launch rockets to verify results obtained in ground facilities, and to investigate problems which can only be studied under actual space environmental conditions. Current experimental objectives include: studies of the behavior and handling of cryogenic propellants (liquid hydrogen) in the zero-g condition to provide information for the design of space propulsion systems utilizing cryogenic propellants; measurements of wind shear profiles in the vicinity of major rocket launching bases to aid in the structural design of launch vehicles and establish launch wind criteria; simulation of meteors by firing pellets of known size into the atmosphere from reentry rockets to provide a basis for deducing the size of photographically observed natural meteors, and thus to establish the probability of encountering meteoroids larger than those likely to be encountered by a meteoroid satellite; measurement of radar cross-section of reentering objects as affected by the ionized air surrounding the object; and exploration of meteoroid showers by means of recoverable probes in the form of paragliders, permitting study of composition of meteoroids and impact phenomena.

Lewis Research Center has management responsibility for the zero-g experiment; Langley Research Center has management responsibility for the others.

Launch schedules are not detailed since this project incorporates a number of small experiments scheduled on a non-interference basis with respect to major rocket and satellite launchings.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

ELECTRONIC SYSTEMS

OBJECTIVES:

The objectives of the Electronic Systems Program are to provide reliable and efficient components, and flexible and proven techniques for developing guidance, stabilization, communications, tracking, instrumentation and data processing systems which will meet the projected needs of the NASA's future manned and unmanned space missions.

SUMMARY OF RESOURCES REQUIREMENTS:

Funds	1962	1963	1964
Supporting research and technology	$4,933,000	$18,846,000	$26,612,000
Small flight projects	---	1,850,000	3,750,000
Subtotal, direct R&D costs	$4,933,000	$20,696,000	$30,362,000
Personnel costs	11,721,000	15,576,000	19,034,000
Operation of installations	7,837,000	8,603,000	9,890,000
Total costs	$24,491,000	$44,875,000	$59,286,000

Personnel			
NASA Headquarters	55	61	62
Ames Research Center	456	479	497
Lewis Research Center	135	132	140
Langley Research Center	739	728	725
Flight Research Center	22	59	65
Marshall Space Flight Center	92	152	155
Manned Spacecraft Center	-	6	11
Goddard Space Flight Center	-	112	113
North Eastern Office	-	1	1
Electronic Research Center	-	47	240
Total personnel	1,499	1,777	2,009

The Office of Advanced Research and Technology at NASA Headquarters has the management responsibility for the Electronic Systems Program. NASA Centers and the Jet Propulsion Laboratory provide support for the implementation of the program through in-house efforts, and through institutional and industrial contracts.

PROGRAM JUSTIFICATION:

The electronic systems in spacecraft and launch vehicles play roles analogous to the senses and nervous systems in human beings. The navigation and control systems are adjuncts to man's sight and sense of balance, the communications systems permit man to extend his senses of sight and sound over great distances and much beyond their natural ranges, and instrumentation, computation and data processing techniques in many cases perform as the spacecraft's "brain and nervous system."

As man ventures into space for longer periods and greater distances, the launch vehicle and spacecraft must contain more refined sensors, instrumentation, computation and data processing facilities along with other elements such as life support equipment, environmental control and power generation.

Guidance and navigation research and technology are aimed at developing the techniques, systems and components required for future spacecraft and high performance vehicles; and are supporting flight research programs to determine the feasibility of their operation in flight environments.

The control system research and technology efforts derive and implement the developments necessary to optimize both manned and unmanned control of aerospace vehicles. Although considerable success has been attained in flight programs, the limited capabilities of equipment and techniques used for the stabilization and control of manned and unmanned vehicles are being strained by today's demands, and will be inadequate for the future. Since NASA objectives in space exploration entail performance requirements that cannot be fulfilled by existing techniques and equipments, it is considered vital that research and advanced technological development be undertaken to meet these objectives.

The communications system research and technology activity is designed to meet the ultimate communication needs of spacecraft on planetary missions, while the immediate results can also benefit lunar programs. Meteorological, communications, and scientific satellite programs are also benefited through the development of advanced, reliable, and small devices for communications system.

The tracking activity is directed towards achieving more effective and accurate tracking systems in range, velocity and angular measurement; and to develop extremely sensitive data acquisition systems for detection of very weak signals from space vehicles.

Work on advanced instrumentation is required to insure the timely availability of advanced measurement techniques, devices and systems. Advanced instruments are prerequisites for exploring, charting and cataloging the nature of near and deep space. The instrumentation of tomorrow must have markedly improved reliability, accuracy, sensitivity, range, and speed of response while obtaining unique data under highly adverse conditions.

Data handling and processing research and technology is aimed at insuring the existence, when needed, of space computing systems which best meet the varying requirements of manned and unmanned missions of long and short duration. The computer is becoming more vital to space exploration; consequently, its operation must be made more reliable for longer periods of time while executing many vital tasks of increasing complexity.

EXPLANATION OF FUNDS REQUESTED:

Supporting research and technology:

	1962	1963	1964
Guidance systems	$ 900,000	$4,590,000	$5,820,000
Control systems	1,025,000	3,527,000	4,928,000
Communication systems	1,220,000	3,952,000	4,585,000
Tracking and data acquisition systems	540,000	1,930,000	3,488,000
Instrumentation	658,000	2,669,000	4,252,000
Data handling and processing	590,000	2,178,000	3,539,000
Subtotal, direct R&D costs	$4,933,000	$18,846,000	$26,612,000
Personnel costs	9,858,000	13,833,000	18,362,000
Operation of installations	6,631,000	7,698,000	9,586,000
Total costs	$21,422,000	$40,377,000	$54,560,000
Total personnel	1,255	1,574	1,933

Guidance systems

Guidance systems research has the general objective of establishing and predicting the spatial position of aeronautical vehicles or spacecraft with instrumentation and components as simple and reliable as the accuracy requirements will permit. Fiscal year 1964 funding will be utilized to continue current research and technology on cryogenic (superconductive magnetic) and electrostatic gyros and accelerometers. Marshall Space Flight Center and the Jet Propulsion Laboratory are the focal points of this research. The fiscal year 1963 success in advancing the state-of-the-art of the

electrostatically-supported sensor and its potential for long term space flight application justifies substantial funding in fiscal year 1964 for these devices. In addition, a number of Center and industry proposals for gyros and accelerometers using atomic particles and micron size (dust particle size) particles are in the formative stages. These new devices offer sufficient promise of increased reliability in an environment of shock, vibration, and varying temperature to warrant fiscal year 1964 funding.

Currently planned manned lunar and possible planetary missions place emphasis upon on-board optical space navigation instruments akin to present day aircraft and marine sextants. This concept offers considerable advantage from the standpoint of simplicity, lightness and optimum use of the man if ways can be found to stabilize adequately and read data out of the instruments. Current concepts require maneuvering of the spacecraft to allow such instruments to sight from existing ports, an unnecessary expenditure of fuel and a compromise to other mission objectives. To alleviate these problems, technology efforts were begun in fiscal year 1963 to provide self-stabilized optical space navigation instruments having adequate performance. This effort will continue at Ames Research Center in fiscal year 1964 at a funding level above that of fiscal year 1963.

The present state-of-the-art in spacecraft radar detectors and trackers is based upon Department of Defense experience in airborne intercept radars for use with short-range guided missiles. The space environment, target sizes and target position uncertainties make this radar technology marginal for space use. Current emphasis in the fields of radar and laser type guidance sensors is on studies to establish requirements for advanced space-borne detection, tracking and navigation systems. Parallel to these studies, limited technology programs in those elements for which a requirement is clear (as an example, advanced spacecraft radar antennas) have received fiscal year 1963 attention. The results of the requirements studies will provide a sound basis for increased fiscal year 1964 emphasis on spacecraft radar-type sensors.

Guidance sensors must be tied in to the overall mission objectives and furnish useful information to the astronaut crew. Additionally, most sensors now planned require simple computation to bring guidance signals out in the proper form. To satisfy these requirements, research has been directed in fiscal year 1963 to the application of advanced computer and display technology (developed elsewhere within NASA) to specific guidance problems for both manned and unmanned missions. This research will continue in fiscal year 1964. Of particular interest are computational systems utilizing power supplies common to other guidance and mission subsystems. As an example, a cryogenic gyro and a cryogenic computer both require a source of super-cooled liquid. This source could be a super-cooled liquid fuel such as liquid hydrogen.

Much of the guidance systems requirement is determined by the path or trajectory followed by the spacecraft in navigating from earth to the moon and planets. Analysis of the various trajectories possible is in its

infancy. During fiscal year 1963, emphasis began to shift from earth orbiting and lunar missions towards advanced planetary mission studies. Continuous thrust, which appears to be feasible for deep space propulsion, will over long-time periods propagate minor errors made by the guidance system into major errors in the vicinity of the planets. Understanding of these problems is vital to future guidance system designers. The fiscal year 1964 program encompasses work at Langley, Ames and Lewis Research Centers and at Marshall Space Flight Center.

Guidance simulation facilities for advanced manned space systems have been built at Langley and Ames Research Centers over the past several years. During fiscal year 1964, further improvement in the sophistication of these devices as well as use on current programs is planned.

Control systems

Vehicle stabilization along the desired flight path is a major objective of control systems. The funds requested for fiscal year 1964 will be applied to theoretical and experimental investigations of manual and automatic flight control systems, flight displays, advanced control theory, advanced flight component technology, and simulation technology as applied to flight control.

The primary goal of the control systems research is to develop technology such that highly reliable control systems may be designed to operate in a very hostile environment, deriving impetus from the environment where possible, and accomplishing the required performance with minimum cost in terms of weight, size, and dollars, and with minimum risk to the humans involved. The research tools used to accomplish these goals include theoretical, mathematical and simulation techniques, followed by practical feasibility demonstration.

Included in the efforts of the NASA Centers in fiscal year 1963 are, for example: at Langley, pilot control (simulator) studies of all phases of a lunar mission; at Ames, passive attitude control studies drawing on the X-15 experience at Flight Research Center to improve spacecraft displays; reaction sphere satellite attitude controls at Goddard; a low altitude sensor for use with rocket landing systems at Manned Spacecraft Center; and thrust vector control of large rocket motors at Marshall.

Future work at Ames will be directed toward the solution of planetary reentry flight control and display problems; Goddard will improve orbital vehicle attitude controls, both passive and active; Langley will intensify lunar environment flight control research related to landing, rendezvous, and docking; Flight Research Center will investigate piloting problems of sail-type vehicles and lenticular shapes; Lewis will investigate application of advanced control concepts to propulsion systems of the future; Marshall will implement efforts to optimize flight control systems for multi-stage launch vehicles; and Manned Spacecraft Center will utilize information gained from the manned space flight program to improve the utilization of instrumentation for attitude control.

Optimal operation of control and navigational equipment is to a large degree dependent on the fundamental properties and behavior of materials used in their construction. Minute errors in this equipment can cause errors which produce destinations thousands of miles off course. Examples of such problems to which effort will be devoted in fiscal year 1964 are:

a. The machining of bearing surfaces to higher and higher accuracies and surface finishes encounters the limitations in accuracy of our machine tools and the unfortunate situation that adjacent smooth clear bearing surfaces will cold-weld to each other in the vacuum of space. Research under way on minimum friction and welding bearing surfaces and coatings will continue, leading to an early development and evaluation of preliminary coatings.

b. The use of gas bearings for gyroscopes and other control components is being aggressively studied. Even these need the non-stick surfaces for missions involving start-up in space and for additional safety in the event of gas flow interruption.

Communication systems

Maintaining voice and/or data-link contact between spacecraft and earth, earth and satellites, planets and earth, or various combinations of these elements is the general goal of communication systems research. Implicit in this goal is reliability, reduced power requirements and increased efficiency. In fiscal year 1964, the communications effort will be directed primarily toward the support of the lunar and planetary missions for achieving adequate bandwidth for TV, voice communications, scientific and trajectory data.

A specific objective is to assure communications during reentry into the earth's atmosphere from lunar and planetary missions, as well as during entry into unknown planetary atmospheres. Another technical objective for the longer missions is to achieve high reliability and tolerance to the space radiation environment in the electronic instruments used for the vital communications links. A further objective is to develop devices and techniques that will permit the use of optical masers (LASERS) in communications systems, which should increase both the channel capacity and range of these systems.

Advances in optical communications devices have been rapid in the past year. A parametric system study was initiated with General Electric in an effort to identify the limitations of the component parts of a coherent optical space communications system, as well as to indicate the constraints imposed on such a system by the environment. It is hoped that this effort will bring to light the many technical disciplines that must be pursued in order to realize a practical optical communications system. The Goddard Space Flight Center will conduct a flight experiment in 1963 using the S-66 satellite, to obtain scientific data on communications systems using optical frequencies. This work will be continued in fiscal year 1964 with added emphasis placed on supporting effort in search of new laser devices which

will prove most useful in NASA communications systems. For instance, as an illustration of a possible breakthrough, the efficient direct conversion of electrical energy into coherent optical radiation has recently been demonstrated by the Massachusetts Institute of Technology, General Electric, IBM, and others. These devices and techniques will be exploited in fiscal year 1964. The Manned Spacecraft Center is already considering manned space flight applications. Also, Marshall Space Flight Center and Goddard Space Flight Center will study the principles more broadly for satellite applications.

Possible applications for optical communications include earth-to-moon links; communications between manned spacecraft; communications relays in which optical techniques will provide the link between systems in space, while the relay link to earth will utilize conventional frequencies; flashing lights for geodetic satellites and for rendezvous missions.

Work in microelectronics in fiscal year 1963 has been accelerated with efforts at Philco, General Electric, and the Harry Diamond Laboratories (formerly Diamond Ordnance Fuze Laboratories). These efforts are directed toward obtaining electronic devices which are small, light-in-weight, use less power, have extremely long life and reliability, and which will be relatively insensitive to the space radiation environments. Also, the Manned Spacecraft Center is initiating a program to develop a belt pack to be worn by astronauts, which will provide two-way simultaneous voice communications and process several channels of environmental and biological data.

In fiscal year 1964, greater emphasis through the Langley Research Center and other Centers, will be placed on advanced technology to further exploit and fabricate devices which can be used in space systems. These devices should provide for long-life, reliable operation in hostile environments. In addition, a study will be initiated to investigate the pertinent applications for specific NASA space systems or subsystems. For instance, the applications missions have a requirement for better telemetry systems which should be light, more efficient and reliable than systems presently used. One proposal is to launch numerous balloons for meterological studies of the atmosphere, requiring a complete electronic communications package weighing only one pound. Microelectronic techniques offer the only reasonable approach for this problem.

Basic research is being undertaken to investigate the mechanism of energy transfer in atoms and molecules by stimulated emission processes. The information is necessary to develop materials which emit radiation in wave lengths from 1 millimeter down to the gamma ray region. This will be the basis for utilizing the extremely high frequency regions for space communications.

Also, research is being conducted in ferroelectric materials and superconducting gyroscopic materials. The understanding of the basic principles involved will lead to the ultimate development of such devices as improved memory devices in computers and guidance equipment.

Research is being directed toward providing better understanding of the physical characteristics of the plasma sheath surrounding reentry vehicles, as well as of the physics of propagating waves through plasmas. The results of such research are expected to prove of value in studies of the reentry communications blackout problem. Up to the present time, certain discoveries involving use of material additives have been made in techniques for overcoming radio blackout caused by ionized plasma. Further work, both theoretical and experimental will be done in fiscal year 1964.

A novel scheme has been suggested for using the charged particles of the upper atmosphere as the propellant in electric propulsors for attitude control and drag compensation for satellites. Research studies will be undertaken to investigate the feasibility of such schemes.

Tracking and data acquisition systems

As spacecraft probe more deeply into space, accurate position and velocity readings on the vehicle are more difficult to obtain; tracking system research devises and investigates new components, techniques and systems which offer promise of meeting the known or anticipated requirements. The fiscal year 1964 efforts in this area will support missions involving injection from orbit, rendezvous in space, and reentry into the earth's atmosphere for both manned and unmanned spacecraft and planetary missions.

Specific technical objectives include the development of real time optical tracking for heightened precision, accurate means for tracking during the critical reentry period of manned spacecraft despite the presence of the ionized plasma sheath, ground data acquisition and tracking techniques of greater efficiency for spacecraft at planetary distances.

Fiscal year 1963 funds have been used primarily for studies in tracking systems, along with some limited laboratory experiments in optical tracking techniques. Work has been initiated on advanced devices for use of coherent light in tracking. Goddard Space Flight Center has designed corner reflectors for installation on the S-66 satellite for optical tracking work. These satellite experiments will test the validity of a number of relativistic concepts that may significantly affect the employment of optical frequencies for tracking. It is expected that these techniques will provide an order of magnitude improvment over present electronic techniques for tracking. In fiscal year 1964, work will be concentrated on further improving laser devices for tracking and on extending the experience gained in transmission and propagation experiments on satellites to supporting research and technology in deep space tracking missions.

A multiple array antenna system has been designed. This system would use an array of small antennas operating cooperatively to produce the equivalent gain of very large aperture antennas. Experimental work has been conducted at Langley Research Center to confirm the feasibility of this technique for arraying a number of independently-steerable antennas.

In fiscal year 1964, increased experimental work and additional funding for prototype hardware involving multiple array antennas will be required.

It is planned to investigate the use of pyrotechnic devices to provide positive indication of important events occurring at critical times during the trajectory, such as in reentry. In this manner positive visible tracking evidence will be available.

Thin film magnetic devices offer considerable promise for reduced weight, low-power-consuming circuits and improved reliability. The basic nature of the magnetic process in thin films, the specification of optimum thickness, composition and process criteria for various thin films remain as the subject of needed research in order to obtain the maximum potential from this new solid-state physics tool for control devices and computers for tracking systems.

Instrumentation

The rapid increase in distance, duration, and complexity of space flights creates correspondingly increased demands on instrumentation. Future missions will impose such stringent requirements on instrument design that current efforts must be accelerated if these requirements are to be met when needed.

Major efforts to advance the state-of-the-art of instrument design are currently being pursued; however, future requirements dictate development of more reliable instruments having increased accuracy, speed of response and stability coupled with the ability to perform reliably in harsh and unknown environments. These instruments must also be designed to minimize power demands and yield information, preferably in digital form, suitable for immediate processing or transmission.

Such instruments will be needed for measuring the atmosphere, and electromagnetic, gravitational and particle fields surrounding major bodies of the solar system. Devices will be developed to determine accurately the numbers and important characteristics of highly energetic charged and neutral particles.

Engineering instruments suitable for use with the very large launch vehicles and multi-manned spacecraft will be developed. These instruments will measure and provide information both to the operations personnel on the ground and to crews in spacecraft concerning the functioning of the various booster and spacecraft systems during launch and in flight.

Instruments will be developed to enable maintenance of close surveillance of the physical well-being of personnel in the spacecraft and of the operation of essential life support systems.

Currently, a prototype device being developed under contract by the United Aircraft Corporation to record cardiograms, respiration rate and volume has been tested. This device is completely self-contained and includes a sensor, battery, and radio transmitter with a range of about 30 feet. When completed, this device, utilizing molecular electronic techniques, will be about 1/2" x 1/2" x 1/8" in size. Its first use will be at the Ames Research Center where it will be applied to the chest of a man riding on a centrifuge. With the centrifuge in motion, it will be possible to receive by radio and record at a stationary monitoring console, a cardiogram of the man as well as his respiration rate and volume. Used ultimately on the crew members of a spacecraft, this device would enable each man's status to be transmitted to a more powerful transmitter in the spacecraft which would then relay the information to earth.

Several NASA Centers are actively engaged in research and development of advanced instrumentation required for future laboratory and mission use. Typically, this includes work on instruments for high and low temperature, very high vacuum, very high and very low thrust values, very low density measurements, and particle detectors. An example of particle detectors is the development by the Ames Research Center of a micrometeoroid impact sensor which will be used on future space probes to collect information needed for extended space missions, including particle mass and velocity. A major effort will be directed towards developing sensors which give a direct digital output. Such sensors will reduce the amount of signal handling necessary for transmission as they would provide data in a form directly compatible with digital telemetry systems. Digitally coded signals are inherently less sensitive to noise; they can be stored for any length of time and read out many times without loss of accuracy.

Data handling and processing

Elaborate data processing systems have been confined, up to the present, to the ground environment. They have been used to rework scientific data transmitted by satellites, to control launchings and calculate subsequent trajectories, to determine orientations of bodies in space, and for other purposes. Gradually equipment on board spacecraft will assume a much larger share of the total burden. In addition, many new tasks will be assumed by computation networks consisting of linked spacecraft and ground computers. These will include the automatic diagnosis of incipient or actual malfunctioning of launch systems or spacecraft components; the automatic recognition of terrain features or cloud formations; and the aiding of man in the solution of intricate scheduling problems.

The automatic and rapid performance of such tasks by the computer system will substantially minimize the workload on spacecraft crews. It will enable reliable and rapid checkout and launch countdown of spacecraft when orbiting about, landing on or taking off from planetary bodies. In addition, it will provide the crew with timely information on flight conditions and the selection of optimum landing sites, thus enhancing the probability of mission safety and success.

In order to realize these goals, it is necessary to continue and expand research leading to the development of advanced computing devices, systems and new applications. The computer must occupy a minimum of space; must consume little power; and must be fast in operation, light in weight, and extremely reliable. Reliability is of particular importance and difficult because the hostility of natural space environment will be markedly increased by the presence of high artificial radio-activity associated with nuclear engines and power supplies.

One example of a specific area of improvement in the application of advanced computer technology is a continuing effort in progress at the Goddard Space Flight Center to reduce the amount of information required to be transmitted from a spacecraft without detracting from the scientific value of the information received on earth. This could be called an intelligent editing job whereby the computer would pass to the transmitter only such data which departs from certain norms. Benefits from success in this effort would be the reduction in demand for transmission power and a reduction in the amount of data which must be analyzed on earth. A complementary effort in this direction is being pursued through a contract with Astropower, Inc., to study the feasibility of using an "intelligent" computer to screen cloud pattern data and to transmit to earth details concerning only those clouds which may influence weather on earth.

Research in computer technology is being done at the other NASA Centers and is concerned with the following specific areas: improvement in the ability of men and computing machines to work together effectively; expansion of the capacity of computer memories, together with a reduction in physical size; many fold increases in reliability; and decreases in overall size, weight and required power. In addition, industrial contractors are and will be investigating new computer logical techniques, memory systems based on unusual properties of materials, and the use of fluid rather than electronic circuitry. This last-named technique is of particular interest because, although it will be slower and larger than electronic computers, it does have the potential of being ultra-reliable and invulnerable to rigorous environmental conditions, including high-level radiation, both from natural sources and from nuclear propulsion engines which will be used in future missions.

Small flight projects

	1962	1963	1964
Radio Attenuation Measurements (RAM)	($1,635,000) 1/	$1,750,000	$2,000,000
Scanner	---	---	1,750,000
Spacecraft Orientation Control System	---	100,000	---
Subtotal, direct R&D costs	($1,635,000) 1/	$1,850,000	$3,750,000

1/ These funds were included in fiscal year 1962 Operation of Installation funds.

Personnel costs.....	$1,863,000	$1,743,000	$672,000
Operation of installation.....	1,206,000	905,000	304,000
Total costs.....	$3,069,000	$4,498,000	$4,726,000
Total personnel.....	244	203	76

Radio Attenuation Measurements

Funds for this project were included in Support of Plant in fiscal year 1962. This project is designed to provide the research and experimental data needed to overcome radio blackout for earth reentry speeds up to approximately 50,000 feet per second. This data will provide the technological basis for the solution of the problems associated with blackouts in manned-lunar type missions and give some insight into the communications problems for planetary missions involving entry into unknown atmospheres. A total of seven RAM flights are planned. Three have been flown (August, 1961, and February and September, 1962). Three of the remaining flights are scheduled for 1963 and the seventh flight for early 1964. There is now strong experimental evidence that certain materials when added to the ionized flow field result in a significant reduction in the attenuation of the radio signals. In fiscal year 1964, more materials will be investigated, such as freon and electro-philic gases, and the theory and mechanism of the phenomena of radio transmission under these conditions will be studied. It is now believed that the technical understanding of this mechanism will have an important bearing on the ultimate solution of the blackout problem. Also being contemplated in fiscal year 1964 is a five- or six-stage Scout flight experiment which will permit attainment of reentry velocities in the order of 30,000 feet per second, as opposed to present experiments which are limited to 20,000 feet per second.

Scanner

The Scanner project has the objective of making detailed measurements, from high altitudes, of the natural radiation gradients which define the horizon. A second objective is to develop flight-proven hardware for gathering extensive statistical data, possibly in earth satellite spacecraft. The project is an extension of the current Langley Research Center research on horizon characteristics. Two flight experiments are planned with an additional set of backup equipment provided. The crux of the project lies in the precise independent determination of the attitude and position of the flight vehicle to allow the relative position of the vehicle to be found during the radiation-measuring scans. This information will be invaluable in the evaluation of the ultimate accuracy attainable with horizon scanner techniques and will provide definitive information on the portions of the spectrum most promising for sensor development and application.

Spacecraft Orientation Control System (SOCS)

The main objectives of this project are to determine the capabilities of the NASA-developed solar orientation control system when used for pointing the axis of a rigid body toward the sun, to determine the capabilities of the NASA-developed planetary orientation control system when used for pointing the axis of a rigid body toward the earth, and the attitude sensing capabilities of the horizonscanner used in this orientation system when used for pointing an elastic body (for example, an erectable flexible solar energy collector) toward the sun. The fiscal year 1963 program consists of one flight to test specific systems, and the fiscal year 1964 program provides for system tests to be flown on other NASA missions on a non-interference basis.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

HUMAN FACTOR SYSTEMS

OBJECTIVES:

The objectives of the program are (1) to obtain a better understanding of man's capabilities and limitations and to determine his utilization in advanced aerospace systems, (2) to obtain design requirements for equipment and subsystems which will guarantee an environment adequate for maintaining the high operating efficiency of crews during programmed and emergency phases of advanced aerospace missions, and (3) to determine overall human requirements and integrate them into the design of advanced aeronautical, astronautical and ground support systems.

SUMMARY OF RESOURCES REQUIREMENTS:

Funds	1962	1963	1964
Supporting research and technology	$1,984,000	$9,945,000	$18,200,000
Projects	420,000	115,000	---
Subtotal, direct R&D costs	$2,404,000	$10,060,000	$18,200,000
Personnel costs	1,546,000	2,480,000	3,635,000
Operation of installations	1,046,000	1,535,000	2,552,000
Total costs	$4,996,000	$14,075,000	$24,387,000
Personnel			
NASA Headquarters	3	30	57
Ames Research Center	141	169	238
Langley Research Center	51	55	61
Flight Research Center	1	6	9
Manned Spacecraft Center	-	12	12
Marshall Space Flight Center	-	9	10
North Eastern Office	-	1	1
Total personnel	196	282	388

Program responsibility is assigned to the Office of Advanced Research and Technology, NASA Headquarters. The major program activity is located at Ames Research Center. Other NASA Centers, listed above, will undertake designated portions of the program. In addition, both government facilities (Department of Defense, Federal Aviation Agency, and Atomic Energy

Commission) and nongovernmental university and industrial groups will be utilized to the maximum extent feasible in the conduct of this program.

PROGRAM JUSTIFICATION:

An overall systematic program is necessary to establish a sound and broad research and technology base to meet advanced aeronautical, astronautical and ground support systems objectives adequately. In order to insure the maximum utilization of current data and capabilities in the life sciences, a close coordination with existing manned space flight and basic biology projects is maintained. The studies of man, man-machine, and man-systems and their basic requirements involves the investigation of the environment, design requirements, bioengineering, simulation and evaluation of performance. Ground based research will be utilized for the currently planned portion of this program in fiscal year 1964. However, some flight experiments will undoubtedly be required in the future to attack major problem areas.

Future space missions such as permanent manned earth orbital space stations, lunar bases, and manned interplanetary exploratory systems will require the ability to maintain human crews for long periods of time. It will also be important in the safety, reliability and payload weight aspects of the mission that the astronauts be called upon to perform those tasks that can best be performed by man. Typically in this latter area, the human can be used as an important link in vehicle control systems, either as a primary component or as a backup. Determination of the assignment of such tasks is dependent upon the physical condition of the crew, their performance, the ability to communicate from machine to man via displays and the reverse communication via controls. Throughout the duration of these missions the crew could be subjected to a variety of natural and mission dependent environments such as vacuum, temperature, weightlessness, radiations and magnetic fields. The crew must be protected from that environment and provided, through lightweight, long duration subsystems, with all the necessities of life support. This includes such areas as atmospheric supply or regeneration, water supply or regeneration, waste storage or cycling, CO_2 absorption, air purification, foodstuff supply and humidity control to mention a few.

Relative to our current technological standing there is enormous progress to be made in the above areas before a few months in space can be considered, let alone a one year long mission in weightless condition. We do not know, for instance, what limitations man will have in a weightless environment. Currently, the Apollo project is planning to have man in space for up to 14 days. This is a major step beyond Project Mercury but still only a start on the several-years problem for possible Mars missions. There is, therefore, a requirement to learn man's limitations in this area through flight programs in order to have the information to provide a basis for design of systems to accomplish anticipated missions.

Another environment that man will face in space is magnetic fields. It has been proposed, for example, that large space stations might be protected from space radiations by shielding with high magnetic fields. Man could well be seriously affected by prolonged exposure to such fields because man is an electricity producing entity. The reactions that he might suffer are largely unknown.

Various facets of man's life support systems development have been mentioned as required items for long duration mission accomplishment. The currently approved space projects require and will support man for 14 days. An advanced research and technology program will shortly demonstrate a 30 day system capable of supporting five men. A contract for a three to six month physical-chemical system is currently being evaluated. It is necessary that systems be developed or the necessary research information to allow their design be obtained to supply the requirements of man in a closed system for periods in excess of one year. This is a mandatory prerequisite to the initiation of long duration space missions.

The incorporation of man into a major space exploration program is a complicated procedure, ranging from the handling techniques for large booster systems, the hazards of expelled propellants, the acoustics of the launches, the repair of ground electronic systems, to the investigation of all the environmental effects on man in the flight system, his ability to perform tasks, the payload space and geometry for him and his supporting equipment, and his ability to perform maintenance and repair functions during the mission. Feasibility planning of space missions and space vehicles must examine such items at an early date to assure the consideration of all factors in the process of attaining technological data for future implementation of programs. Various techniques for accomplishing missions must be investigated to determine the requirements that mission phases place upon the control and display requirements and upon mission safety.

The achievement of our long range plans of successfully designing manned aerospace systems for the next 10-20 years requires more than just analytical and ground-based laboratory experiments. The biotechnology activities call for extensive test programs to evaluate the effectiveness of the human, the equipment designed for his survival and use, and the integrated manned system. An orderly multi-phased approach utilizing fixed ground-based environmental and simulation facilities in conjunction with balloons, aircraft, ballistic rockets, satellites and manned space vehicles will provide research information to permit the development of advanced life support and protective systems, bioinstrumentation, and research techniques and methodology. The Ames Research Center will contain a prime in-house group for this program; however, it is planned that other NASA Centers will undertake specific portions of the program where unique competence exists.

EXPLANATION OF FUNDS REQUESTED:

Supporting research and technology	1962	1963	1964
Advanced concepts.....	---	$640,000	$900,000
Human research and performance.....	$1,984,000	2,457,000	4,900,000
Man-system integration.....	---	2,345,000	5,600,000
Life support and protective systems.....	---	4,503,000	6,800,000
Subtotal, direct R&D costs...	$1,984,000	$9,945,000	$18,200,000
Personnel costs.....	1,546,000	2,480,000	3,635,000
Operation of installations.....	1,046,000	1,535,000	2,552,000
Total costs.....	$4,576,000	$13,960,000	$24,387,000
Total personnel.....	196	282	388

Advanced concepts

Study of advanced concepts includes the various areas of human research, biotechnology and man-system integration which could lead to improvement of existing techniques or reveal the potentials of new approaches, such as system analyses, human analogs and bionics. Studies of various manned support systems which appear to be beyond our present day technology include the adaptability of man to such environments as high acceleration, manned-nuclear systems or fusion rockets, which might be involved in future manned operations. The fiscal year 1963 studies on systems analyses includes a study of advanced aeronautical-systems (e.g., V/STOL) as well as man-operated ground support equipment. At the Langley Research Center effort is being devoted in fiscal year 1963 to the study of the utilization of existing space vehicle hardware for a biotechnology space laboratory. This study considers the feasibility of modifying existing hardware for possible use as rendezvous targets and necessary equipment for modifications in orbit to make it an early manned space laboratory. Work in these areas will be coordinated with other efforts in man-system integration. In fiscal year 1964 preliminary studies on small extra-vehicular systems will provide some of the human factors answers related to eventually transporting man on the lunar or planetary surfaces.

Human research and performance

Fundamental direct studies of the human heart and circulation are needed in order to develop and use indirect techniques for monitoring man's survival and performance in space. In fiscal year 1963, scientific

in-flight experiments are planned to obtain data which will accurately portray the individual or combined effects of prolonged orbital flight on the circulatory systems of man. The data obtained, by using indirect techniques, must be correlated with exact data relative to mechanical forces, resistances and blood flow. Studies in biotelemetry are needed to identify physiological parameters to determine the physical, emotional and psychological state of man in flight or in orbit. These functional studies cannot be obtained through the use of conventional electrocardiographic, blood pressures and other available methods. The absence of normal cardio-vascular stimuli may not be serious during orbital flight but during re-entry it could lessen the circulatory system's adaptability to sudden transition from prolonged zero-g to rapidly-rising and high positive g-force. Therefore, long zero-g flights in excess of 30 days and preferably in excess of 100 days, will be needed in the future using animals as subjects. Under radiation, studies on effects of the entire electromagnetic spectrum (radio frequency, invisible light, ionizing and particulate, and ultraviolet) will continue. The extension of studies on low magnetic fields on humans may indicate some possible physiological effects such as disrupted biological rhythm, and space and time perceptions. Pharmaceutics research, relative to therapeutics and prophylaxis and previously limited to radiation protection, will be expanded to include remedies for counteracting motion sickness and other environmental stress factors.

At the University of Maryland, psychological and habitability studies are underway to determine whether confinement in restricted environment and reduced physical activity may influence the ability of man and space crews to perform critical mission tasks during a lunar landing, rendezvous and re-entry. The human research and performance program through fiscal year 1964 also calls for extensive studies of variables such as the oxygen and nitrogen content of specific environments. It has been determined thus far that variations in concentrations of either of these gases result in extremely important biological effects. It is also conceivable that the many processes of aging may be understood by the fundamental effects of O_2 toxicities.

New areas of intensive investigations are the planned studies on nutritional adequacies. Future dietary state-of-the-art must include consideration of essential components such as amino acids, trace elements and vitamin co-factors. Such studies are underway to ascertain in detail the exact determination of the above components.

Advanced concepts for monitoring cellular metabolism of individuals are being developed. These techniques are recommended for muscle metabolism and function, and other integrated techniques will measure blood flow to the brain and to other parts of the body.

Man-system integration

Through fiscal year 1963, the program in this area has included systems research and analyses of the total man-machine complex. Medical monitoring equipment is being provided for the motion flight simulators at the Ames

Research Center and for use in aircraft such as the F100C at the Flight Research Center and a backup system for the X-15 aircraft. This program will permit refinement of the existing equipment with a view towards its ultimate availability for orbiting and other space vehicles.

Several programs initiated in fiscal year 1963 are aimed at improved safety in aircraft. Continuation and expansion of effort will be required in fiscal year 1964. One such program is to set up design principles aimed at providing increased pilot capability in affecting recovery from unusual attitudes brought about by post-stall gyrations, transition from visual contact (VFR) to instrument (IFR) flight and lateral-directional cross-coupling. Other such studies include the effects on and requirements of passengers, crew, and aircraft for flight through turbulent air; the ability of a pilot to cope with or adapt to abrupt changes in stability and damping such as stability augments failures; abrupt changes in information input, specifically transition from instrument to visual references and from normal to emergency display modes, and abrupt changes in control behavior; and the determination of analytical expressions describing pilot operation in complex flight control systems and tasks such as landing approach and flare, height control of lunar and V/STOL vehicles, and the lateral directional or "dutch roll" mode.

An additional group of studies which began in fiscal year 1963 are aimed at understanding the involvement of the pilot in planetary or spacecraft missions. These tasks will require continuation in fiscal year 1964. One task involves piloted simulations and flight tests to determine the proper function of the human operator in a planetary landing system, the characteristics to be built into the vehicle and its systems for optimum performance and reliability, and the requirements for applicable research and training simulators. Another study is being made using simulation techniques to determine the role of the pilot in the rendezvous of spacecraft. Other studies include the effects of individual environmental stresses of space flight on human pilot performance; the pilot control problems in a manual abort of a planetary mission; decision making in space operations including the types of problems to be faced, the environment at the time of the required solution and the ability of the pilot to respond; and a rather major personnel problem of operator selection and training. A study is also being initiated to obtain design requirements related to the physical needs of man for early space stations and is in support of the advanced concepts studies.

A program, recently initiated by NASA to provide information on the performance capabilities of man in space will be continued in fiscal year 1964. This program involves the testing of man's capabilities to perform tasks when in space suits, and will influence the maintainability of space systems. An additional study area to be initiated in fiscal year 1964 involves the requirements for man-rating nuclear space vehicles currently under development or envisioned in the near future.

Preliminary design studies will be conducted on payload concepts which will be applicable to future biotechnological flights. The experiments, equipment, and instrumentation derived under human research and biotechnology

investigation will be integrated together with necessary communications, power, structure, and other considerations in order to yield specific concepts of flight packages.

Life support and protective systems

Studies in the area of advanced life support systems will receive major emphasis through fiscal year 1964. A contract is underway with Boeing on a one-month multi-manned life support system to be demonstrated about June 1963. Manned Spacecraft Center, Houston, has been authorized and funded to study and develop life support systems just beyond the Apollo system. A competitive contract on an advanced 3 to 6 months life support system (physical-chemical), under the technical monitorship of Langley Research Center, is in process. The feasibility of this extended concept should be demonstrated early in calendar year 1964. Study work, in progress through fiscal year 1963, will determine the requirements for a 6 month to one year life support system. This advanced system will be contracted for in fiscal year 1964, depending on the progress of the other work.

The biological life support concepts have been critically reviewed and a systematic approach within NASA and collaboration with other interested government agencies will continue. As an example, Ames Research Center is responsible for advanced biological life support and is technically monitoring a contract on a closed ecological cycle (biological) with a photosynthetic gas exchanger at the University of Minnesota. Bio-power systems (generation of electric power) are being investigated and this interesting area offers great promise in that the waste material produced on long duration manned space missions may be utilized profitably to produce auxiliary power. Advanced anthropometric and non-anthropometric space suits and self transporting devices are being investigated in-house in fiscal year 1963, principally at the Manned Spacecraft Center, and on contract. Examples of projected goals in this area are the development of life support systems from a current capability of 30 days through a 6 months system compatible with a future manned space laboratory and on to more advanced systems for interplanetary flight.

Specific investigations will be conducted to provide information on the type of life support equipment and instrumentation that would be utilized for very long duration biotechnological flights of the types discussed under human research and performance. Each of the experimental variables will be investigated as to instrumentation requirements and required instrumentation will be evolved. Life support systems compatible with mission requirements will be obtained and tested.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

NUCLEAR-ELECTRIC SYSTEMS

OBJECTIVES:

The objective of the Nuclear-Electric Systems Program is to provide the scientific and engineering knowledge and to develop the systems necessary for the early and practical utilization of nuclear electric propulsion and power generation systems in space.

SUMMARY OF RESOURCES REQUIREMENTS:

Funds	1962	1963	1964
Supporting research and technology	$ 8,210,000	$15,068,000	$20,018,000
Development and flight projects	12,248,000	28,463,000	48,750,000
Subtotal direct R&D costs	$20,458,000	$43,531,000	$68,768,000
Personnel costs	10,492,000	12,204,000	14,373,000
Operation of installations..	7,244,000	5,363,000	6,464,000
Total costs	$38,194,000	$61,098,000	$89,605,000
Personnel			
NASA Headquarters	64	63	70
Lewis Research Center	1,284	1,300	1,364
Marshall Space Flight Center	12	6	14
Wallops Station.....	32	40	47
Western Operations Office...	2	2	5
Goddard Space Flight Center.	-	1	3
North Eastern Office.....	-	1	2
Total personnel.....	1,394	1,413	1,505

Primary responsibility for the Nuclear-Electric Systems Program is in the Office of Advanced Research and Technology at NASA Headquarters and at the Lewis Research Center. Support for the program is accomplished at the other locations listed above and at the California Institute of Technology, Jet Propulsion Laboratory.

PROGRAM JUSTIFICATION:

Nuclear-electric power generating systems offer the only practical source of electric power in the kilowatt and megawatt levels which are needed for future satellite communications systems, spacecraft on-board power, and electric propulsion systems.

Nuclear-electric propulsion systems have the highest performance potential of any system capable of development within the predictable future. The need for such high performance is emphasized by the enormous size and weight of the relatively low performance chemically powered systems now being developed for NASA's space missions.

NASA's nuclear-electric program is composed of a fundamental and applied research effort, component development, and selected flight tests and feasibility demonstrations of components and complete systems. It is designed to advance the technology in a series of steps, each one of which can yield useful systems for space flight application. Previous years' programs have resulted in the initiation of such steps as the SNAP-8 (System for Nuclear Auxiliary Power) and the ion engine for a spacecraft station keeping and attitude control system discussed later. The primary emphasis in fiscal year 1964 is on the continuation of these and related projects with a vigorous supporting research and technology effort directed toward defining the next steps to be taken.

The major portion of the NASA nuclear-electric program will be conducted by industry. Complementary in-house research and technology projects as well as limited university investigations will be conducted.

Both the Atomic Energy Commission (AEC) and the Air Force are also conducting programs in the nuclear-electric area. The AEC effort is aimed at providing reactors for the SNAP-8 system and at developing the SNAP-2 and SNAP-10 systems for the Air Force. In addition, the AEC is developing isotope power generation systems and is responsible for the SNAP-50 work. Coordination is achieved through meetings of such groups as the Supporting Space Research and Technology Panel of the NASA-Department of Defense (DOD) Aeronautics and Astronautics Coordinating Board and the SNAP-8 Coordination Committee composed of NASA-AEC[redacted] and associated industrial contractors. Further, in accordance with the joint AEC-DOD-NASA agreement on the SNAP-50 work, NASA will assign an employee to the SNAP-50 Office of the AEC. In addition to the formal arrangements, there is the usual coordination by means of informal meetings, visits to various laboratories and exchange of reports.

EXPLANATION OF FUNDS REQUESTED:

Supporting research and technology

	1962	1963	1964
Nuclear-electric power			
Basic properties	$ 527,000	$ 1,670,000	$ 1,870,000
System components	390,000	4,790,000	5,700,000
Materials and environmental effects	981,000	2,428,000	3,962,000
Advanced concepts and system studies	1,802,000	1,203,000	1,000,000
Subsystem evaluation	---	---	600,000
Electric propulsion			
Electrostatic propulsion	2,231,000	1,833,000	1,900,000
Electrothermal propulsion	913,000	603,000	500,000
Electromagnetic propulsion ...	1,366,000	1,714,000	2,386,000
Mission analysis	---	388,000	400,000
Component technology	---	439,000	1,700,000
Subtotal, direct R&D costs ...	$8,210,000	$15,068,000	$20,018,000
Personnel costs	7,781,000	9,055,000	10,726,000
Operation of installations	5,331,000	3,929,000	4,807,000
Total costs	$21,322,000	$28,052,000	$35,551,000
Total personnel	1,033	1,052	1,122

Nuclear-electric Power

Advanced nuclear-electric space power systems producing electrical power in the range of hundredths to tens of megawatts will be needed in the NASA space programs for both auxiliary power and propulsive power in the 1970 through late 1980 time period. Multimegawatts of electrical power will be required for propulsion applications involving planetary probes and manned planetary expeditions; and kilowatts to multi-kilowatts of electrical power will be required for auxiliary or non-propulsive power application involving communication satellites, lunar bases, deep space communications, and space laboratories.

Both auxiliary power and propulsive power make two important demands on power systems, namely, long-life (i.e., months to years) and low specific weight. The operating conditions to meet these demands are technologically beyond those of ground-based power generating devices. This is particularly true with respect to operating temperatures. The high operating temperatures and extended operating times, together with the attendant effects on

materials, the unknown hazards of micrometeoroids, and the lack of both basic and engineering knowledge, present serious obstacles to be overcome in the development of advanced systems.

The two concepts of converting nuclear energy to electrical energy are the Rankine-Cycle turbine-driven generator system and the direct conversion system which utilizes a thermionic emission device.

Basic properties

The high temperature requirements make it necessary to use liquid metals as working fluids and coolants for the turbo-electric systems and as coolants for the direct conversion systems. Since a component or system design is highly dependent on the properties of these fluids, fundamental physical and engineering properties of the liquid metals of interest (potassium, sodium and cesium) must be known as accurately as possible. Accordingly, Battelle Memorial Institute and the Naval Research Laboratories are obtaining high temperature data on such properties as specific heats, viscosities, and thermal conductivities.

An experimental and analytical program is being conducted by the General Electric Company to obtain boiling and condensing alkali metal heat transfer data. As part of this contract, an extensive test program is proceeding dealing with boiling stability phenomena, which is a major problem area at the present time. The University of Michigan and Hydronautics, Inc. are conducting experimental studies of liquid metal cavitation, which is an important factor in pump design.

Increased reliability and reduced system weights are expected by the application of the direct conversion of reactor thermal energy to electrical energy. In order to obtain the data necessary to assess the feasibility of using the concept a vigorous basic research effort is underway. The United Aircraft Research Laboratories are performing measurements of the electron and plasma conditions within the diode electrode gap, for example, the electron energy distribution and the collision cross sections of electrons with ions and neutral atoms. Electro-Optical Systems, Inc., is determining the properties of thermionic materials such as effects of crystal orientation, materials impurities, and the presence of cesium on electron emission.

A major in-house program is being conducted in these program areas, as well as the contract and grant work at industrial contractors and universities. The acquisition of data will be accelerated in fiscal year 1964 as a result of the completion of construction of major test facilities both in and out of house. From a systems component standpoint the experimental data in the coming year will be more meaningful, for example, multi-tube heat transfer data will be obtained rather than the single tube data presently being measured. These data will more nearly approximate operating conditions in an actual system boiler or condenser.

System components

The components of a Rankine turbogenerator system include vapor turbines, liquid metal pumps, boilers, waste heat radiators, liquid metal lubricated bearings and electrical components such as the alternator and power conditioning equipment. Many of these components are common to both Rankine and thermionic systems, for example, pumps, radiators and electrical conducting equipment. The principal component in the thermionic system is the thermionic vapor diode proper and its associated controls. This includes special insulators and leads, as well as the electrodes which are required to operate in a cesium environment and at elevated temperatures and severe temperature gradients.

The components of both systems, almost without exception, are presently far beyond the state-of-the-art. The fiscal year 1963 program includes experimental and analytical work on all of the components of both systems. The General Electric Company has constructed and is performance testing two stages of an axial flow potassium vapor turbine to verify fluid flow design principles and to investigate the parameters affecting turbine erosion. General Electric is also conducting a program investigating stability phenomena in journal bearings. Pratt and Whitney Aircraft Corporation is experimentally investigating hydrodynamic losses in waste heat radiators and methods of isolating radiator segments following penetration of coolant tubes by a meteroid. The Lewis Research Center has fabricated multicell thermionic diodes and is conducting electrically-heated performance tests to investigate the stability effects of series and parallel connections.

Major test facilities were completed and put into operation in fiscal year 1963. Examples of these are a liquid metal radiator-condenser test rig, liquid metal pump and bearings test rigs at Lewis, and vapor turbine and high temperature heat transfer facilities at the General Electric Company and the AiResearch Manufacturing Corporation.

The fiscal year 1964 program will continue the vapor turbine test program, the bearings and electrical equipment program and will also provide for the construction and testing of certain flight weight components such as pumps, condensers, and vapor liquid separators. Evaluation of bearing stability characteristics will be completed. It will be possible in fiscal year 1964 to begin design and testing of liquid metal lubricated bearing hardware. Elemental components of thermionic conversion systems will continue to be tested both in and out of a nuclear reactor.

Materials and environmental effects

From past experience it has not been the inability to design a system that has prevented or delayed development, but the lack of knowledge of system materials or materials requirements. The advanced power systems are no exception; success will be based largely on the development of suitable materials. Both the fiscal year 1963 and 1964 programs are weighted heavily in this area.

The materials problems associated with the Rankine systems are affected by three major considerations: (1) the external effects as a result of the space environment, principally ultra-high vacuum, meteoroids and to a lesser extent, electromagnetic and particle radiation; (2) the physical strength requirements for both rotating and non-rotating components; and (3) the internal problems such as corrosion and erosion caused by highly reactive coolant and the flow properties. Under the conditions of power system operation only alloys of the refractory metals, such as columbium, tantalum and vanadium, have the requisite strength and ease of fabrication.

All of the materials mentioned are readily oxidized resulting in embrittlement and drastically accelerated liquid metal corrosion. In space, oxidation is not a problem, but in ground testing, which accounts for the bulk of R&D effort, it is a major source of trouble. Major advances in the understanding of test environment requirements have been made within the past year. A program is being followed at the General Electric Company and in-house to determine the effects of quantitative amounts of impurities in inert cover gases, methods of measuring minute quantities of impurities, and proper preparation of test specimens and liquid metals prior to testing. Another factor contributing to the difficulty of materials evaluation is the test time required to get reliable data for systems operating well over 10,000 hours. The corrosion problem in boiling metal loops is just beginning. NASA corrosion work in progress includes reflux capsule screening tests on columbium and tantalum alloys both at the Lewis Research Center and the General Electric Company. A contract for constructing pumped boiling corrosion loops of promising alloys will be initiated in the last quarter of fiscal year 1963.

During fiscal year 1963 projects have also been initiated to determine the long time creep properties and weldability of refractory alloys, development of liquid metal lubricated bearing materials and development of a high strength tantalum dispersion hardened alloy. All of the above fiscal year 1963 projects will be continued through fiscal year 1964. In addition to these programs, new projects will be started to determine special methods of fabricating these new materials.

The General Atomic Division of General Dynamics Corporation is conducting under contract an extensive program in the thermionic materials area, which includes metallurgical studies of electrode materials, insulator development, and corrosion studies. During fiscal year 1964 two additional major thermionic materials programs will be contracted with industry. The industrial and university contract work is supplemented by a substantial in-house program, principally at Lewis Research Center.

From a systems standpoint, the present of meteoroids in space far outweighs the factors mentioned previously, i.e., hard vacuum and space radiation. The armor protection required to minimize the possibility of meteoroid penetration can range from 5 to 60 percent of the total system weight, depending upon the meteoroid design criteria chosen. There are three areas of uncertainty with respect to the meteoroid hazard. The first is the meteoroid population in space. There are orders of magnitude variation in our knowledge of the distribution and densities of meteoroids in space. As more data become

available they are being compiled and analyzed by the Lewis Research Center for the effect on space power systems. The second uncertainty is the penetration mechanism of the very high velocity meteoroids. The Cornell Aeronautical Laboratory, Technical Operations Limited, and General Motors Research Laboratory are conducting analytical and experimental programs in this area. Recent advances in the performance of hypervelocity guns for ground simulation of meteoroids has has been a notable accomplishment. The third uncertainty is the effectiveness of methods of reducing the vulnerability to meteoroid damage. Various methods have been proposed such as bumpers, segments which can be isolated, and the use of non-fluid radiators. The fiscal year 1964 program includes continuation of the analytical studies and expands the ground impact program to include actual radiator modules and tests of protection methods. Weightlessness in space principally affects the Rankine-cycle turbine-generator systems with respect to the condensing and boiling process and system startup. With regard to the thermionic systems it would be much less of a factor. Zero gravity testing as it specifically applies to the advanced nuclear systems will begin in late fiscal year 1964.

Advanced concepts and system studies

The successful development of advanced space power systems requires a continuous evaluation of advanced concepts and missions to properly identify performance requirements and problem areas requiring research and development effort. Specifically it is necessary to (1) define power, weight and operating life requirements and environmental specifications for missions of major interest to NASA, (2) investigate the promising power plant concepts, and (3) select the concept or concepts of interest for more concentrated effort.

The present program includes analytical studies of nuclear Rankine and Brayton cycle systems, reactor in-pile and reactor out-of-pile thermionic systems, and various approaches to magnetohydrodynamic power generation. The studies are being performed principally out of house, the contractors including Pratt & Whitney Aircraft, Martin-Marietta, Westinghouse Electric and Atomics International Division of North American Aviation.

The program also includes experimental work dealing with critical problem areas of systems which are in the concept feasibility phase. An example of this is the construction and testing of vapor-liquid separators as a part of a feasibility determination of a two fluid magnetohydrodynamic concept. The concept originated and is being investigated at the Jet Propulsion Laboratory (JPL). A JPL experimental program to determine the feasibility of converting the energy of nuclear fission fragments or other charged particles directly to high voltage electricity is another example of this type of effort.

The fiscal year program will have slightly less funding than fiscal year 1963. Many of the programs initiated in fiscal year 1963 will continue through the coming fiscal year. More emphasis will be placed, however, upon experimental studies.

Subsystem evaluation

Under this heading endurance tests of major subsystems will be performed. These will include such items as complete turbo-alternator pump combinations operating on liquid metal bearings. Endurance testing of a complete multi-cell vapor diode under probable system conditions will be conducted. These demonstrations are contingent upon progress in the advanced technology areas of basic properties, materials, system components, and environmental effects. It is intended that the subsystem demonstration will provide detailed evidence of performance of key areas involved in megawatt nuclear electrical systems.

Electric propulsion

Electrostatic propulsion

The objectives of electrostatic propulsion research are to provide basic process and applied component information necessary for the logical development of electrostatic (ion and colloid) thrustors in the thrust range of 0.1 to 10 pounds or greater at specific impulses of 3,500 to 10,000 seconds or greater. Basic data to be supplemented include the relationship of ion generation, electrical theory concerning the structure of ion beams, and charge exchange effects. Applied technology areas include the factors affecting construction of porous emitters, various materials for the construction of the different components, electrical design considerations, fuel corrosion effects, engine performance and instrumentation.

Studies of contact ionization in the NASA program and in the contract program with Electro-Optical Systems, Hughes Research Laboratories, and Space Technology Laboratories will serve to evaluate the best available porous tungsten ion emitters.

The attainment of leak-free seals between the porous ion emitter and its support structure is a difficult problem, especially in larger ion engine sizes. Satisfactory techniques for brazing and for electron beam welding of porous ion emitters have been evolved for small ion engines and efforts are currently underway to extend these techniques to larger emitter sizes.

The General Electric Company is working on a new type of contact ion source which will operate at high current densities with simultaneous emission of ions and electrons. If successful, this type of ion source would permit much higher power efficiencies than are attainable with conventional contact ion sources at intermediate levels of specific impulse.

Investigations of bombardment ion sources have been underway at Ion Physics Corporation, Electro-Optical Systems, and Thompson Ramo Wooldridge Corporation.

Most of the ion optic studies necessary to ion engine development are being carried out as integral parts of the engine development projects. However, two specific ion optics technology contracts are in existence. One of these is on the analytical study of curved beam optics at Stanford University.

The second ion optics contract will be an electrolytic tank analog study of accelerator electrode geometries for use with bombardment type ion engines at Hughes Research Laboratories.

The neutralization of ion beams remains as one of the major questions regarding feasibility of ion engine operation in space. It is hoped that final proof of this feasibility will be determined in the SERT I flight project, described below. In the meantime, in order to obtain better understanding of the phenomena involved and to permit optimization of engine neutralizer systems, theoretical studies are underway on three contracts with General Atomics, Litton Industries and the National Bureau of Standards.

The development of improved instrumentation is an essential part of any meaningful ion engine development program. Accordingly, Space Technology Laboratories are at work on the development of an electron-emission type electric field meter; beam potential probes; a cesium D-line resonance apparatus for neutral atom detection; and a similar apparatus for detection of neutral mercury atoms. Flight models of the elctric field meter and beam probe will be used in the SERT II flights.

Sputtering erosion of the accelerator electrode is the major obstacle to long ion engine operating life. A fundamental study of sputtering mechanisms is being conducted at Convair using propellant materials, electrode materials, and voltage differences typical of ion engines. Another critical problem in ion engines is electrical breakdown between the high voltage electrodes. A study of such electrical breakdown in cesium vapor atmospheres has been underway at the General Electric Laboratory.

Electrothermal propulsion

Funding in electrothermal propulsion research will cover two prime objectives; (1) to advance the technology of electrothermal engines (arc jets) and resistance heated rockets, in order to provide efficient and reliable electric engine systems for the impulse range 700 to 1500 seconds; and (2) to investigate electrothermal devices for a thrust range of 0.1 to 1.0 pounds, specific impulses of 1,000 seconds or larger, and power levels of 1.0 to 100 kilowatts. Pertinent analytical and experimental studies on components and basic processes include electrode geometry, cooling techniques, non-equilibrium flow effects, propellants, and materials.

The development of long-life arc jet thrusters depends upon efficient regenerative cooling. This, in turn, depends upon a knowledge of the heat flux patterns from the arc region. Two contracts to study arc heat transfer have been in existence until recently. Additional work of this type is recommended for fiscal year 1964 in order to obtain more data on the pattern of heat flux from the positive column of a capillary arc. The second of the two contracts, with the University of Minnesota, is directed primarily towards obtaining data on distribution of heat flux into the electrodes themselves.

Only one technology contract remains for study of electrode geometries for DC arc jets. This contract is for an investigation of a two-phase arc jet by Space Dynamics Corporation.

The study of arc engines effects in vacuum at McDonnell Aircraft Corporation is aimed at obtaining experimental data on recombination rate coeffecients at pressures below 1 millimeter mercury. A related study is the investigation of hydrogen recombination catalysis at Convair. The work to date has been at low temperatures and has resulted in the discovery of effective catalysts for this temperature regime. Aliphatic hydrocarbons with a structure conducive to bond resonance appear to be effective in absorbing energy from hydrogen atoms. The recombination of these de-energized hydrogen atoms then proceeds as a bimolecular reaction. These catalysts must now be investigated in an actual arc jet engine. This work is also of importance to the nuclear rocket.

Electromagnetic propulsion

The objective of electromagnetic propulsion research is to conduct feasibility studies of various types of magnetohydrodynamic (MHD) engine system concepts for propulsion application. These investigations place particular emphasis on studies to determine the physics of the plasma production and acceleration processes. The investigations also include analytical and experimental studies to determine the mechanism of plasma acceleration to select propellants, and to devise efficient methods of plasma production.

Preliminary investigations of feasibility are currently underway on six different magnetohydrodynamic plasma accelerators as follows: a microwave accelerator (General Electric); a traveling wave accelerator (Clauser Technology); two different coaxial pulse type accelerators (General Electric and General Dynamics/Astronautics); a steady-state Hall current accelerator (Electro-Optical Systems); and a steady-state EXB accelerator (MHD Inc.-Marquardt).

Princeton University has a contract to study the fundamentals of the pinch discharge in plasmas. The mechanisms of sheath formation and sheath instability are of primary concern in this study. This work has general application to plasma heating and power generation as well as to propulsion.

A contract with Tobe Deutschmann Laboratories for the development of lightweight, low-inductance capacitors is intended to provide the research hardware necessary for studies of pulse-type plasma accelerators in both the in-house and contract research programs.

Preliminary laboratory results of investigation on the General Electric repetitively pulsed coaxial accelerator indicate power efficiencies of 20 to 30 percent at 7000 seconds specific impulse. This MHD device shows the most promise for early electric propulsion application. It is too early, however, to make firm predictions on any MHD propulsion concept.

Feasibility studies will continue during fiscal year 1963 and increased work scopes are being planned for the fiscal year 1964 time period.

Mission analysis

Studies will be conducted on mission applications for electric propulsion to provide and support the ultimate goals of the engine research and development program. The objectives of the mission analysis and electric propulsion system application studies are: (1) to study propulsion and vehicle requirements for probe and manned round trips to other planets for systems employing electric propulsion devices; and, (2) to determine mission capabilities and requirements of early and advanced electric propulsion systems.

Mission analysis for electric propulsion is currently being carried on at the Lewis Research Center, Marshall Space Flight Center and Goddard Space Flight Center. Also, several contractors, Hughes (Culver City), United Aircraft Corporation, General Electric Company (Cincinnati), and Rand Corporation, either have had or have contracts to perform studies that will provide the information necessary for an electric propulsion research and development program. These studies must be updated and continued in parallel with the R&D programs since experimental design and performance data continually change, thereby affecting the nature and results of the analysis.

This work attempts to focus and direct research and development efforts on electric propulsion systems by analysis of the payload capabilities of nuclear electric spacecraft in the four major areas of space activity, which are: (1) Unmanned interplanetary exploration (instrumented probes and orbiters) (2) Manned interplanetary exploration, (3) Ferry freight for logistic support (unmanned), and (4) Satellite raising and orbital station-keeping (communication and scientific satellites).

Component technology

The studies in this area cover technology associated with the design and development of components for the electric propulsion subsystems such as the propellant feed control and storage and the power conditioning subsystem, and also for the thruster subsystem.

Development and flight projects	1962	1963	1964
SNAP-8 Development			
Direct R&D costs	$6,103,000	$15,100,000	$15,000,000
Personnel costs	1,719,000	1,731,000	1,998,000
Operation of Installations	1,186,000	773,000	888,000
Total costs	$9,008,000	$17,604,000	$17,886,000
Total personnel	230	198	209

The objective of the SNAP-8 Development Project is to develop a nuclear-powered electrical generating system which will generate a minimum of 35 KW of electrical power at the vehicle load switch and be capable of launch, orbital startup, and continuous reliable operation in space flight for periods of 10,000 hours or more. At the present time, no space power system except SNAP-8 is being developed in the United States to provide electrical powers in the range between 3 KW and 300 KW. Such power levels will be required for future space mission applications that fall into two categories: (1) auxiliary or non-propulsive power such as that required for manned lunar base operations, communication satellites, orbiting space laboratories; and (2) early propulsion power wherein SNAP-8 will provide the electrical power required to operate electric rocket engines for such applications as planetary probes, station keeping and orbital transfer missions, as well as providing a source of power for long duration engine development flight tests.

The SNAP-8 is a Rankine-cycle turbine powered electrical generating system consisting of a nuclear subsystem and a power conversion subsystem. The nuclear subsystem includes a nuclear reactor, reactor controls, and reactor shielding; and, the power conversion system includes a turbine, alternator (generator), a condenser, boiler, radiators, pumps, and associated controls.

The SNAP-8 Development Project is a joint NASA-AEC program. The Aerojet-General Corporation under contract to NASA is responsible for development of the power conversion subsystem and its integration with the nuclear subsystem into a reliable electrical generating system. The nuclear subsystem is being developed by Atomics International under contract to the AEC. The Lewis Research Center has been assigned project technical direction and contract administration. In addition, the Center is providing in-house technical support in the areas of the effect of zero gravity environment on fluid dynamic characteristics, component performance system dynamics, radiation damage of SNAP-8 electrical components, and reliability and quality assurance.

The SNAP-8 project was started on May 9, 1960. Aerojet-General and Atomics International have designed, fabricated, and tested various components of their respective subsystems as well as providing or initiating construction of the necessary facilities required for the overall development project. As a result of an extensive technical review during the fall of 1962, the design of the power conversion subsystem has been changed to alleviate some of the development problems encountered during the previous year and to provide greater assurance of obtaining a reliable, 10,000-hour life system.

The Aerojet-General Corporation is currently designing the power conversion system, preparing model specifications, and laying out the necessary development program. In addition, component testing is continuing. Results of the boiler test program indicate that a satisfactory design has been achieved. Remaining to be established is the endurance of the design. The initial experimental reactor went critical in September 1962 and is currently undergoing physics experiments at Atomics International for the AEC. The in-house effort at Lewis Research Center continues to provide technical support for the SNAP-8 project.

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Fiscal year 1963 funds will be used to accomplish necessary design changes, modify test facilities, initiate fabrication of component hardware, and initiate additional component testing. All work started in fiscal year 1963 will be continued in fiscal year 1964 in addition to starting new tasks as required by the development program. During fiscal year 1964, all power conversion system components will be under performance, reliability, and limited life testing in preparation for long-term power conversion system and electrical generating system endurance testing (i.e., for periods of the order of 10,000 hours). In addition, the first zero gravity mercury condensing flight experiment will be conducted during fiscal year 1964 in support of this project (see Small nuclear-electric propulsion and power flight projects).

The first integrated system test with nuclear power is scheduled for CY 1965 followed by extensive endurance and proof testing in a simulated space environment. These tests lead to a first flight in CY 1967 as described in the section on the SNAP-8 flight evaluation project.

SNAP-8 flight evaluation	1962	1963	1964
Spacecraft design development	---	$518,000	$5,500,000
Supporting research and development...	---	200,000	1,000,000
Ground and launch support	---	125,000	2,000,000
Thor launch vehicles	---	---	500,000
Subtotal, direct R&D costs	---	$843,000	$9,000,000
Personnel costs	$66,000	194,000	305,000
Operation of installation	49,000	79,000	120,000
Total costs	$115,000	$1,116,000	$9,425,000
Total personnel...	9	22	32

Flight Schedule

Mission	Launch vehicle	Calendar Year of launch	Launch location
Zero gravity effects on system dynamics Ballistic (2 flights)	Thor	1964, 1965	AMR
SNAP-8 system evaluation Orbital tests (2 flights)	Saturn B	1967, 1968	AMR

The SNAP-8 flight evaluation project is required to demonstrate the feasibility of starting and operating SNAP-8 nuclear electric power generation and propulsion systems in the actual space environment. Additional objectives are to evaluate the system's ability to perform satisfactorily in space for a minimum of 10,000 hours (approximately one year) and to evaluate these systems for mission applications. The level of effort for this project is determined by the status of the SNAP-8 development project. Hence, no major hardware development commitments for the flight project will be made until satisfactory SNAP-8 development progress is demonstrated.

The essential elements of the flight evaluation project are: (1) design, development, integration, and flight testing of spacecraft; (2) supporting research and development; (3) ground and launch support; (4) launch vehicle/spacecraft compatibility; and, (5) test evaluation.

The Lewis Research Center serves as technical director for this project. Ground and launch support will be provided by the Launch Operations Center and launch vehicle technical support will be provided by the Marshall Space Flight Center. Goddard Space Flight Center will assist in collection and collation of flight test data. A principal contractor will be selected to design and build the spacecraft.

The present overall flight program plan consists of orbital and ballistic flights of SNAP-8 electric generating systems, subsystems, and components. Ballistic flight tests, utilizing the Thor launch vehicle, will be conducted to verify zero gravity effects on the start-up of the SNAP-8 power conversion subsystem, and the operating suitability of the power conversion system. The orbital flight tests, utilizing the Saturn B launch vehicle, will be conducted to determine the long-term operating characteristics of complete SNAP-8 electric generating and propulsion systems in space. The orbital flight spacecraft will consist of the SNAP-8 electric generating system, power conditioning, guidance and control, and instrumentation systems. Provisions for incorporating electric engine propulsion systems will be included in the spacecraft designs, although such engines may not be included until later in the program. The spacecraft will be ground tested, prior to flight testing, in the Space Propulsion Facility at the Lewis Plum Brook Station.

In fiscal year 1963 procurement actions were initiated for studies and preliminary design of spacecraft, supporting research and development in the areas of spacecraft materials, instrumentation, and components, and studies of ground and launch support. In addition, preliminary SNAP-8 integration facility requirements were formulated, and their locations at Plum Brook Station and at Cape Canaveral were established. Procurement of equipment for the ballistic test will be initiated in calendar year 1963.

Fiscal year 1964 funds will be utilized to complete the SNAP-8 orbital flight test studies and to initiate spacecraft detailed design and development.

Small nuclear electric propulsion and power flight-project MECCA

	1962	1963	1964
Direct R&D costs	---	$1,850,000	$1,400,000
Personnel costs	---	130,000	142,000
Operation of installation	---	46,000	50,000
Total costs	---	$2,026,000	$1,592,000
Total personnel	---	15	15

There is a critical need for design criteria on the heat transfer, pressure drop, and dynamic behavior characteristics of variable quality two-phase flows of working fluids in a heat exchanger under zero gravity and other space environmental conditions. It is the purpose of this project to obtain experimental information that will permit the establishment of such design criteria, with particular emphasis on SNAP-8 system requirements.

Under the technical direction of the Lewis Research Center, which has the overall responsibility for all NASA zero gravity fluid physics experiments, especially designed experimental equipment and instrumentation will be combined into payloads suitable for adaptation to small solid rocket boosters, like the WASP vehicle. These payloads will include single and multi-tube configurations, operated under transient (start-up) and steady-state conditions. The payload will be launched from Wallops Station on a ballistic trajectory. Selected portions of the recording equipment used in the experiment will be recovered at the end of the flight. Checkout and supporting experiments will be conducted with the AJ-3 airplane stationed at the Lewis Research Center.

Lewis Research Center has been engaged in research on the effects of zero gravity on fluid behavior since 1959. Ground testing techniques have been developed and appropriate facilities built. Such facilities yield approximately 2 seconds of zero gravity exposure. Airplanes (AJ-3s) have been used to provide occasional longer duration zero gravity tests (10 to 30 seconds). The bulk of the required testing can and is being conducted in the above manner. However, the results obtained to date indicate the need for test durations of 4 - 5 minutes in order that certain long-time transient effects (e.g., boiling heat transfer) can be stabilized and equilibrium conditions obtained.

During fiscal year 1963, the engineering design and fabrication of two WASP vehicles will be completed. Instrumentation design and engineering for both payloads and vehicles is almost complete. Experimental apparatus design is nearly complete with a portion of this equipment purchased. Some ground testing and various component tests are already underway. Work is proceeding toward the first flight in the first quarter of fiscal year 1964 with two more in the same year.

Electric engine development projects:

	1962	1963	1964
Large ion engines	$1,975,000	$3,800,000	$6,000,000
Large arc jet engines.....	600,000	500,000	500,000
Small arc and ion engines.....	---	1,200,000	1,500,000
Subtotal, direct R&D costs	$2,575,000	$5,500,000	$8,000,000
Personnel costs	152,000	254,000	277,000
Operation of installations	97,000	101,000	111,000
Total costs	$2,824,000	$5,855,000	$8,388,000
Total personnel	19	29	29

The primary objective of the Electric engine development projects is to develop the engines necessary to demonstrate the feasibility of: (1) Low power engines (3 KW and less) for spacecraft position control; that is, attitude and orbital control, and (2) High power engines (30 KW to 15 MW or greater) for prime propulsion of spacecraft.

Illustrative NASA missions for which these systems could be applicable during the period 1967-1975 are propulsion for:

(1) Venus, Mars, Jupiter planetary exploration probes,

(2) Raising satellites in cislunar orbit,

(3) Solar and out-of-the-ecliptic scientific probes,

(4) Orientation and station keeping of long life satellites, and

(5) Mars and Venus manned interplanetary flight.

The engine development program is comprised of three separate projects:

(1) Large ion engines (30 KW to 15 MW)

(2) Large arc jet engines (30 KW and greater)

(3) Small arc and ion engines (3 KW and less)

Each of these three engine categories offers superior performance in a different range of specific impulse or thrust capabilities for different potential mission applications. They will be developed on a time schedule compatible with the development of electric power generation systems.

Large ion engines (30 KW to 15 MW)

This project is comprised of two separate engine development programs: (1) a contact engine, and (2) an electron bombardment engine. The contact ion engine shows promise of yielding highest overall engine efficiency for values of specific impulse above about 7000 seconds. This engine type is therefore the most likely choice for the ultimate engine to be used with lightweight electric power generating systems on interplanetary missions.

The bombardment ion engine offers the highest efficiency in the intermediate range of specific impulse from about 4000 seconds up to 7000 seconds. This engine type is the most likely choice for use on early interplanetary missions with fairly heavy electric power generating systems. The objective of this project is to develop large ion engine systems (multi-kilowatt to 15 megawatts) capable of performing missions in cislunar and planetary space, and to explore and provide experimental confirmation of the problems involved in developing large ion engines.

The technical plans include the design, development, fabrication and environmental testing of a series of ion engine systems and the assessment of problems involved in developing, scaling and producing such systems for various space missions. To achieve reliable large (high power level) ion engines, it is necessary to utilize the building block technique; that is, developing low power engine modules and systematically scale or cluster these modules into the high power level regime. This will involve: (1) the fabrication of small engine modules (approximately 1 KW) for laboratory and flight evaluation (SERT I) of such basic problems as beam neutralization; (2) development of 3 KW flight prototype systems (SERT II) which will be modules for scaling or clustering to the 30 KW size; (3) development and qualification of 30 KW systems for determining scaling and system performance problems for reaching the next higher power level plateau (100 KW to 1 MW); (4) projecting the design criteria of the 30 KW engine into a compact unit which can be scaled to the 500 KW (SNAP-50) power level and finally scaled or clustered into the megawatt power engine regime.

At the present time, this ion engine development project is in phase I, wherein the main goal is to evolve the design concepts necessary to obtain high efficiency for these thruster systems. In this phase of the work, the advanced techniques and new concepts being evolved under the advanced research and technology project are being used to improve the performance of the thruster systems.

Phase II of this project, which will begin during the latter part of fiscal year 1963, will consist of the development of reliable, long life thruster systems. Phase II will be conducted with small (3 KW) modular units suitable for scaling to larger size by arranging a large number of these units into a cluster. During phase II of this project, it will be necessary to continue to make use of new concepts arising from the electric propulsion advanced technology program. This project must be closely coordinated with

the SERT project in order to insure proper delivery schedule of flight system SERT II. The SERT II flight project will have the specific goal of establishing the reliable space operation of the ion engine modular units to be developed in the early parts of phase II of this project.

Fiscal year 1964 funds will cover work on phase III of this project. Phase III will consist of the clustering of the ion engine modules developed under phase II in order to obtain 30 KW and large ion engine size. Multiple beam interactions and control problems will be investigated and 90-day tests will be conducted in the Lewis Research Center 25-foot vacuum tank before supplying 30 KW engine systems for integration with SNAP-8. These ion engine systems will be operated during orbital flights of the SNAP-8 system. These long duration flights, with reasonable electric engine sizes and geometries, will provide valuable data not to be obtained in the earlier SERT flights. Of particular interest will be the long-term effects of micro-meteoroids, corpuscular radiation, and hard vacuum on the performance of the elctric thruster systems. Also of interest will be interactions between the electric thrusters and the power generating system.

Large arc jet engine (30 KW and greater):

The objective of this project is to develop arc jet engine systems in the 30 to 500 KW power range in order to provide the technology for scaling from small engines to the sizes that will be useful in future mission requirements. These missions are those that require maintaining or changing the orbit of relatively large systems such as space laboratories or communications satellites. The arc jet engine system is suited to these requirements because of its high specific impulse relative to chemical systems and high thrust relative to ion engines.

In order to assess and solve the problems involved in developing multi-kilowatt arc jet engines up to 500 KW, the building block technique will be utilized by starting with the development of a 30 KW engine capable of operating continuously for periods of 90 days to several months.

Two types of arc jets are being investigated; a 30 KW direct current engine and a 30 KW alternating current three-phase engine both using hydrogen or ammonia for a propellant.

Power efficiencies of 38 - 40 percent have been obtained over a range of specific impulse from 1000 to 1500 seconds for the two engines using both hydrogen and ammonia propellants. Further improvement in the power efficiency at 1000 seconds specific impulse is desired before considering phase I of this project to be completed. To determine whether existing thruster configurations have an operating life adequate to permit the start of phase II of the program, 50-hour continuous tests at 1000 seconds with ammonia will be conducted in late fiscal year 1963. The selection of an AC or DC arc jet system for potential mission applications will depend upon the simplicity of design and construction reliability and performance at the various high power levels.

Major milestones in fiscal years 1963 and 1964 will be thruster life tests and propellant and power conditioning subsystems tank tests for future system integration.

Small arc and ion engines

This project consists of two engine development programs: small arc jets (1 - 2 KW), and small ion engines (500 watts - 1 KW).

The objective of this project is to develop electric engine systems with long life and high reliability with a large number of restarts over a period of several months or years. In addition to providing the technology and experimental verification of long life and high reliability, the engine systems will be capable of being integrated in a three-axis attitude control and station-keeping system for various orbit missions. The engine systems will also be capable of lifting small satellites from one orbit to another. The arc jet will be designed to be capable of operating continuously for at least 90 days. The ion engine will be capable initially of cyclic operation for one year and ultimately for three years. The number of required cycles will be varied within the number estimated to be necessary for various perturbation forces and orbit accuracies of potential missions.

Space electric rocket test (SERT)	1962	1963	1964
Spacecraft design, development and support	$2,070,000	$4,570,000	$ 8,650,000
Launch vehicles	1,500,000	600,000	6,700,000
Subtotal, direct R&D costs ...	$3,570,000	$5,170,000	$15,350,000
Personnel costs	774,000	840,000	925,000
Operation of installations	581,000	435,000	488,000
Total costs	$4,925,000	$6,445,000	$16,763,000
Total personnel	103	97	98

Flight Schedule

	Launch vehicle	Calendar year of launch	Launch location
SERT I	Scout (ballistic)	1963	Wallops
SERT II	Scout (ballistic)	1964	Wallops
	Thor-Agena (orbital)	1966	PMR
SERT III	Scout (ballistic)	1964	Wallops
	Thor-Delta (orbital)	1965	AMR

At present all electric propulsion experimental investigations have taken place in ground vacuum chambers. Analysis of these data have raised significant questions as to the usability of these results for spacecraft design. The SERT project will provide the flight information needed to check the ground facility test results and for the development of specific electric engines for mission application. The electric engines to be tested are being developed under the electric engine development project. The SERT Flight Project has been subdivided into three phases. They are: SERT I - Flights required to provide basic information; SERT II - Flights required in the development of high power engines for spacecraft propulsion systems; and SERT III - Flights required in the development of small engines (less than 1 KW) for station-keeping and attitude control systems. All are planned to be under the technical direction of the Lewis Research Center.

The most significant uncertainties in the application of electrostatic ion propulsion to space travel relate to beam neutralization. Although successful neutralization of the exhaust stream from ion accelerating devices has been demonstrated in ground vacuum chamber facilities, proof demonstration that neutralization will occur in space is still required. In vacuum chambers, electrons emitted from the chamber walls may be the major contributor to beam neutralization. Furthermore, such space environment factors as magnetic fields, cosmic and solar radiation, and absence of gas molecules, may significantly alter the ionization and neutralization mechanisms of the engine. The answers to these questions are the primary objectives of SERT I. The secondary objective of SERT I is to provide meaningful measurements of radio frequency radiation that are generated by the ion engine. It is possible that radio interference from RF radiation can present a serious problem in the use of ion propulsion on space missions.

The SERT I capsule will be launched by the Scout vehicle, which will provide a ballistic flight time of approximately 50 minutes at altitudes above 250 miles. The capsule is designed to be spin stabilized. Changes in capsule spin rate caused by engine operation will be used to determine engine performance. The test time will be divided equally between a Hughes Corporation cesium contact-ionization engine and a Lewis Research Center mercury electron-bombardment engine of different basic designs and utilizing different methods of beam neutralization. The principal payload integration contractor is the Radio Corporation of America, Astro-Electronics Division, Princeton, New Jersey.

The purpose of the SERT II flights is to qualify the 3 KW module to be used as a basic building block in the development of 30 KW and larger engines for spacecraft propulsion systems. Data will be obtained on ion beam optics, particularly on multiple adjacent beam interactions (SERT I has a single beam). The SERT II flights will be both ballistic and orbital as determined by the ground development project requirements.

The objective for SERT III is to qualify a pulsing ion rocket engine system (approximately 150 watts) capable of maintaining the three-axis

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attitude control and station-keeping of a satellite. The immediate use proposed for this type of engine system will be for maintenance of a non-spinning satellite payload in a 24-hour synchronous orbit for an operating life time of approximately three years. The flight spacecraft for the SERT III will consist of the ion rocket engine system and the necessary spacecraft subsystems to conduct the experimental investigation ballistically and orbitally.

The principal contractor for SERT I, Radio Corporation of America, was selected in August 1960 to proceed with the design and development of the spacecraft. The first complete capsule vibration survey was completed by RCA on April 12, 1962, which indicated the vibration levels experienced by the components and subsystems. The development of flight qualified components is approximately 90 percent complete and flight simulation tests of an integrated capsule with ion engines operating will be conducted in a vacuum chamber in calendar year 1963. Ballistic flights using the Scout vehicle are scheduled in calendar year 1963.

The engine development contract for SERT II has been awarded to the Hughes Aircraft Corporation. The development of the companion power converter and the spacecraft will be initiated at an early date. During fiscal year 1964, the SERT II ballistic spacecraft will be under construction while the orbital spacecraft will be in the design phase. The first ballistic launch (Scout) is scheduled for calendar year 1964, and the first orbital launch (Thor-Agena) is scheduled for calendar 1966.

The SERT III spacecraft design was initiated during fiscal year 1963. In fiscal year 1964, the ballistic spacecraft will be in both prototype and flight hardware phases while the orbital spacecraft will be in the prototype hardware stage. The first ballistic launch (Scout) is scheduled for CY 1964, and the first orbital launch (Thor-Delta) is scheduled for CY 1965.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

SPACE POWER

OBJECTIVES:

Conduct research and technology work leading to a better basic understanding of solar and chemical energy processes and to devise new and improved methods of utilizing these energy sources for developing the electrical power required for the accomplishment of space exploration.

SUMMARY OF RESOURCES REQUIREMENTS:

Funds	1962	1963	1964
Supporting research and technology	$ 6,302,000	$10,859,000	$16,524,000
Personnel costs	3,512,000	5,111,000	5,934,000
Operation of installations	2,442,000	2,346,000	2,726,000
Total	$ 12,256,000	$ 18,316,000	$ 25,184,000
Personnel			
Ames Research Center	5	9	9
Goddard Space Flight Center	16	23	22
Langley Research Center	48	50	57
Lewis Research Center	349	430	459
Marshall Space Flight Center	19	36	33
NASA Headquarters	25	24	28
Electronics Research Center	-	3	10
Total	462	575	618

The cognizant Headquarters office responsible for program management is the Office of Advanced Research and Technology.

The field installations where the program is carried out are the Jet Propulsion Laboratory and the Centers listed above.

PROGRAM JUSTIFICATION:

Space power from chemical and solar energy sources is used aboard space vehicles for many things, such as communications, guidance, controls, measurements, life support, and mechanical power. The major factors to consider

in power generation are the power level and duration, although in providing these the factors of reliability, weight, volume, the environment in which it must work, and cost are also important.

Power generation systems using chemical energy generally fall into the short to moderate duration applications ranging from the few minutes needed for electric power on a stage of a launch vehicle to the several weeks planned for the Apollo spacecraft. Durations of months are possible with intermittent use. Typical examples of chemical generation systems are batteries, fuel cells, and mechanical engines. The power level for this class of power generation extends from a few watts to kilowatts. Launch vehicles, and the manned Mercury, Apollo, and Gemini spacecraft are examples of space vehicles using chemical power generation.

Power generation systems utilizing solar energy include the familiar solar cell, thermionic diodes in connection with solar collectors, thermoelectrics, magnetohydrodynamics, and engine systems driven by solar power such as turbines and reciprocating engines. These systems are characterized by relatively long life extending from over a month into years and with power levels from a few watts into tens of kilowatts. It is interesting to note that practically all of our unmanned spacecraft and those planned for the immediate future use solar cells. This includes Surveyor, Mariner, Ranger, Nimbus, the Orbiting Solar, Geophysical, and Astronomical Observatories, Relay, Tiros, Syncom, and a variety of scientific satellites.

With such a broad spectrum of power level and duration requirements, and faced with the availability of only solar cells and batteries as proven systems, it is clear that research and technology should be accelerated on the many other chemical and solar generation systems possible. The systems must be versatile enough to meet the new environmental and operating conditions of future missions. Better power generation systems must be devised to meet different as well as more complex environmental and operating conditions that are planned in future missions. The radiation effects on solar cells must be better understood, and better protection methods must be devised. Better methods of packaging and deploying large solar collectors are needed, and the effects of micrometeoroids or other aspects of the space environment on their operation must be evaluated. Batteries must be made to withstand greater temperature ranges and have longer life. The advantages of fuel cells, which can produce useful byproducts, such as water, or operate on human waste, must be pursued. Operating life of dynamic systems needed for substantial power loads must be extended. Further, particular attention must be given to the problems of efficient and reliable management of the flow of electrical energy throughout the spacecraft and matching the electrical characteristics of the power source to the input requirements of the utilizing equipment. Protective features must be incorporated to minimize the effects of component or system malfunctions upon the capability of the power system to fulfill its intended functions. For example, power conditioning equipment capable of efficient conversion of the low voltage, direct current output of the source to a usable voltage level is needed, as well as improved voltage and current regulation techniques, logic circuitry for detection and correc-

tion of system or component malfunctions, etc. These and other problems are being attacked by a broad research and technology program in NASA. The widespread need for power accounts for the large Center participation in the program, but the major research and technology effort is concentrated at the Lewis Research Center, the Langley Research Center, Goddard Space Flight Center, and the Jet Propulsion Laboratory of the California Institute of Technology. In addition to work at these and the other Centers, a broad contract program with industry and universities is underway.

EXPLANATION OF FUNDS REQUESTED:

Supporting research and technology

	1962	1963	1964
Solar cells.....	$1,510,000	$2,409,000	$3,350,000
Thermionic power technology...	1,710,000	2,519,000	3,993,000
Solar engine technology.....	1,060,000	2,064,000	3,138,000
Batteries and fuel cells.....	1,120,000	2,147,000	2,545,000
Chemical engines.....	350,000	520,000	1,868,000
Thermoelectric, magnetohydrodynamics, and advanced concepts.....	552,000	1,200,000	1,630,000
Subtotal, direct R&D costs.....	$6,302,000	$10,859,000	$16,524,000
Personnel costs.....	3,512,000	5,111,000	5,934,000
Operation of installations....	2,442,000	2,346,000	2,726,000
Total costs.....	$12,256,000	$18,316,000	$25,184,000
Total personnel.....	462	575	618

Solar Cells

Solar cells continue to be the primary source of electrical power for unmanned spacecraft. The major problems with solar cells are their susceptibility to damage from space nuclear radiation, their decrease of efficiency with increased temperature, and the relatively large weight and areas needed. Work underway now and planned for fiscal year 1964 is aimed at these problem areas, and already significant gains have been realized. Last year radiation from a nuclear explosion in the upper atmosphere caused a rapid drop-off in the power output of several satellites using conventional type solar cells (p-on-n type cells). Fortunately, research by the Signal Corps and others resulted in a way to make solar cells more resistant to radiation than conventional cells. These are called "n-on-p" type cells and are being ordered for new solar cell installations. Research is also underway on improved solar cells that can maintain their efficiency with increased temperatures, a characteristic that is important for applications such as solar probes.

The most promising area, however, concerns research on thin film solar cells. This work may lead to solar cells of less than one-seventh the present weight, and structurally sufficiently flexible to be part of inflatable or furled structures, and significantly lower in cost than present ones. Thus larger power output per pound of weight and the possibility of building large solar cell areas for higher power levels can be attained. Such applications hold great promise for space stations which have large surface areas, lunar bases which also require large surface areas for other purposes, and perhaps for generating power in certain remote earth regions. Many research problems are yet to be solved, including improvement of the efficiency of thin film solar cells; work at the Lewis Research Center and by industry through contracts will be focused on these problems.

Thermionic power technology

A thermionic power system converts the heat from solar energy to electrical energy by driving electrons between a hot surface (emitter) and a cooler surface (collector). The main parts of the system consist of a solar collector to concentrate the solar energy and a group of thermionic diodes, the cathodes of which are heated by solar energy, and the anodes are maintained relatively cool by radiation to space. It is often advantageous to add a method of storing thermal energy when the unit is out of the sunlight. During the last year, research on ceramic oxides has identified substances which are compatible with refractory metal containers and have demonstrated their life for several thousand hours at approximately 3500°F. Such systems have great potential for certain applications such as solar probes, long interplanetary flights, or in the radiation belts of the earth where the insensitivity of the thermionic diodes would be important. Efficiencies almost twice that of solar cells appear possible and thermionic systems do not have the temperature problem of solar cells. During the past year, thermionic diodes were operated successfully for over 1000 hours, a major milestone in the development of this type of power conversion equipment. Also during the year methods were developed for fabricating light-weight precision collectors up to five feet in diameter. In the coming year work will be continued to extend the life of the thermionic diode and to increase its efficiency. The Lewis Research Center is conducting fundamental research on thermionic systems and the Jet Propulsion Laboratory of the California Institute of Technology is working with contractors on the experimental thermionic system.

The design goals for the five-foot collector previously mentioned and the cluster of five diodes are to provide a power output of 135 watts for flight missions to Mars with a system efficiency of 15%, operating life of one year, and a total weight of 30 pounds. Achievement of these goals through flight demonstration would make this type of power generation available for missions and would mean a significant step forward.

Solar engine technology

Solar engines convert solar energy to electrical energy by first heating a working fluid which drives an engine, which in turn drives a generator. The engine is usually a turbine but some reciprocating engines are also of interest. The largest part of the effort in this area last year was directed toward a system called Sunflower. In this system mercury is the working fluid. Last year significant progress was made in the Sunflower program. The mercury boiler and components were successfully tested. Fabrication techniques for the foldable 32-foot diameter mirror were developed and the mirror is undergoing various optical and mechanical tests. The most significant progress, however, was made in the turboalternator, where an operating life of over 2000 hours was achieved. The test was terminated by a build-up of mercury corrosion byproducts; this problem is under study at present. This progress is the most significant in the liquid metal turboalternator field in the past two years and the results will be of benefit to the nuclear-electric field as well as the solar electric area. It is anticipated that systems of the Sunflower type will be needed for multi-kilowatt, long duration missions such as those which could be launched by the Saturn booster (e.g. a manned laboratory). A ground test of the Sunflower system, exclusive of the solar collector, is expected during the coming year. The solar collector will be tested separately. Other solar engines which are of interest include the Stirling engine, and turbines operating on the Brayton cycle.

Research is underway on other solar-collector fabrication techniques such as the inflatable rigidized type. Work on this concept is conducted by the Langley Research Center and, if successful, it will allow very large solar collectors to be erected in space from a small package carried aboard the spacecraft. Such large collectors will have application for providing high power levels both in space and on the lunar surface. Part of this work involves the study of materials, such as polymers processed to instill an inherent memory and energy that will be activated by the space environment and automatically deploy a tightly packaged collector.

Batteries and fuel cells

Recent research led to improvements in the quality of batteries for space use. A significant accomplishment included the development of an improved ceramic seal for batteries which greatly increases their reliability and life. This work was conducted through technology contracts managed by the Goddard Space Flight Center. This effort also produced improved silver cadmium batteries which have a higher energy level per pound than the present nickel-cadmium batteries, and are non-magnetic, which is an asset in scientific measurements. These batteries operated successfully in the Explorer XII satellite launched in August 1961. Much progress remains to be made in broadening operating temperature limits and obtaining better reliability for batteries in the space environment.

Fuel cells, like batteries, are electrochemical devices that convert chemical energy directly into electrical energy. In fuel cells, the fuel and oxidant for the reaction come from external tanks and the products of the reaction are removed from the cell. If hydrogen and oxygen are used, the product is water which can be used aboard the spacecraft. Technology developed as part of this program served as the technical basis for the development contract of the fuel cell planned for Apollo. This cell will use hydrogen and oxygen. A fuel cell also using hydrogen and oxygen, but operating in a different manner, is planned for Gemini. There are many possible fuel-oxidant combinations of interest in fuel cells and these are being studied. Fuel cells have high efficiency, high energy density, long life, few moving parts, and are capable of regenerative operation. These advantages make them promising for a number of applications such as manned flight, space stations, and lunar stations. For example, as the result of promising NASA-sponsored research, the Jet Propulsion Laboratory is now evaluating one kind of regenerative hydrogen-oxygen fuel cell for use on deep-space probes. In other work, the NASA is extending work started by the Air Force in developing a thermally regenerative fuel cell for possible use with a nuclear or solar power sources.

Fuel cells will be studied during the coming year for their ability to convert human waste by biological action into electrical energy. This is done by the degradation of biological materials, either indirectly or directly in fuel cells, and the production of electricity from the products. This could be very useful in spacecraft for getting rid of human waste and at the same time generating power from it.

Chemical engines

Chemical engines convert chemical energy to electrical energy by an engine cycle such as a turbine or a reciprocating engine. They are of interest because of the low equipment weight and the relatively high power available for short periods, up to four days or a week, or for intermittent high-power use over a long period of time. There are several interesting engine cycles that are being studied, and this work will continue. During the year, a contract was started on a simple engine that used hydrogen and oxygen instead of the conventional air and gasoline. In the coming year, the possibility of using an engine to operate from waste heat or gases will be investigated. Research will be conducted on specialized lubrication and fuel handling peculiar to power systems.

Thermoelectric, magnetohydrodynamics, and advanced concepts

Several other methods for producing power will also be investigated in the coming year. One of these is by the familiar thermoelectric process, in which dissimilar materials kept at two temperature levels, generate electricity. Another method is conversion of thermal energy to electrical energy by ionized gas in the presence of electric and magnetic fields. These two

techniques are also of interest in nuclear-electric systems, and an integrated approach is planned. As part of a continuing effort, studies will be conducted to determine future space power requirements and the interrelationships between space power systems and other spacecraft systems. These studies serve to guide the planning and integrating of space power systems that will be of greatest utility in future space missions.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

NUCLEAR ROCKETS

OBJECTIVES:

The nuclear rocket program has the primary objective of establishing the basic technology and developing and providing qualified nuclear rocket engines for accomplishing operational missions in advanced launch vehicles. Implementation of this program will encompass basic research on reactors, engine systems, and vehicles, development of practical heat-exchanger-type rocket reactors and engine subsystems, ground test of reactors, engines, and stages, development of reliability, and operation of nuclear powered stages in launch vehicles for flight test purposes.

SUMMARY OF RESOURCES REQUIREMENTS:

Funds	1962	1963	1964
Supporting research and technology	$1,791,000	$13,339,000	$22,687,000
Projects	24,985,000	58,487,000	74,000,000
Subtotal, direct R&D costs	$26,776,000	$71,826,000	$96,687,000
Personnel costs	6,766,000	12,194,000	15,170,000
Operation of instllations	4,468,000	5,228,000	7,062,000
Total costs	$38,010,000	$89,248,000	$118,919,000
Personnel			
Space Nuclear Propulsion Office	40	106	160
NASA Headquarters	27	26	26
Lewis Research Center	761	1,027	1,082
Marshall Space Flight Center	60	192	217
Western Operations Office	3	3	3
Launch Operations Center	10	36	47
Total personnel	901	1,390	1,535

This program is conducted jointly by the Atomic Energy Commission and the National Aeronautics and Space Administration with the AEC responsible for the reactor portions of the effort and the NASA responsible for the non-nuclear components and for integrating the reactors into engines and flight vehicles.

Within this framework, responsibility for the overall Nuclear Rocket Program is shared by the Space Nuclear Propulsion Office, a joint office of the Atomic Energy Commission and the National Aeronautics and Space Administration, and the Office of the Director of Nuclear Systems, Office of Advanced Research and Technology in the NASA Headquarters. The SNPO has primary responsibility for the KIWI, NERVA and Nuclear Rocket Development Station, Operations Projects and Supporting research and technology relating to propulsion. The Office of the Director of Nuclear Systems has primary responsibility for the Reactor In Flight Test (RIFT) Project and Supporting research and technology relating to vehicles. Single manager direction and integration of the entire Nuclear Rocket Program is provided through one person who serves both as Manager, Space Nuclear Propulsion Office and Director of Nuclear Systems.

PROGRAM JUSTIFICATION:

Nuclear energy offers the space program the high energy required for difficult long range, high payload missions which cannot be duplicated by other systems. The application of a nuclear upper stage to large launch vehicles can potentially increase their payload capability by a factor of two or three for near-earth missions and by a factor of ten or more for deep-space missions. For example, an all-chemical rocket to perform a manned round-trip mission to Mars would require an initial weight in an earth orbit of 10,000,000 pounds as compared to a nuclear spacecraft weight of 1,000,000 pounds. Thus, nuclear rockets offer significant economic and technical advantages.

In order to realize these improved capabilities a broad, comprehensive, well integrated research and development program is required to solve the complex problems and establish an adequate technology. Areas of effort will include reactor development, engine development, stage development, flight safety, radiation effects and design construction and operation of facilities for ground testing, handling and launch.

Budgetary estimates are based on maximum utilization of simulators and ground tests, in order to minimize the number of costly flight tests, to insure early successful resolution of major engine/stage integration problems, and to furnish the operational radiation environment for engine and vehicle systems and sub-systems development. The program is at present primarily directed toward developing the technology of the major components of the nuclear rocket system. Until the availability of a suitable reactor is demonstrated, major hardware procurement and full-scale development of all components and flight systems will not be undertaken.

The program includes three projects designed to fulfill the objectives outlined above. These three projects combine the reactor technology with propulsion-system and vehicle research and development capability to provide early flight test experience. The projects can, with further development, lead to safe, reliable, fully qualified systems for operational use.

The projects within this program are:

(1) KIWI: design, development, fabrication and testing of hydrogen-cooled nuclear reactors;

(2) NERVA (Nuclear Engine for Rocket Vehicle Applications): design, development, fabrication, ground testing and qualification of nuclear-rocket engines employing reactors based on a selected KIWI reactor design; and the delivery of engines for flight tests in an upper stage of Saturn-class launch vehicles; and

(3) RIFT (Reactor In Flight Test): design, development, fabrication, and flight test of a NERVA-powered stage as an upper stage on a Saturn-class launch vehicle.

EXPLANATION OF FUNDS REQUESTED:

	1962	1963	1964
Supporting research and technology			
Rocket reactor research.....	$1,054,000	$8,060,000	$10,187,000
Nuclear rocket engine systems.....	737,000	4,826,000	11,200,000
Safety.....	---	200,000	500,000
Vehicle technology.....	---	253,000	800,000
Subtotal, direct R&D costs.	$1,791,000	$13,339,000	$22,687,000
Personnel costs.....	4,900,000	7,270,000	8,720,000
Operation of installations.....	3,248,000	2,749,000	3,289,000
Total costs.....	$ 9,939,000	$23,358,000	$34,696,000
Total personnel.....	653	860	913

The purpose of the supporting research and technology is (1) to supply general supporting research and technology for current projects, (2) to establish a base of technical information for the design and operation of nuclear rocket components and engines, (3) to provide the necessary basic technology for the development of future generations of nuclear rocket engines and vehicles, and (4) to evaluate the feasibility of advanced concepts.

The KIWI, NERVA, and RIFT projects represent the first generation of nuclear systems for space missions. To support the objectives of these current projects and to supply the necessary broad technological basis for design and development of future systems, a supporting research and technology program has been established to cover all of the major technical areas involved with nuclear rocket engines and vehicles.

As in other portions of the nuclear rocket program, funding and operational responsibilities for supporting research and technology are split between NASA and AEC. Management of all the activities except vehicle technology is centered in SNPO.

Rocket reactor research

The reactor component of a nuclear rocket engine is the key item in establishing the capabilities of nuclear systems. It must be capable of heating hydrogen to thousands of degrees in temperature, and operate stably during start-up, steady-state, shut-down, and restart. It should be able to fire up to a total of several hours and some missions may require intermittent use of the engine for as long as a two year period in space.

Reactor research is primarily the responsibility of the Atomic Energy Commission. The NASA funded activities are of two distinct types: (1) the in-house program of research related to reactors and advanced concepts, and (2) the contractor effort to supply hardware for the reactor tests that are run by two AEC National Laboratories. The Los Alamos Scientific Laboratory (LASL) is devoting most of its efforts to the KIWI project, and as success is achieved with KIWI, LASL will shift its capabilities to the Phoebus program which has the objective of broadening the technical base for reactor design, through research into high power-density operation, high powers, temperature limits, and the lifetime of fuel elements. Phoebus reactor experiments are planned to be conducted in fiscal year 1965.

The Argonne National Laboratory (ANL), is conducting during fiscal year 1963, studies and research pertaining to alternate reactor concepts to determine whether other reactors should be developed as a backup to KIWI or for more advanced performance capabilities. To support reactor tests to be conducted by the AEC National Laboratories, NASA must fund for the development of nozzles and liquid hydrogen feed systems.

The Phoebus reactors, which are planned for testing in fiscal year 1965, require the development of a new liquid hydrogen feed system and new nozzles. The feed system consists of two turbopumps mounted and operated in parallel to provide high liquid hydrogen flows. It is being developed by the Rocketdyne Division of North American as was the turbomachinery now being used in the KIWI reactor tests. According to current plans, the feed system and Phoebus nozzle program will be brought to completion in fiscal year 1964 with the delivery of hardware for installation at the Nuclear Rocket Development Station (NRDS).

The NASA in-house research activities include the following areas: materials development, conceptual studies and design, neutronics design and development, and shielding. The Lewis Research Center conducts research related to solid core reactors having refractory metals and ceramics for fuel materials. This research is directed at the determination of mechanical properties (tensile strength, modulus of elasticity, creep rates) and thermal properties (conductivity, expansivity) for fueled materials. Fabrication and

joining techniques will also be explored along with tests to determine operating limits in hot flowing hydrogen.

Studies of water-moderated reactors are being extended to high-power levels to determine their applicability for a range of conditions. Verification of analytical techniques for predicting criticality of heterogeneous systems is under way in a zero-power facility.

Lewis and the Jet Propulsion Laboratory (JPL) are exploring several cavity reactor concepts. JPL directs its basic research toward the gas vortex system, whereas the Lewis Research Center has been examining the features of a co-axial flow reactor. While the feasibility of cavity reactors is still under study, their performance potential makes research and development effort on various concepts attractive. A high-thrust engine, having a specific impulse potentially achievable with cavity reactors would make dramatic changes in our concepts of space travel. For example, round-trips between the moon and the earth would be possible using only a one-stage rocket, round-trips to Mars and Venus would last several months rather than a year or more, and a high degree of safety and reliability could be provided for manned space flights. Studies of the gas dynamics of cavity reactors are continuing in addition to research on radiant heat transfer and fission fragment physics. The feasibility of obtaining a nuclear test with a cavity system is also being studied. Research is being initiated on the technology of predicting criticality in cavity systems.

Nuclear rocket engine systems

The purpose of this research is to provide the necessary component and systems technology for nuclear rocket engines. This research coupled with rocket reactor research will provide 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 systems technology is the responsibility of NASA and the in-house effort is conducted by the Lewis Research Center. Contractor effort, which is nominal at the present time, will be expanded during fiscal year 1964 with technical direction supplied largely by the Lewis Research Center.

Research is being conducted in the following areas: flow components and systems, turbomachinery, controls and instrumentation, design and analysis, radiation effects, nozzles, bearings and seals, and fluid property research. The activities in these areas, while aimed at certain engine types, are essentially oriented toward improving technology prior to incorporation into an engine project. Included are design studies, research on components, fabrication research and supply of component hardware to support systems research. Research on flow components and systems is to provide data on the performance of components and engine systems during the transients in a nuclear rocket engine. Some of this work is directed toward the NERVA-class of engines, while other work is aimed at high-power engines.

Research in turbomachinery is aimed at advancing the technology for pumps and turbines used in various types of nuclear rocket engines. The turbopump of an advanced engine is like a very large turbojet with additional technological problems caused by liquid hydrogen and intense radiation. Particular problems include cavitation, stall and stability, and induced vibrations coupled with requirements for high efficiency, small size, and off-design operation.

Advances in the technology for control and instrumentation are required for nuclear rockets. The requirements for startup of an entire reactor-engine system in a very short time pose many unsolved control problems (complicated by intense radiation) such as adequate temperature sensing, chilldown control to prevent boiling during startup, pump control to prevent cavitation, thrust control, restart programs, and control for economical and safe operation during cool-down after operation. Research is directed at means for engine control, and at new control components such as sensors, actuators, and signal conditioning devices.

Engine design studies will be performed to establish power levels, engine cycles, chamber pressures, and other engine parameters. Studies of mission and vehicle aspects will be supported to assist in establishing important features that should be incorporated into engine designs.

The radiation effects effort is pointed at defining the fundamental behavior of materials in combined radiation, cryogenic, and vacuum environments. Such information supports all phases of the nuclear rocket program and is the basis for design work.

Research on nozzles for nuclear rocket engines is essential, because current technology is extended to the limit to provide a nozzle for the NERVA engine. The next step is to explore novel designs and materials of fabrication for high performance nozzles. The fiscal year 1964 effort will explore such designs with emphasis on refractory metal, coated, and film-cooled approaches. Near the end of fiscal year 1964, a hot-hydrogen facility will be available at the Lewis Research Center for testing models of advanced nozzles. The fiscal year 1964 funding would supply nozzle hardware to be tested in this facility.

The combined environments of radiation, vacuum, extreme temperatures and very high bearing speeds create difficult development problems in regard to bearings, seals and lubrication. In fiscal year 1963, work began to explore wear phenomena in a basic research program in the Lewis Plum Brook Reactor. In addition, a start has been made on providing a bearing test rig for operation in the reactor. The fiscal year 1964 funding will permit completion of the test rig and testing of various bearing configurations.

Fluid property research is needed to provide basic data on propellants and fluids used in nuclear rockets and to supply a basic technology and consulting capability in cryogenic engineering. For several years, NASA

has supported 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, and the J-2 engine) by supplying basic property data and cryogenic engineering support. This program will be continued in fiscal year 1964. Additional small contracts are planned to measure properties at very high temperatures.

Safety

The safety work reflected in the level of effort above is a small part of the over-all safety program being conducted in connection with the total program. The major safety program is being conducted by contract as part of the over-all NERVA and RIFT contract efforts. The safety research reflected herein is for certain special studies particularly with regard to the effects of the use of various destruct systems under diverse conditions and environments.

Vehicle technology

Analytical and experimental work has been undertaken and is planned for future years to provide a base of technology for nuclear vehicles. The analytical efforts are directed mainly to a determination of performance capabilities and operational requirements. Investigation will be made of the guidance problems created by unique operating characteristics of nuclear rockets.

Studies and research are underway to determine the behavior of liquid hydrogen in a propellant tank as influenced by neutron and gamma heating. An extension of this effort is planned in fiscal year 1964 to refine techniques of analysis and test, to introduce more complicated geometries, and to assess the relationship between propellant flow rates and neutron flux as it relates to a net propellant temperature rise and stratification.

Initial steps are underway in fiscal year 1963 to determine the gross effects of nuclear radiation on tankage structures including insulation at cryogenic temperatures. Engineering data will be obtained in fiscal year 1964 on the effects of radiation, combined with a simulated space environment where practicable, on typical vehicle components such as electrical and thermal insulation, bearings, seals, and lubricating materials.

Projects:

KIWI	1962	1963	1964
Reactor test support components....	$4,529,000	$2,400,000	---
Propellants.....	140,000	1,670,000	$1,000,000
Subtotal, direct R&D costs..	$4,669,000	$4,070,000	$1,000,000
Personnel costs.....	23,000	73,000	89,000
Operation of installations.....	16,000	29,000	40,000
Total costs.....	$4,708,000	$4,172,000	$1,129,000
Total personnel	4	8	8

In 1954 the AEC undertook preliminary studies on the development of nuclear propulsion for rockets as the result of an expression of interest in this area from the U. S. Air Force. Because these studies indicated that nuclear rocket propulsion systems appeared to offer potential advantages over chemical rocket propulsion systems, a joint AEC-USAF program was initiated in 1955 with the objective of demonstrating the feasibility of nuclear rocket propulsion. The Los Alamos Scientific Laboratory was selected to carry on the AEC work. U. S. Air Force responsibility was transferred to NASA by Executive Order on October 1, 1958. The first significant milestone in the program was achieved with completion of the test of KIWI-A, the initial test device on July 1, 1959. In 1960 two more reactors, KIWI-A Prime and KIWI-A3 were tested. The KIWI-A series of tests was aimed at demonstrating the materials technology and design methods needed for the development of operationally useful nuclear rocket reactors. The test series also defined many of the problems to be solved before development of the KIWI reactors to rocket engines could proceed.

The project is now directed at testing the KIWI-B series of reactors from which evaluation and selection of a specific design for the NERVA engine will be made. This project is funded almost entirely by the AEC. NASA funding consists of providing reactor test support components such as nozzles and turbomachinery and also providing required propellants. With the completion of development in fiscal year 1963 of the NFS-2 liquid hydrogen feed system and delivery of all required nozzles to support KIWI reactor tests, NASA support of KIWI test components will phase out. However, liquid hydrogen will continue to be required to support the reactor test schedule during fiscal year 1964.

NERVA	1962	1963	1964
Engine systems development.....	$3,817,000	$4,983,000	$11,000,000
Component and subsystem development	5,258,000	19,348,000	30,000,000
Ground test and operations support.	10,229,000	12,690,000	13,000,000
Propellants.....	12,000	6,196,000	6,000,000
Subtotal, direct R&D costs..	$19,316,000	$43,217,000	$60,000,000
Personnel costs.....	780,000	1,413,000	2,064,000
Operation of installations.....	463,000	467,000	691,000
Total costs.....	$20,559,000	$45,097,000	$62,755,000
Total personnel.....	115	161	200

The justification of the NERVA project rests generally on that of the entire nuclear rocket program. The specific objective of the NERVA project is to develop a nuclear rocket engine. Such a development will permit work on the solution of operating problems so that nuclear rockets may be applied in the advanced space flight missions for which they offer major performance advantages over the lower specific impulse chemical rocket systems. The NERVA engine is being so designed that it may be used for advanced space missions such as those required to perform extensive lunar operations, including lunar exploration bases, and to the performance of heavy payload missions to the planets. Such an engine would eventually be required for manned planetary missions.

The NERVA engine is a propulsion system in which hydrogen is heated to high temperature in a nuclear reactor. The high temperature hydrogen is accelerated through a jet nozzle producing the thrust that propels the rocket vehicle. In this engine, the hydrogen is pumped from the vehicle propellant tank by a turbopump into the tubes that make up the regeneratively cooled jet nozzle walls. Hot hydrogen drawn off at the discharge of the reactor is mixed with cold hydrogen to provide the gas that drives the turbine of the turbopump system. The entire engine will be swiveled about a gimbal bearing in the propellant line connecting the propellant tank to the pump to permit control of the thrust direction. The reactor to be used in the NERVA engine will be developed from the basic reactor design developed in the KIWI Project being conducted by the AEC's Los Alamos Scientific Laboratory.

The NERVA engine is being developed by the Aerojet-General Corporation as the prime contractor, and with the Westinghouse Astronuclear Laboratory as the principal subcontractor. Other major subcontractors on this project are Bendix Research Laboratories, American Machine and Foundry, and Edgerton, Germeshausen and Grier.

Through the end of contract year (September 30, 1962), contractor accomplishments were briefly as follows: Aerojet-General Corporation had nearly completed necessary changes to facilities at its Liquid Rocket Plant in Sacramento. These facilities will be used to conduct turbopump, nozzle and engine simulator tests. Westinghouse Astronuclear Laboratory had started operations in a new fuel-element-fabrication facility and had initiated work in a core mechanical and thermal test facility. The U. S. Air Force Nuclear Aerospace Research Facility, Fort Worth, was selected as a radiation-effects testing center, and tests are now under way, with design of liquid hydrogen flow equipment also going ahead. Engine Test Stand No. 1 (ETS-1), at the Nuclear Rocket Development Station is under construction (AEC funded) and construction of the Engine Maintenance-Assembly-Disassembly Building (E-MAD), funded in NASA's 1962 budget, started during the summer. Tests have been conducted by Aerojet on turbopumps, hot bleed-port nozzles and engine simulators. The selection of a hot-bleed turbine drive cycle for NERVA was made, as was the tentative selection of the KIWI-B4 reactor design as the basis for the NERVA reactor design. Westinghouse is designing the first NERVA reactor and some components are being fabricated or procured. An internal reactor radiation shield was built and delivered to LASL for use in a shielded KIWI-B4 experiment (designated at KIWI-B5). Preliminary design of the total hot-bleed engine is in progress.

The contractor activities for fiscal year 1963 include the following: Engine design will continue. Fabrication of the first NERVA reactors will be accomplished. Fabrication and research testing of engine non-nuclear components will be a major activity. Simulated engine tests will be continued, including a simulator incorporating prototype hardware. Design of an exhaust duct for ETS-1 will be completed and fabrication initiated. Assembly-disassembly equipment for the E-MAD Building will be designed. The engine installation vehicle for ETS-1 will be designed. Construction of Engine Test Stand No. 2 (ETS-2), will be initiated.

The work to be performed in fiscal year 1964 will involve fabrication or procurement of engine components, supported by appropriate design, analysis test, and simulation activities. NERVA reactor tests will be conducted at Test Cell A, at the Nuclear Rocket Development Station. Activation of ETS-1 and the E-MAD building will be under way. Simulation runs for the purpose of design will be continued, with the Aerojet-General Corporation Liquid Rocket Plant facilities also continuing component testing to obtain verification of design.

Major milestones in the program are as follows:

	CY
Tentative selection of KIWI design for NERVA Reactor	1962
Initial NERVA reactor experiment	1963
Initial engine static test	1965

Engine systems development

This area of effort has as its objective the development of the overall NERVA engine system by integrating engine components and sub-systems into a system, fabrication of test hardware, analysis of engine integration problems, and testing of engine systems using both non-nuclear simulation devices and full scale nuclear engine ground tests. Because of the costs associated with nuclear testing, non-nuclear engine simulators will be used extensively prior to and beyond calendar year 1964. This will give a high degree of assurance of successful nuclear engine testing.

Some of the major problems which will be investigated using non-nuclear simulators are: engine startup capability with liquid hydrogen, flow stability problems, flow leakage rates, pressure losses in the system, and control response times. Many of these problems will be investigated prior to fiscal year 1964; however, in fiscal year 1964 it will be possible to perform these tests with the latest available prototype engine hardware and with a system which resembles the first nuclear engine in all but the nuclear aspects.

Analyses to support these tests and to analyze test results will be conducted. Engine system modification resulting from these tests and analyses will be incorporated into the simulators as rapidly as possible to permit finalizing the nuclear engine design on a timely basis. Engineering support for drawings and specifications will also be provided.

Component and subsystem development

Development testing of radiation resistant bearings will be conducted in fiscal year 1963 making use of bearing testers in both a nuclear and non-nuclear environment and by tests in the turbopump system, also with and without the nuclear environment. In fiscal year 1964 further development of the propellant feed system will be conducted to incorporate design refinements. For example, mechanical design to permit remote handling and disassembly will be incorporated into the turbopump to be used in the engine tests. Propellant feed systems for developmental testing in component test facilities, up-to-date versions of the non-nuclear simulators, and early nuclear engine tests will be fabricated in fiscal year 1964. Tests to determine operational characteristics of the propellant feed system will be conducted. If found necessary on the basis of these tests and other considerations, a boost pump will be added and tests initiated.

The reactor subassembly work is funded by the AEC and is directed toward supplying subassemblies and supporting engineering design and analysis for reactor development tests and nuclear engine tests. Aerojet and Westinghouse will initiate testing of NERVA (NRX) reactors in early fiscal year 1964, and testing will continue throughout the year. The first NERVA reactor design is a direct outgrowth of the KIWI-B4 reactor now under testing investigation by the Los Alamos Scientific Laboratory. Modifications by Westinghouse involve reactor core support, flow balancing and seals, and incorporation of

a radiation shield. The design, fabrication and test efforts will be supported by component tests, fuel and materials developments, neutronic, heat-transfer, fluid flow and mechanical design analyses, and reactor integration studies.

The thrust chamber assembly consists of the nozzle, nozzle extension, pressure vessel, upper and lower thrust structure, and gimbal system. Prior to fiscal year 1964, nozzles and nozzle extensions will have been fabricated and successfully subjected to chemical and nuclear firings. Structural tests will have been conducted on the pressure vessel, thrust structure and gimbal assembly. In fiscal year 1964, development will require further tests to determine performance and reliability for long duration firings and the sensitivity of the components and their materials to the radiation environment. Design and fabrication of thrust chamber assemblies for use in engine tests will reflect the results of these tests.

The control system for the NERVA engine must provide proper control of flow and nuclear power so as not to exceed temperature limitations for the materials fabrication and provide safe nuclear operation. The control system must operate properly in three different regimes; startup, power cycle and the shutdown and afterheat removal phases. Further development of the components and system will be conducted in fiscal year 1964 to permit the final design of the control system for use on the first nuclear engine tests in the last quarter of fiscal year 1964. Fabrication and acceptance tests of these systems is to occur in fiscal year 1964.

The hazards associated with nuclear engines made it mandatory that a destruct system be provided. Prior to fiscal year 1964 several anticriticality and post-operation destruct concepts will have been analyzed and sufficient component development tests will have been conducted to provide the basis for selection of a destruct system to be integrated into flight engines. Research and development in several areas will continue through fiscal year 1964 to obtain complete information on the type and shape of explosive charges to be used, the effects of nuclear radiation on candidate explosives, data on fragmentation of the reactor and design and operational characteristics of the activation and positioning system of the destruct system. Performance tests using simulated full scale engines will be conducted in fiscal year 1964 on systems problems which are not uncovered by analyses and component tests.

The pneumatic supply system is to provide the engine with gas to power the pneumatic activation devices and to pressurize the propellant tank to the positive suction pressure required by the liquid hydrogen pump. Therefore, integration and coordination with the vehicle contractor, who has the responsibility for the propellant tank will be conducted. The effort by the engine contractor has thus far been limited to system design analyses. In contract year 1964, it will be necessary to make firm selection of the pneumatic supply system components, procure and/or fabricate these components and carry out development testing to ensure a suitable ground and flight test system.

To achieve the objective of reliable component development, a radiation effects program has been outlined and facilities have been activated to permit testing with liquid hydrogen and nuclear radiation. During fiscal year 1964 detailed testing of selected materials, components and component assemblies will be accomplished. Major radiation environmental tests involving actuator and control systems and the propellant feed system to be used in the first nuclear engine ground test are planned.

Ground test and operations support

The primary engine support systems are the remote handling system, the checkout and test system and the transport, ground handling and maintenance system. The reliability and safety programs are also funded as part of this task area.

By fiscal year 1964, handling, test and transport systems for reactor development testing will have been completed and will be in use. In fiscal year 1964 additions and changes to these systems will be made to permit functional use with the entire engine system. Design of modifications required for handling of ground vehicle tests will also be accomplished in fiscal year 1964.

The reliability program will be accelerated. The safety program will generate documents and procedures for safe engine handling, operation and personnel procedures.

During fiscal year 1964 many of the facilities begun in fiscal year 1962 and fiscal year 1963 will be nearing completion, and checkout and activation of these facilities will be conducted. Also planned for fiscal year 1964 are studies to gain criteria required for exhaust duct modifications and additions to the test stands. A spare exhaust duct to support the engine program will be procured.

Propellants

This task area covers propellant procurement which is based on test schedules for NERVA. Over 90% of the propellants procured will be liquid hydrogen.

RIFT	1962	1963	1964
System technology.....	500,000	$2,336,000	$1,750,000
Subsystem technology.....	500,000	3,119,000	9,000,000
System integration.....	---	5,245,000	1,250,000
Subtotal, direct R&D costs...	$1,000,000	$10,700,000	$12,000,000
Personnel costs.....	1,063,000	3,124,000	3,766,000
Operation of installations.....	741,000	1,897,000	2,876,000

	1962	1963	1964
Total costs.....	$2,804,000	$15,721,000	$18,642,000
Total personnel.....	129	326	366

The RIFT project is designed to provide the vehicle for flight testing the NERVA engine and the sub-systems required to evaluate the operating characteristics and problems associated with nuclear propulsion in the space flight environment.

In order to minimize the time and cost required for transition to operational usage, the RIFT vehicle, will be designed as a third stage for the Advanced Saturn vehicle and will be as close as possible to an operational vehicle within the special requirements of the flight test program. The stage will be approximately 33 feet in diameter and 88 feet long and will include all necessary instrumentation, control and tankage required to accomplish the primary objectives of testing the NERVA engine.

In addition to the primary NERVA performance and radiation data acquisition, the vehicle will provide the structural, flight dynamics, operational experience, instrumentation, and control data required to design and build nuclear powered operational vehicles for lunar, deep space and utility missions (tankers and/or ferry vehicles).

During fiscal year 1960 and fiscal year 1961 four contractors were given contracts to study technical and management approaches to the vehicle design problem. Review of the proposals submitted under these study contracts resulted in the award of the development contract to the Lockheed Missile and Space Company.

The RIFT project commenced in June of 1962 with the level of effort paced by the progress made in the KIWI reactor program. No major hardware is being procured during fiscal year 1963, and the effort is primarily in conceptual design leading to definition of major technical problem areas and overall program requirements. In fiscal year 1964 the emphasis will be on solution of the major technical problems such as tank insulation, tank structure, radiation effects and fabrication techniques.

System technology

Conceptual design initiated in fiscal year 1963 will lead to preliminary RIFT stage design in fiscal year 1964. From this design effort are developed the specifications for tank capacity, structural requirements, all subsystems (such as attitude control, electrical, destruct, and communications) flight test trajectories, hazards evaluations and hazards countermeasures. The basic design will be based on the best compromise between an optimized operational nuclear third stage as obtained from studies of manned lunar and planetary missions, and the special requirements dictated by the nuclear rocket engine test program and by the Advanced Saturn vehicle that

will carry RIFT as a third stage. Analysis of the present conceptual design has already shown that the critical items in RIFT development will be problems of insulation, structure, fabrication techniques, radiation effects and propellant heating.

Subsystem technology

Subsystem technology will represent the major area of effort in fiscal year 1963 in order to ensure that technology problems do not delay RIFT stage development when major fabrication, assembly and engine-stage testing are started. In fiscal year 1963 efforts are concentrated on the problem of the liquid hydrogen insulation that is to be installed internal to the tank. This work includes fabrication and utilization of a 4-foot diameter tank and a 9-foot diameter tank for testing insulation materials, vapor barrier materials, insulation fabrication, installation, and bonding. In fiscal year 1964 this work will be continued and extended to provide for radiation testing. In addition, a full scale 33-foot diameter heavy gauge tank will be purchased to provide a means for full scale verification of insulation effectiveness and reliability. Verification of the effectiveness of the RIFT stage insulation will represent one of the major milestones in RIFT technology.

Components of the structural system, including tank sections, thrust structure and interstage structure will be fabricated and tested. Much of this work will use scale model and test panel specimens although it is anticipated that a 33-foot diameter flight weight section will be tested for burst strength because extension of available stress theory to very large diameters is not necessarily valid.

The most critical factor in development of RIFT stage fabrication techniques is considered to be the method of welding the massive sections together. In fiscal year 1964 a full scale jig will be assembled to permit development of a welding procedure in which the welding machine will rotate around the tank as it mills, welds, and x-ray the joint. It is anticipated that this welding technique will provide more reliable and faster fabrication with a substantial cost saving over the tooling required in current practice, which requires rotation of the tank sections past a stationary welder. Other fabrication technique effort evolves from work now in progress on the scale model 9-foot tank. It was found that the transition section between the tank and the unique conical bottom cannot be spin formed; therefore other methods of forming must be investigated.

System integration

Initial activities have already provided much valuable information to the engine contractor in the form of preliminary requirements for engine gimbal response, weight penalties versus net positive suction head provided to the engine pump, and preliminary layouts of engine installations. A survey of the road from Port Hueneme to Nuclear Rocket Development Station has been made and a list of about 5000 required modifications has been compiled.

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Preliminary criteria for the test facilities at the Nuclear Rocket Development Station and launch facilities at the Atlantic Missile Range are now being generated. In fiscal year 1964, as throughout the entire program, coordination support will be effected with the engine contractors, the test facility design and construction contractors, the Advanced Saturn vehicle managers, and the launch operations and launch facilities groups.

Propellant heating investigations in a radiation environment will be initiated in fiscal year 1963 and continued through fiscal year 1964 in order to determine the effects and mechanism of propellant heating resulting from the neutron current emanating from the nuclear engine. The propellant heating investigation will incorporate results from more fundamental studies and is required for tank vent valve and tank pressurization design, engine shield design, inlet pump pressure specifications and engine-tank separation distance, as well as finalization of the tank bottom design.

Basic radiation effects and cryogenics programs will be continued in order to provide verification of materials and "off-the-shelf" items such as cables, seals, electrical connectors and other components of RIFT subsystems.

All of this work is required to verify or develop information required in RIFT design. Development of major hardware components for RIFT will not be undertaken until the reactor tests demonstrate the availability of a basic reactor design that can be incorporated into the NERVA engine and then into RIFT.

Nuclear Rocket Development Station Operations

	1962	1963	1964
General site support.....	---	300,000	$600,000
Facility checkout and maintenance.	---	100,000	350,000
Capital equipment.....	---	100,000	50,000
Subtotal, direct R&D costs.	---	$500,000	$1,000,000
Personnel costs.....	---	314,000	531,000
Operation of installations.....	---	86,000	166,000
Total costs.....	---	$ $900,000	$1,697,000
Total personnel.....	---	35	48

The mission of the Nuclear Rocket Development Station is to provide a national site for static testing the reactors, engines and vehicles associated with nuclear rocket development.

The NRDS is located in the Jackass Flats area of the State of Nevada approximately 90 miles northwest of Las Vegas. Three major test facility complexes are planned at the Station, one to provide test support for reactor, engine and vehicle testing respectively. The development of a nuclear rocket is an extremely complex undertaking and an adequate test program is essential. The facilities used in nuclear rocket testing represent advances in the state-of-the-art because of critical cryogenic, exhaust ducting and remote handling requirements. Management of the NRDS and responsibility for its construction and operation belong to SNPO. The major users of the Station are Aerojet-General Corporation, Westinghouse Astronuclear Laboratory, Los Alamos Scientific Laboratory and Marshall Space Flight Center.

The NRDS was established by Interagency Agreement between the AEC and the NASA on February 16, 1962. This agreement provided that SNPO would set up an extension of its office to manage over-all activities at the Station, but did not extend to programmatic direction of site users. It also provided that SNPO would assume responsibilities for all facilities already in existence within Station boundaries. All tests of the KIWI series of reactors have been conducted at this location including those which took place prior to the establishment of the NRDS (the NRDS was sited on property formerly part of the AEC's Nevada Test Site).

General site support

These costs represent support services for 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. It includes the cost for a support service contractor to maintain and operate various shops such as the plumbing, electrical, carpenter, welding and machine shops. Also included are the costs of activation of all facilities, maintenance and operation of support facilities and equipment, and the operation of computer services to be used for data reduction, theoretical problems and management applications. It should be emphasized that these are routine or recurring services and do not include any costs for test operation services to be requested by individual test contractors on a work order basis . These costs are budgeted through their respective NASA project manager's office. Examples of these latter costs are services for facilities modifications, stand-by of test runs, field support, operational support, and test material and supplies.

Facility checkout and maintenance

All major facilities making up the reactor test facility complex are basically complete although considerable checkout remains in fiscal year 1963 to make them all operational. In addition, modifications to certain of the reactor facilities must be accomplished by the first quarter of fiscal year 1964. The construction of engine test facilities is just getting under

way with the first engine test stand due to be available in the second quarter of fiscal year 1965 and the Engine Maintenance, Assembly and Disassembly Building due to be available in the third quarter of fiscal year 1964. Other engine facilities are in the design stage. The facilities which will make up the vehicle complex are in the design stage only.

Major milestones are as follows:

	Calendar Year
Complete Reactor Test Cell "A" Modification	1963
Engine Maintenance, Assembly and Disassembly (E-MAD) Building	1964
Engine Test Stand No. 1 (ETS-1) available	1964
Engine Test Stand No. 2 (ETS-2) available	1965

The funding for support and management of the NRDS is based on the current schedules of construction and operation of the test facilities as gathered from contractor and Governmental program manager schedules.

Equipment

This represents the cost of equipment purchased by the Government for the use of Government and contractor personnel in carrying out Station support activities. Examples are vacuum cleaners, cafeteria equipment, tools, waxers, etc.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

CHEMICAL PROPULSION

OBJECTIVES:

Conduct research and advanced technology studies to increase knowledge of chemical propulsion processes, to investigate new concepts and techniques, and to advance chemical propulsion to meet future requirements.

SUMMARY OF RESOURCES REQUIREMENTS:

Funds	1962	1963	1964
Supporting research and Technology	$7,003,000	$14,219,000	$22,497,000
Small flight project	---	250,000	---
Subtotal, direct R&D costs	$7,003,000	$14,469,000	$22,497,000
Personnel costs	6,087,000	7,285,000	8,558,000
Operation of installations	4,074,000	3,365,000	4,020,000
Total costs	$17,164,000	$25,119,000	$35,075,000
Personnel			
NASA Headquarters	35	49	57
Langley Research Center	118	126	135
Lewis Research Center	645	626	675
Marshall Space Flight Center	8	12	17
Goddard Space Flight Center	-	7	7
Wallops Station	-	6	8
North Eastern Office	-	1	1
Total personnel	806	827	900

The cognizant Headquarters office responsible for program management is the Office of Advanced Research and Technology.

The field installations where program emphasis is underway or proposed are the Jet Propulsion Laboratory and the NASA Centers listed above.

PROGRAM JUSTIFICATION:

The supporting research and technology described herein is the search for a better understanding of chemical propulsion and the application of

this knowledge to increase national capability to meet future challenges in space. This work will be helpful to developments in present programs, but the purpose is to provide increased capability for developing advanced engines to meet future requirements.

Chemical propulsion is and will be for some time to come, the only method of propulsion for space exploration. It is essential that a vigorous and imaginative research and technology program be conducted to provide the ability and knowledge to do increasingly more difficult tasks that lie ahead. Even with the advent of man-rated nuclear and nuclear-electric propulsion systems there will be many tasks uniquely and best done by chemical propulsion.

The chemical propulsion program is primarily liquid and solid rocket propulsion, but it also includes the possible use of extra-terrestrial materials, and heating of propulsive fluids by solar radiation. The work can be conveniently divided into five parts: chemical propulsion research, high-energy propellants, advanced launch vehicle engine technology, advanced spacecraft engine technology, and an experimental high-energy engine. Chemical propulsion research includes analytical studies of future requirements, conceptual designs, and effort on ignition and combustion, fluid flow, gas expansion dynamics, materials, and heat transfer. High-energy propellants include the synthesis of new materials, determination of properties, and evaluation of their potential in small-scale tests.

In technology programs, the knowledge of the basic processes is exploited through the use of new devices and systems which can do a more thorough job than those in use today and where experiments on devices can establish sound design and operating criteria. This engineering type of effort is often classified around the types of propulsion systems to be used, such as advanced launch vehicle engines and advanced spacecraft engines. Special propulsive devices such as attitude controls, stage separators, retro-thrust, and others, are generally placed in one of the two categories. Oftentimes work in one category is applicable to the other. The experimental high-energy engine relates to a potential hydrogen-fluorine engine system.

EXPLANATION OF FUNDS REQUESTED:

Supporting research and technology

	1962	1963	1964
Chemical propulsion analysis, aerothermochemistry and materials	$2,144,000	$5,459,000	$7,525,000
High-energy propellants	1,744,000	2,818,000	3,306,000
Advanced launch vehicle engine technology	1,322,000	1,607,000	4,474,000

Advanced spacecraft engine technology.....	$1,793,000	$4,035,000	$5,618,000
Experimental high-energy engine...	---	300,000	1,574,000
Subtotal, direct R&D costs...	$7,003,000	$14,219,000	$22,497,000
Personnel costs.....	6,087,000	7,285,000	8,558,000
Operation of installations.....	4,074,000	3,365,000	4,020,000
Total costs.....	$17,164,000	$24,869,000	$35,075,000
Total personnel.....	806	827	900

Chemical propulsion, analysis, aerothermochemistry and materials

Research in chemical propulsion ranges from fundamental studies to experiments with propulsion devices. Analytical work is needed across the propulsion spectrum to tell what is needed and the characteristics of the propulsion system best suited to accomplish future missions. Such studies provide a framework of reference or decision for choosing technology programs of maximum benefit to the space effort. Analyses and experiments in combustion are needed to better understand combustion instability and how to control it. Combustion instability is an undesirable combustion oscillation that can rapidly destroy an engine. It has occurred during many development programs and to try to eliminate it by cut-and-try procedures is very costly.

During 1962 studies of pump cavitation in inducers at the Lewis Research Center revealed an unsteady pressure fluctuation that can cause oscillations in the thrust chamber. Analytical studies show that the vaporization of the least volatile propellant is a controlling factor in influencing oscillations. Work will be done in the coming year to experimentally verify this analysis and relate it to engine design parameters.

In other research, chemical reaction rates at high temperatures are studied to gain new insight into the chemical processes involved and lead to improvements in their use. In studies of expansion of hot gases thru large nozzles, the thermodynamic processes are not fully understood, especially when there is simultaneous flow of gas and solid particles and where there are large and rapid changes in pressure and temperature.

Work on materials will be continued to provide new and improved materials for advanced propulsion systems. The ever-increasing combustion temperatures encountered with high-energy propellants and the erosion characteristics of exhaust gases increase the problem of materials. Promising techniques under study are the use of high temperature materials that are cooled by radiation to outer space, the use of materials that ablate or sublime at high temperatures, and the use of a relatively cool film of gas adjacent to the engine walls.

High-energy propellants

The significant potential gains in propulsion may be exploited through research into new and more energetic chemical reactions. Efforts will be continued on searching for new energetic fuel and oxidizer combinations which have desirable chemical and physical characteristics. Also, evaluation of these materials in the laboratory and in small-scale combustion experiments will be continued. This process will allow a systematic evaluation and screening of a number of potential reactions and selection of the most promising ones for use in engine experiments. Some of the work in this area is directed toward improving the characteristics of present propellants, by means such as additives, in order to make them react spontaneously on contact or change their physical properties, such as gelling, in order to overcome sloshing or other problems associated with liquids in a zero-g environment. Work is also being directed toward more energetic chemicals, such as fluorine and fluorine compounds as oxidizers, as well as light metals and boron compounds as fuels.

During the past year, work was done on the properties of ozone difluoride as a possible additive to oxygen to make it ignite on contact with hydrogen. Following the stability work, ignition tests will be conducted over a range of conditions to evaluate this interesting concept. Also, work was conducted on the evaluation of oxygen difluoride and diborane as a high-energy propellant combination. This work showed high combustion efficiency in a small rocket motor. It is planned to increase the work in the coming year. Theoretical work has indicated a significant gain in performance can be achieved if beryllium is added to the hydrogen-oxygen combination. In the coming year experimental work will continue to determine the feasibility of using this tri-propellant combination.

In solid propellants a number of attractive propellants are emerging from Advanced Research Projects Agency (ARPA) programs in this area. The synthesis of these materials is only the first step in the development of useable propellants. The NASA work in solid propellants will bridge the gap between these new and interesting compounds and their use as practical solid propellants. Two hydrazine-borane compounds are under study at the Jet Propulsion Laboratory.

Advanced launch vehicle engine technology

As a result of studies undertaken during the past two fiscal years, and experimental verification of new concepts that were undertaken in fiscal year 1963, it is believed that extraordinary advances in the state-of-the-art of liquid rocket engines are imminent. The new concepts that are being actively investigated are multiple chamber engines, toroidal chamber construction, aerodynamic nozzles, secondary gas injection for thrust vector control, staged combustion cycles, and others. The new nozzle concepts will allow larger expansion ratios in a shorter length than the conventional DeLaval or bell type now in use. Each of these concepts is in a different phase of study. They will be pursued, on an individual basis, in fiscal year 1964

until the feasibility of each is evaluated. In fiscal year 1964 it is also anticipated that some of these concepts will be combined in order to test their compatability. Experimental models will be constructed and operation will be verified. In addition, continuation of work, which was started in fiscal year 1963 on high-chamber pressure operation, will also support post-development improvements of current liquid rocket engines.

In solid rocket propulsion, work is continuing on hot gas valving. The study of the mechanisms of secondary injection for thrust vector control, which will be useful for all applications of solid rockets, has been started and will be continued in fiscal year 1964.

Advanced spacecraft engine technology

A coordinated program involving many tasks in liquid rocket propuslion has been undertaken in order to create the capability for designing advanced spacecraft engines for future missions. The work has included efforts in positive expulsion devices, advanced pressurization systems, advanced valving techniques, work on high expansion ratio nozzles, advanced chamber and nozzle materials, coatings for refractory metals, and integrated engine concepts. In fiscal year 1964, work will be continued on those concepts which exhibit technical merit. Investigations will be conducted on components as well as in subsystem and system areas. Work will be undertaken on advanced attitude control systems, on instrumentation to better sense engine conditions, and on a flight-type engine monitor to control the engine during normal conditions and take corrective action during abnormal conditions. Work will also be done on advanced seals and new techniques to prevent leakage in valves and other flow components.

In solid rocket technology, high-mass fraction motors (where the proportion of inert weight is low) will be studied to increase case strength, resist the damages of the space environment, and provide better techniques for grain inspection. Work will be conducted on techniques for start-stop control for solid motors. Hybrid motors (one component liquid) will be investigated for their versatility in start-stop and thrust control.

Experimental high-energy engine

Fluorine-hydrogen gives the highest performance yet obtained experimentally with chemical reactions and has the potential for increasing payload weight for space missions and for performing difficult missions. Much experimental work has been done on this combination in thrust chambers and some work has been accomplished on pumps, but it remains to determine the feasibility of a complete fluorine engine suitable for flight. Studies in fiscal year 1962 and fiscal year 1963 will be augmented in fiscal year 1964 with the first phase of an experimental program leading to a small but complete engine system using this combination.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

AERONAUTICS

OBJECTIVE:

The objective of the NASA Aeronautics program is to conduct research to generate the technology for the design, construction, and operation of advanced aeronautical vehicles and missiles to support current and projected civil and military requirements and to maintain United States leadership in these fields.

SUMMARY OF RESOURCES REQUIREMENTS:

Funds	1962	1963	1964
Supporting research and technology.....	$ 996,000	$ 7,174,000	$ 9,910,000
Projects.....	1,958,000	10,904,000	6,290,000
Subtotal, direct R&D costs.....	$2,954,000	$18,078,000	$16,200,000
Personnel costs.....	15,639,000	17,468,000	18,959,000
Operation of installations.	10,180,000	8,444,000	9,967,000
Total costs.....	$28,773,000	$43,990,000	$45,126,000
Personnel			
NASA Headquarters.....	41	51	47
Langley Research Center....	956	1,007	1,083
Ames Research Center.....	393	372	378
Flight Research Center.....	443	407	388
Lewis Research Center.....	151	161	172
Total personnel....	1,984	1,998	2,068

Primary responsibility for the Aeronautical Research Program is in the Office of Advanced Research and Technology at NASA Headquarters. Support for the program is accomplished at the other locations listed above.

PROGRAM JUSTIFICATION:

The NASA aeronautical programs are being continued in the established framework of the theoretical and experimental research activity of the NASA Research Centers and is primarily an in-house effort.

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Substantial effort has already gone into research related to a supersonic transport, and NASA is cooperating actively with the Federal Aviation Agency and the Air Force in this program. A detailed research program is underway at the Langley, Ames, Lewis, and Flight Research Centers, and industry will soon have sufficient information to choose among several design concepts. In the joint FAA/NASA/DOD effort, it is the NASA's responsibility to provide the required research information and technical support to enable the industry to build a reliable, economical, safe and **publicly acceptable** commercial supersonic transport for the U.S. airlines.

The advanced area of research in aeronautics is the manned hypersonic air-breathing aircraft, which has the potential of providing hypersonic reconnaissance and bombing capabilities in the outer fringes of the atmosphere, as well as hypersonic transport capabilities. There is also an economic incentive to develop recoverable hypersonic air-breathing space boosters. Present studies indicate that the use of wings to provide maneuver capability during the ascent phase of flight will offer an operational versatility with regard to satellite rendezvous which cannot be obtained with conventional launch systems. The use of air-breathing propulsion for at least a portion of the flight offers potential advantages. The NASA has outlined a research program in cooperation with the Air Force to pursue vigorously the answers to these problems.

In the hypersonic speed range the X-15A has been highly successful and will continue to provide valuable research information during fiscal year 1964. During fiscal year 1963 a flight program using the X-15A as a test-bed for other space research programs was initiated. These space experiments will be carried piggy-back on X-15A flights and will continue through fiscal year 1964.

Studies of vertical and short take-off and landing (V/STOL) aircraft and helicopters will continue in fiscal year 1964. The highly successful test-bed program of the past two years has defined many of the problems inherent in the various VTOL concepts and has indicated certain concepts that show promise. Work will continue in fiscal year 1964 with particular emphasis on those types nearing military operational status. In the commercial field, STOL transports will be an important part of the overall future air-transport system, particularly when the supersonic transport becomes operational. STOL transports show promise for the dispersion of cargo and passengers from large major trunk-line airports. In addition, because of their capability for operating in and out of clearings and improvised landing strips, STOL aircraft can also carry cargo and transport passengers in remote areas and help to open up underdeveloped countries.

The helicopter is and will be a key vehicle in the military support and commercial transport systems of the future. The optimum utilization of its unique hovering capability has not been realized because of mechanical complexity, high cost, and operating difficulties: research and

development is then aimed at a target of more economical, reliable, and all-weather machines. A major aim of the work in fiscal year 1964 will be to provide information to enable the development of helicopters and V/STOL machines with flying and handling qualities and operational characteristics to permit all-weather operation.

In addition to the specific areas described above, research in basic areas that have application to aeronautical vehicles will be continued in fiscal year 1964. These include development of new materials for airframes that will be required to operate for long periods of time at high temperatures, and for high temperature air-breathing engine components which will increase engine efficiency and economy; basic studies of noise to gain a better understanding of its origin and means of alleviating it; basic studies of the boundary layer and boundary-layer control to reduce drag; studies of structural concepts to provide reliable light-weight structures; and fundamental studies of air-breathing propulsion cycles and engine components to increase efficiency and permit the design of efficient light-weight engines for V/STOL aircraft, supersonic transport, and hypersonic aircraft.

Advanced technical development in support of military and civil aircraft procurement is continually conducted in the NASA centers. This work is performed in cooperation with government-sponsored contractors at the request of cognizant government agencies when in the national interest. NASA will continue to provide this assistance in fiscal year 1964.

EXPLANATION OF FUNDS REQUESTED:

Supporting research and technology:

	1962	1963	1964
Aircraft aerodynamics.....	$130,000	$879,000	$1,907,000
Aircraft loads and structures.	762,000	1,610,000	2,450,000
Air-breathing propulsion.....	104,000	1,713,000	3,053,000
Aircraft operating problems...	(1,426,000) 1/	2,972,000	2,500,000
Subtotal, direct R&D costs.....	$996,000	$7,174,000	$9,910,000
Personnel costs.....	7,474,000	8,816,000	9,873,000
Operation of installations....	4,822,000	4,366,000	4,547,000
Total costs.....	$13,292,000	$20,356,000	$24,330,000
Total personnel.....	974	1,025	1,101

Aircraft aerodynamics

1/ Amount provided for direct project effort in Operation of Installations in 1962.

The technological feasibility and practical usefulness of flight in the atmosphere depend on the airflow over the vehicle because this determines its performance and control. With continual improvement in propulsion capabilities, aerodynamics remains a key research area for advanced aeronautical vehicles and systems concepts.

The research effort in aircraft and missile aerodynamics embraces speeds and Mach numbers from zero to orbital values. In the last two years, primary emphasis has been placed on theoretical and experimental investigations of the aerodynamic efficiency, stability, and control of advanced supersonic aircraft configurations and concepts. The remainder of available resources has been applied to the aerodynamic problems of take-off and landing, basic boundary-layer research, and flows over bodies at hypersonic speeds.

A large portion of the increase in funds for fiscal year 1964 will be expended on aerodynamic research to evaluate the practical possibilities of winged hypersonic flight utilizing air-breathing propulsion systems. The aerodynamic configurations for this purpose will have very large air inlets, bodies of very large volume, and abnormally small lifting and control surfaces. The critical aerodynamic problem is one of integrating the various elements into a unified whole which will provide suitable flight characteristics. Preparations must also be made during fiscal year 1964 for flight tests to validate ground-based data on heat transfer, pressure distributions, skin friction, and control effectiveness in order that the development of advanced hypersonic or orbital vehicles for the 1970 time period can be undertaken with technical confidence.

Included in these estimates, as in the past, are funds for wind-tunnel and other studies in direct support of the Department of Defense in its development of military aircraft and missile systems. Also provided for are basic studies of drag reductions by improvement of wing shape and by boundary-layer control to improve performance at supersonic speeds, and of novel high-lift devices to improve take-off and landing characteristics.

Aircraft loads and structures

The purpose of structures research is to obtain the information required to design airframe structures which will withstand operational loads and flight conditions with efficiency and reliability. This involves research studies of the loads associated with gusts, landing and maneuvers, studies of structural behavior under design conditions, studies aimed at more efficient structures, and studies aimed at preventing dynamic instabilities such as flutter.

Past research has produced notable advances toward definition of the maximum or critical loads to which an airplane can be subjected. However,

structures are prone to failure through repeated application of relatively small loads. Such fatigue failures have become more important as the design knowledge regarding critically large loads has increased. A modest expansion of fatigue research is underway during fiscal year 1963. A further expansion is required for fiscal year 1964 to cope both with problems of current aircraft and those of the supersonic transport.

Flutter is another important structural problem warranting increased level of effort during fiscal year 1964. More advanced configurations, such as the use of variable-sweep wings, represent critical problems which must be studied if flutter-free structures of minimum weight are to be attained. Another problem is the flutter of thin skin panels of aircraft. Such flutter is especially critical for supersonic aircraft whose exterior skin undergoes compressive stresses and incipient buckling as a consequence of aerodynamic heating.

Successful hypersonic aircraft are contingent on research to provide materials that can meet the very severe demands engendered by such vehicles. Needed materials include high-strength, low-weight alloys for storage and transport of liquid hydrogen, thin-guage refractory alloys for highly-stressed structural members, highly refractory materials which are reusable for leading edges and other stagnation locations, and more efficient insulating materials.

Air-breathing propulsion

Air-breathing propulsion research efforts are aimed for application to both military and commercial aircraft. Analytical and experimental research will be conducted on components (propellers, fans, air inlets and diffusers, jet exit nozzles and afterbodies) and/or complete systems (turbo-jets, turbofans, pulse jets, and new or unconventional propulsion concepts). Studies will also be conducted to determine airframe-propulsion system integration problems and to determine the most desirable engine cycles from the standpoint of overall vehicle performance. This research is a continuing effort and close coordination is maintained with other Government agencies and private industry to insure adequacy of the effort and elimination of undesirable duplication.

In the field of hypersonics, the basic problem in the propulsion area is that of determining how an air-breathing system should be designed, (1) so that the high specific impulses which are theoretically possible with such systems can in fact be obtained at speeds higher than those at which we have experience, and (2) so that it will operate with high efficiency over broad speed ranges. The NASA research efforts are closely coordinated with the Air Force. Investigations are being made to provide a basis for determining the feasibility of air-breathing propulsion systems for hypersonic vehicles. Particular attention is being given to propulsion system and mission analysis, hypersonic inlets, supersonic combustion, and

the exhaust nozzle recombination problem.

Realistic simulation on the ground of the actual environment to which hypersonic vehicles will be subjected is another problem: ground and flight-test facility requirements for conducting experimental research and for the eventual development and qualification of hypersonic air-breathing systems will also be investigated.

Aircraft operating problems

Research in this area is directed toward improving all phases of aircraft operations in order to increase the safety of flight. Technical objectives include basic and applied research on aircraft flying and handling qualities, operational techniques in landing and takeoff and under all weather conditions and in ground and airborne environments, and work on instrumentation directly related to the safety of flight. This area also includes the NASA work in the field of sonic boom and aircraft noise.

In many of these areas the work is closely coordinated with the FAA, the United States Weather Bureau and the Department of Defense. An analytical and experimental program to establish the effects of runway slush on aircraft operations has been conducted with the FAA, and extensions of this work using the Langley Research Center's Landing Loads Track will be continued in fiscal year 1964. The joint USAF-Weather Bureau-NASA National Severe Storms project will receive continued support with personnel and funds. Sonic boom studies have included NASA analytical work and wind tunnel tests, and joint programs with the USAF and the FAA to measure the intensity of booms reaching the ground from various types of aircraft and to assess damage claims resulting from such occurrences.

In fiscal year 1964, an increased emphasis will be placed upon studies of engine noise. Basic studies will be initiated in the determination of flying and handling qualities for high-speed, low-altitude flight to support the DOD F-111 (TFX) program. Variable-stability equipment will be purchased in fiscal year 1964 for the NASA variable-stability airplane (a Lockheed Jetstar) which is being purchased with fiscal year 1963 funds. This research vehicle will be used at the NASA Flight Research Center to study, by simulation in flight of the aerodynamic and inertia characteristics of advanced aircraft configurations, the requirements for adequate flying and handling qualities. Results from these and similar studies using NASA ground-based simulators will feed back into the wind tunnel programs to modify the aircraft aerodynamics to achieve optimum and safe flight characteristics.

PROJECTS

X-15A research aircraft

	1962	1963	1964
Aerodynamics.....	(29,000)	$35,000	$70,000
Loads and structures.....	(53,000)	60,000	140,000
Propulsion.....	(10,000)	10,000	40,000
Operating problems.....	(447,000)	5,475,000	650,000
Subtotal, direct R&D costs.....	($539,000)1/	$5,580,000	$900,000
Personnel costs.....	3,470,000	3,370,000	3,280,000
Operation of installations	2,225,000	1,459,000	2,525,000
Total costs.....	$5,695,000	$10,409,000	$6,705,000
Total personnel.	410	360	327

The X-15A research airplane, which was funded under Operation of Installations in fiscal year 1962, is the latest vehicle in a long series designed to investigate manned high-speed, high-altitude flight. Specifically, the X-15A was designed to obtain fundamental research information at velocities of 6,600 feet per second (4,500 miles per hour) and at altitudes up to 250,000 feet. Since aerodynamic heating was one of the prime research areas to be explored, the X-15A was designed to withstand structural heating rates of 30 BTU per square foot per second and maximum structural temperatures of 1,200°F.

The first X-15A flight, on June 8, 1959, was a glide flight planned to check airframe-system characteristics. The first powered flight was on September 17, 1959. Since that time more than 70 flights have been made to investigate aerodynamic and structural heating, structural dynamics, supersonic and hypersonic aerodynamics, piloting aspects, and advanced aircraft systems. Examples of these systems are reaction controls with automatic stability augmentation, adaptive flight control systems, ground-based energy management displays and, later, airborne energy management systems, and man-rated high-thrust rocket-propulsion systems capable of being throttled. During the course of these investigations, a velocity of 4,093 miles per hour was achieved on November 9, 1961, and a slightly higher speed of 4,104 miles per hour was attained on June 27, 1962. On April 30, 1962, the design altitude was essentially achieved in a flight to 246,700 feet. Two and a half months later, on July 17, 1962, this was exceeded in a flight to 314,750 feet. All of these flights were developed by the NASA Flight Research Center and flown by NASA, Air Force and Navy pilots to provide a maximum amount of research information in the areas listed above.

1/ Amount provided for direct project effort in Operation of Installations in 1962.

As some of the basic research programs will be completed in fiscal year 1963, attention is being given to other areas already partially explored, such as cockpit instrument displays, boundary-layer flow characteristics, noise, skin friction at high Mach and Reynolds numbers, and structural-panel-flutter tests. In addition, a follow-on research program consisting of advanced aeronautical and space science experiments has been approved by the NASA-USAF-USN Research Airplane Committee to use the X-15A's proven capabilities. Of the 15 experiments in the follow-on program, 10 are space-oriented. These experiments capitalize on the ability of the X-15A to provide on-the-spot pilot input in the conduct of the experiment and return the equipment to the ground for detailed evaluation and adjustment or correction of deficiencies. Included in the many experiments being prepared for the follow-on program are ultraviolet stellar photography, infrared exhaust signature, letdown computer, detachable high-temperature leading edges, and horizon definition. Except for the monies required for operation of the X-15A in its basic program, which are funded here, funds for special equipment or any required aircraft modifications to perform the additional experiments will be funded by the group responsible for the experiment.

The fiscal year 1964 program is planned to accomplish most of the objectives outlined above. It is presently planned to conclude the remainder of the program by the end of fiscal year 1965. This plan may, however, require modification because of the X-15 landing accident in November 1962, which severely damaged one of the three aircraft.

Supersonic transport

	1962	1963	1964
Aerodynamics	$1,842,000	$ 492,000	$ 700,000
Loads and structures	(195,000)1/	886,000	590,000
Propulsion	(104,000)1/	442,000	1,300,000
Operating problems	116,000	2,467,000	1,200,000
Subtotal, direct R&D costs	$1,958,000	$4,287,000	$3,790,000
Personnel costs	2,690,000	3,246,000	3,580,000
Operation of installations	1,803,000	1,576,000	1,798,000
Total costs	$6,451,000	$ 9,109,000	$9,168,000
Total personnel	344	375	391

1/ Amount provided for direct project effort in Operation of Installation in 1962.

In June 1961, a program of assistance to the aircraft industry was initiated by the Federal Aviation Agency, Department of Defense, and the NASA. It was directed toward the possibility of developing an economically

competitive, supersonic commercial air transport. NASA's role is to produce the research information necessary for the project. The major goals of the program are the maintenance of U. S. leadership in aeronautics, public acceptability with regard to factors such as noise and sonic boom, and satisfactory safety and reliability characteristics.

The concentrated research effort underway at the NASA Research Centers has brought the project to the stage where technical feasibility has been demonstrated and industry will soon have sufficient information to choose among several design concepts. Fiscal year 1964 effort will be devoted to the solution in depth of several problems. A new engine is needed, fuels, bearings and lubricants must be improved, aerodynamic efficiency must be improved, dynamic stability and control problems must be solved, and the noise and sonic boom problems need added work. In addition, basic studies of mechanical and thermal fatigue, fracture mechanics, and prediction of long-time physical properties of materials, and current investigations to survey the effects of operational conditions on ductility and static strength of sheet materials will be continued.

Funds are required for complete wind-tunnel models of considerable sophistication for dynamic and static tests of the promising design concepts, as well as large-scale inlets, exits, and control systems. Funds are also required in fiscal year 1964 for instrumentation for flight studies of supersonic transport operations using available aircraft to simulate the supersonic transport.

Vertical/short take-off and landing (V/STOL) aircraft

	1962	1963	1964
Aerodynamics	($ 89,000)	$ 562,000	$ 820,000
Loads and structures	(4,000)	9,000	55,000
Propulsion	(21,000)	136,000	175,000
Operating problems	(68,000)	330,000	550,000
Subtotal, direct R&D costs	($182,000)	1/ $1,037,000	$1,600,000
Personnel cost	2,005,000	2,036,000	2,226,000
Operation of installations	1,330,000	1,043,000	1,097,000
Total costs	$3,335,000	$4,116,000	$4,923,000
Total personnel	256	238	249

1/ Amount provided for direct project effort in Operation of Installations in FY 1962.

Through research undertaken in the past few years, it has been shown that vertical or very short take-off and landing aircraft flight is practical

for various purposes. The NASA V/STOL flying test bed program conducted at the Ames and Langley Research Centers has provided the first insight into the flying qualities this class of aircraft must have if it is to be operationally useful. It is now possible to draw general conclusions as to the missions best suited to the several types and to examine each within the scope of the likely missions.

However, none of the vehicles studied in the current program, which will be completed in fiscal year 1964 has proved more than marginally flyable. Each one has exhibited many problems in aerodynamics, operation and performance, which must be overcome if this class of vehicle is to become practicably useful. These flight studies have confirmed that operation of V/STOL aircraft will be more demanding and more difficult than operation of conventional aircraft. Whole new concepts in control and stabilization and pilot information to enable safe, all-weather operation for the helicopter and other V/STOL types must be developed through continued simulation and flight test of more advanced vehicles. Planned studies with the Vertol YHC-1A helicopter, recently modified to provide variable stability and control characteristics, the Lockheed YH-51H non-articulated rotor helicopter, and the C-130 boundary-layer control STOL airplane should produce valuable information in these areas. Investigation in future years of such new aircraft as the Vought XC-142A tilt-wing, General Electric XV-5A lift-fan, and Brequet 941 deflected-slipstream-STOL should clarify most of the requirements of future operational civil and military V/STOL aircraft.

The V/STOL aircraft is even more dependent on the characteristics of its various components than is the conventional aircraft. A very small percentage change in propulsive efficiency of an airplane propeller, a fan or a helicopter rotor can make a very large difference in the vehicle payload. A similar effect results from a very small change in structural weight, wing maximum lift, flap lift increment, or induced drag. Work in fiscal year 1964 will involve more detailed study of several V/STOL types, their components, the manner in which their operation should be carried out for maximum utilization, and refinement of detail to reach maximum efficiency.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 ESTIMATES

TRACKING AND DATA ACQUISITION

OBJECTIVE:

The objective of the NASA tracking and data acquisition program is to provide the operational ground instrumentation support required by all NASA flight projects.

SUMMARY OF RESOURCE REQUIREMENTS:

Funds	1962	1963	1964
Supporting research and technology	$ 9,097,000	$12,600,000	$17,000,000
Network operations	41,853,000	55,510,000	80,500,000
Equipment and components	16,352,000	67,732,000	134,000,000
Subtotal, direct R&D costs	$67,302,000	$135,842,000	$231,500,000
Personnel costs	7,678,000	11,994,000	15,221,000
Operation of installations	8,852,000	11,945,000	14,887,000
Total costs	$83,832,000	$159,781,000	$261,608,000

Personnel			
NASA Headquarters	77	95	118
Goddard Space Flight Center	756	1,028	1,101
Langley Research Center	9	64	71
Marshall Space Flight Center	11	42	49
Flight Research Center	28	38	38
Wallops Station	109	125	140
Western Operations Office	17	42	42
North Eastern Office	---	1	2
Manned Spacecraft Center	---	---	9
Total personnel	1,007	1,435	1,570

The NASA Headquarters Office of Tracking and Data Acquisition has the responsibility for tracking and data acquisition for all flight missions. Elements of the program are performed by the NASA installations listed above, either directly or through contractors, and by the Jet Propulsion Laboratory.

PROGRAM JUSTIFICATION:

Every space flight mission, whether rocket development, scientific satellite, space probe, or manned spacecraft, is undertaken to gather information. The critical element in getting such information back to the managers of the mission is the worldwide network of tracking and data acquisition stations. These stations, linked together and to the NASA data centers by a communications net, receive and record telemetered and voice data, track the spacecraft in order to determine its position, and transmit command signals as required. Each flight mission has its own specific requirements for tracking accuracy, amount and kind of spacecraft-gathered information to be transmitted, command signals to be received, and location of ground instrumentation to perform these functions. The NASA networks, supplemented as required by cooperating stations, are a flexible and responsive tool used to fulfill the requirements of the flight missions.

EXPLANATION OF FUNDS REQUESTED:

	1962	1963	1964
Supporting research and technology			
Integrated systems study, development and test.....	$1,458,000	$1,650,000	$2,000,000
Improvements to existing systems.....	6,257,000	8,732,000	11,500,000
New systems development.....	1,382,000	2,218,000	3,500,000
Subtotal, direct R&D costs....	$9,097,000	$12,600,000	$17,000,000
Personnel costs.....	3,065,000	1,990,000	2,519,000
Operation of installations.....	3,565,000	1,848,000	2,321,000
Total costs.....	$15,727,000	$16,438,000	$21,840,000
Total personnel.....	402	222	264

Proper tracking and data acquisition support of the NASA space-flight programs requires adequate, reliable and fieldworthy ground instrumentation for the diverse projects planned for the future. With the increased number and complexity of planned spacecraft, existing instrumentation systems will have to be augmented either by increasing the capabilities of existing stations or by establishing new stations. Such augmentation can involve the addition of existing subsystems, the incorporation of improvements to existing subsystems, or the installation of new subsystems having capabilities greater than those currently available.

To be in a position to provide the ground instrumentation systems support for future missions, it is necessary to plan and execute an

integrated development program with the aim of obtaining instrumentation subsystems superior to those presently available. Such a program must consider the following: anticipated tracking and data acquisition requirements for future missions and the dates of such requirements; the present state-of-the-art; ground instrumentation capabilities available and planned by NASA, the Department of Defense, the general scientific community, and foreign organizations; and the engineering feasibility of improvements in existing or proposed instrumentation systems. In the execution of this development effort, existing instrumentation systems are the basic building blocks about which the program is developed.

Prior to the initiation of a development program, studies must define the tracking and data acquisition mission requirements for the planned spacecraft missions. In addition, studies define instrumentation system parameters capable of meeting the developed requirements. Conceptual instrumentation systems are analytically evaluated to determine the most promising avenues of approach, and particularly, their possible use in support of future NASA flight programs.

Studies of ground instrumentation systems required for the Gemini and Apollo projects have been initiated and will be continued to define the optimum system parameters necessary to support these missions. Additional studies of proposed and conceptual ground instrumentation systems for support of earth satellites, lunar and planetary probes, and applications satellites are also under way; these studies cover the functions of tracking, command, guidance, communication, data handling and processing, orbit computation, and data display. The system studies define the avenues of approach open for improvements in existing systems. Studies conducted to date indicate that existing systems can be substantially improved by incorporating new techniques.

The sensitivity of data acquisition receiving systems will be improved by incorporation of the latest parametric and maser amplifiers into the operational systems. Over the past several years, development work has been under way on these amplifiers and the applicability of these devices to tracking and data acquisition systems has been demonstrated. However, deficiencies in the operational utilization of these devices do exist. The available parametric and maser preamplifiers do not yet have adequate bandwidth or gain stability to meet the operational requirements of future spacecraft missions, and continuing development effort will be needed in fiscal year 1964.

Electronic tracking systems have been and will continue to be used by NASA as the primary means of determining spacecraft position. Tracking systems developed and used to date include precision radars, interferometers, and range and range-rate systems. These systems are under constant review to determine their suitability to the mission requirements and to plan improvments or modifications to increase their capabilities to the required level. Improvements planned include the development and test of

doppler or rate measuring equipment for radar tracking stations, continued development of antennas for the recently assigned space frequency bands, ranging systems of greater accuracy for planetary missions, and the development of new and more efficient modulation techniques. Studies of propagation anomalies due to the heterogeneity of the transmission media will permit the development of improved compensation techniques and devices that will increase tracking systems accuracy. The transmission media to be considered must include the earth and planetary atmospheres, interplanetary plasmas, rocket exhaust, and plasmas surrounding re-entering spacecraft.

In addition to electronic system improvements, development efforts will be continued on optical tracking systems, with particular emphasis on lasers, to determine the applicability of these new devices and techniques to tracking systems. Laser tracking systems potentially offer an improvement of angular tracking accuracy by a factor of 10. Ranging techniques using coherent sources of this type will also be investigated to determine their possible advantages in meeting the requirements of planned spacecraft missions. Photo-multiplier techniques will be investigated as a possible means of improving the range or sensitivity capability of optical tracking systems.

The development of a first-generation automatic data reduction system is nearing completion. During this development, possible changes have been outlined that will improve the basic system by broadening its applicability to include the requirements of the new spacecraft. With the advent of the new wide-band telemetry systems required by and planned for future spacecraft, pulse code modulation techniques will be employed to a greater extent than in the past. This will necessitate the development of data processing systems compatible with this technique as well as with the analog systems that are currently being employed.

Development efforts to improve orbit computation techniques that incorporate data from the new tracking methods will be continued. Since the accuracy of orbit determination is a function of the trajectory being computed, the tracker employed, and the mathematical approximations used, improved computational techniques are always necessary to obtain ephemerides of spacecraft to the precision required. For example, highly eccentric orbits are much more difficult to determine precisely than are circular orbits. The computation techniques employed in these two cases differ greatly. For this reason each proposed orbit must be analyzed, considering the variables of tracking and mathematical approximations, to determine and develop the appropriate computational technique.

New command systems have been developed for the first generation of the large complex satellites like the Orbiting Astronomical Observatory, Orbiting Geophysical Observatory and Orbiting Solar Observatory. Future spacecraft will require an even greater command repertoire which can be accommodated by expanding the word length or the tone system as appropriate. These future spacecraft will also require more extensive realtime data handling and control systems, both on-board and in the supporting ground

systems. In addition, the increased ranges and command word lengths will require the development of more sensitive on-board command receivers and of more powerful ground-based transmitter systems.

The tracking and data acquisition stations of NASA use a large variety and number of antennas for communicating with spacecraft. These antennas are one of the basic elements of the NASA ground instrumentation system. Need for improvement in nearly all of the subsystems of these antennas has been demonstrated as a result of several years of operational experience. Angle data takeoff systems are one example of units that must be improved to increase the accuracy, reliability and versatility of these antennas. New multi-purpose feed systems capable of accommodating several frequency ranges will be developed to allow the basic antennas to support, easily and quickly, a variety of flight missions. The feed systems, in combination with the drive or servo system, largely determine antenna performance characteristics. In addition, structural improvements of the large reflector antennas will be undertaken to increase the frequency range over which efficient operation can be realized. Analytical and experimental measurement programs will obtain the necessary correlation between electrical and mechanical measurements to provide design data for the construction of newer and larger antennas.

In any instrumentation project, standards must be available to determine the absolute accuracy of the measurements. As new systems are evolved or as existing systems are improved, better calibration units and techniques must be developed. One goal of this development is the reduction of operator errors through the automation of the necessary calibration functions.

In response to the new techniques being applied in flight projects, new tracking and data acquisition systems must be developed. Without proven ground support systems, new space missions cannot meet their developmental or experimental goals. In some cases, new systems must have capabilities that do not exist in any current instrumentation. For example, the range and range-rate systems developed over the last several years can now provide orbital information previously unavailable from any source. New systems are developed both to meet new mission needs and to permit new missions to be planned with a minimum of technical constraints. At the same time, these systems can be designed for high reliability, operational simplicity, and ease of maintenance.

For example, a promising new tracking system under development has the traditionally large ground transmitter and receiving systems replaced by a simple, possibly unattended, ground unit which responds to a vehicle-borne interrogator. In this system the usual roles of the ground-and vehicle-based units are reversed. The development of the vehicle-borne portion of this system has many technical challenges. It will employ the latest modulator construction techniques and solid state electronic units to reduce to a minimum the size, weight and power consumption while maintaining a maximum of design reliability. The ground-based portion of the system will be developed to be extremely simple, readily transportable and capable

of unattended operation. With such easily transportable ground units, the system flexibility of ground station location and operation will permit far greater tracking coverage and hence more varied launch azimuths.

Network operations	1962	1963	1964
Satellite network.....	$ 9,374,000	$11,760,000	$17,000,000
Manned flight network.....	15,183,000	16,260,000	24,000,000
Deep space network.....	6,743,000	7,860,000	10,000,000
Launch area instrumentation.....	500,000	3,850,000	5,000,000
Aerodynamics test range.....	---	450,000	800,000
Network communications.....	8,393,000	10,760,000	16,000,000
Data processing and handling....	1,660,000	4,570,000	7,700,000
Subtotal, direct R&D costs....	$41,853,000	$55,510,000	$80,500,000
Personnel costs.....	$ 4,613,000	10,004,000	12,702,000
Operation of installations.....	5,287,000	10,097,000	12,566,000
Total costs.....	$51,753,000	$75,611,000	$105,768,000
Total personnel.....	605	1,213	1,306

Basically, three space flight networks are used in NASA programs: the satellite, manned, and deep space networks. In addition, there is an aerodynamic test range at Flight Research Center. Launch area instrumentation, network communications, and data processing are other categories of costs necessary to the successful operation of networks.

Satellite network

The stations in this network provide the tracking and data acquisition support for unmanned scientific and application satellites. There are thirteen electronic stations operated by the Goddard Space Flight Center and twelve optical stations operated by the Smithsonian Astrophysical Observatory. The electronic stations provide the principal tracking and data acquisition support to the program while the optical stations, as described below, provide a more specialized service generally directed towards precision orbital tracking.

The electronic stations provide tracking data which is used to compute predictions for the data acquisition antennas so they can be pointed at the satellite. These stations also provide data on spacecraft position in relation to time so that measurements made by experiments in the satellite can be related to its position relative to the Earth at the time of measurement. The data acquired by the stations recording telemetry from the spacecraft include scientific measurements made by instruments on the satellite; engineering information concerning performance of the satellites such as

temperatures, battery voltages, and status of on-board systems; and wide-band data such as the cloud cover photographs obtained from the meteorological satellites. For tracking, these stations use radio interferometers to provide a measurement of spacecraft angular position with respect to the station in relation to time. These interferometers are activated by a radio signal transmitted from the spacecraft. In this system, the telemetry transmitter is used in the tracking of the satellite; being a radio system, it can operate without weather constraints. Supplementary tracking to meet the needs of satellites in highly eccentric orbits is being provided by the range and range-rate system developed during fiscal years 1962 and 1963.

All stations are capable of receiving and recording the relatively narrowband telemetry which indicates the status of systems on the satellites and carries the scientific data from the smaller scientific satellites such as those launched by Scout and Delta. The data acquisition capability of this network is being expanded to handle the more sophisticated and accurate telemetry systems required by the more complex satellites which will be launched during fiscal year 1964. Additional capability is also planned to handle the increased number of satellites which are being placed in orbit.

In addition, large data acquisition facilities are being established to handle the increased bandwidth requirements of the Orbiting Astronomical Observatory, Eccentric Geophysical Observatory, Polar Orbiting Geophysical Observatory, and Nimbus spacecraft. Such facilities, using 85-foot diameter parabolic antennas, are now in operation at Fairbanks, Alaska, and under construction at Rosman, North Carolina. An additional antenna at Rosman, North Carolina, and a new antenna site in the Pacific area are under construction.

The optical stations use Baker-Nunn satellite tracking cameras which provide certain satellite tracking measurements more accurately than do the electronic systems. Data obtained from these stations can show extremely small variations and perturbations in the orbits of satellites. These data are used to determine the density and variation of density of the upper atmosphere, the gravitational field of the Earth, the shape of the Earth, and more precise distances between continents and islands on the Earth. Only certain satellites of generally simple shapes and orbiting at proper altitudes are useful for these precision tracking studies. Although the optical stations are limited in the total tracking support they can give since they can track only during periods of clear skies and at dawn and dusk when the satellite is in sunlight and the camera is in darkness, they are providing vital data concerning behavior of the Earth's atmosphere and factors affecting the shape of the Earth.

The stations are operated under several different arrangements. Those in the United States and in certain foreign countries are operated under commercial contracts. Other stations are operated by foreign government agencies in close liaison with NASA.

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The fiscal year 1964 flight program includes the large scientific satellites which have on-board data storage and require high-speed communication circuits, and the smaller but very complex scientific satellites which do not have data storage capabilities and require ground stations located around the Earth to track, command, and record the data acquired by experiments carried on board the spacecraft. All stations will require additional staffing support to meet these programs. The Rosman, North Carolina, facility will become operational early in fiscal year 1964 and will require full staffing. The Pacific area facility will become operational late in fiscal year 1964 and will require a build-up of operating personnel to full capability by the end of the year.

Manned space flight network

The network consists of 16 prime stations that collect and communicate real-time information concerning the location of the manned spacecraft, status of the equipment onboard, and, most important, the condition of the astronaut. This information must be immediately and continuously available to the control center so that corrective action can be taken if emergencies should arise during the mission.

To meet these requirements, key stations have tracking capabilities that allow real-time orbital determinations. All stations receive telemetry data concerning the condition of the astronaut and the functioning of systems in the capsule and, if necessary, transmit the necessary commands required to complete a successful mission. In addition, all stations have radio voice communications with the astronaut. Data received by the stations are transmitted in real-time to a processing and computation center and then to the manned space flight control center for display. It is this information upon which the mission director must rely in his management of the flight.

NASA has overall responsibility for network operation, station modification, and implementation. Five stations are operated by a commercial company under contract to NASA, nine are operated by elements of the Armed Services, and two are operated under an inter-governmental agreement by the Weapons Research Establishment of the Australian Department of Supply.

The Gemini flight program requires expanded communication and telemetry systems to provide full operational coverage. This coverage is being met by the addition of pulse code modulation telemetry receiving and command systems at ten sites. Additional operating personnel will be required to operate and maintain this equipment and to man the stations for the long-duration flights which are planned during this period.

Deep space network

The stations in this system are used to obtain tracking and telemetry data from, and to send commands to, space vehicles at lunar and interplanetary

distances. Because of the extreme distances and the modest spacecraft powers involved, large high-gain parabolic antennas are needed, along with the most advanced receiving and signal detection equipment available.

Stations in this network are spaced approximately every 120° of longitude around the world so that any space vehicle more than eight thousand miles from the Earth will be visible to at least one of the stations at all times. In addition, there is a mobile tracking station which can be moved to the appropriate location to provide "gap filling" tracking data and acquisition information during the critical launch phase. This station provides early trajectory data that must be obtained within a short period after launch so that the relatively narrow beams of the prime stations' antennas can be pointed in the proper direction and acquire the spacecraft. The stations are operated by commercial contractors and foreign government agencies under the direction of the Jet Propulsion Laboratory.

The tasks of tracking, maintaining radio contact, and collecting and processing information received from the Ranger and Mariner spacecraft to be launched during this period will require additional personnel to man expanded shifts and to maintain the tracking and data acquisition equipment which is becoming more and more complex.

Launch area instrumentation

Launch area instrumentation supports numerous sounding rocket programs, testing of the Scout vehicle, flight testing of spacecraft components, and various research programs such as RAM, Trailblazer, and the re-entry heating projects. (See Electronic Systems and Space Vehicle Systems program narratives).

One important operational job is the optical tracking of re-entry capsules which requires both field and laboratory operational equipment to collect and process data. The re-entry area varies with the various booster combinations and trajectories. To provide the necessary coverage, therefore, mobile optical units housed in vans must be positioned in specific areas for each launch. This type of operation requires ballistic cameras, communication equipment, X-band telemetry, and peripheral electronic instrumentation. Other facilities used to meet the mission requirements include permanent installations for radar tracking, telemetry, communications and data processing.

Launch area instrumentation is located principally at Wallops Station Virginia, with supporting coverage by mobile equipment located along the eastern seaboard between North Carolina and Delaware. Additional support is furnished by the Bermuda Station and by a range ship operating off Wallops Island and in the vicinity of Bermuda. This ship also participates along with specially instrumented aircraft in recovery operations of specific payloads. Launch operations are also carried out at Fort Churchill, Canada, in support of probes into the aurora and other atmospheric and space phenomena

associated with the high latitudes. Complete launch, tracking, and data acquisition instrumentation is available for these missions.

Operations are carried on by NASA and contractor personnel to provide all necessary installation, checkout, calibration and operation of instrumentation prior to and during all flight missions.

Aerodynamic test range

The aerodynamic test range, sometimes referred to as the "High Range," is the group of stations required to support the developmental and experimental flights of the X-15 airplane. The High Range provides coverage of the X-15 flights to assure accomplishment of the desired missions. This coverage includes initial guidance and vectoring of the launch airplane (B-52), monitoring of the initial climb of the research airplane, monitoring of the flight path for emergency landing area choices, escort plane rendezvous information, communications, space-trajectory data, and real-time data monitoring capability. The range consists of three stations: a main terminal station at the NASA Flight Research Center, and two uprange stations near Beatty and Ely in Nevada. Each site is equipped with instrumentation radars and recording systems, plotting boards, velocity computers, telemetry systems, data monitoring systems, timing and communications. The Flight Research Center station is presently operated by NASA personnel, but will be contractor-operated next year. Contractor sources provide necessary checkout and calibration of equipment prior to flight missions and operate the two up-range sites.

Network communications

The tracking and data acquisition stations must have communications circuits to tie them into the control centers. Summarized data concerning the status and operation of the space vehicles is sent from the stations to control centers so that decisions may be made concerning future operations of the vehicles. The majority of the present communications circuits consist of teletype links. Voice channels permit the manned space flight stations to provide critical "hand-over" tracking instructions from station to station and to pass emergency instructions from the control center.

In addition to present communication facilities at Goddard Space Flight Center with subcenters at Jet Propulsion Laboratory and the Smithsonian Astrophysical Observatory, the establishment of the manned space flight communication center at Houston will result in a greatly expanded communications network. The Gemini flights alone will require more than twice as much communication service as is being provided in support of Project Mercury. Bandwidth requirements for transmission of data by land lines and microwave systems are increasing as it becomes necessary to handle large volumes of data for real-time and post-time processing, reduction, and analysis. Wideband data lines for housekeeping and scientific information will be available for the large satellites such as the Orbiting Geophysical Observatory, Polar

Orbiting Geophysical Observatory, and Nimbus.

Commercial common carriers, both foreign and domestic, provide the majority of NASA communications services but other government agency lines are used when available. Careful engineering and management is necessary to assure reliability, effective alternate routing, and maximum utilization of the leased circuits. During fiscal year 1964, it is estimated that NASA will lease some 496,000 miles of voice and teletype circuits; some 251,000 miles are presently being used.

Data processing and handling

The majority of data acquired from the NASA flight projects is processed into a form useful to the experimenter at the NASA Center responsible for the flight mission; it is necessary, however, to supplement this in-house effort with the contractor services. The level of this additional support is a function of the flight schedule and the available in-house capability. Additional contracted data processing services will be necessary in fiscal year 1964 to handle the extra load generated by the increased number of space vehicles planned for launching during the year, especially the large satellites. For example, several equipment complexes to process pulse code modulated information will be put into operation during fiscal years 1963 and 1964 at the Goddard Space Flight Center to cope with the increased data processing workload. The staff to perform the necessary equipment alignment, checkout, calibration, and operation for final processing of the data will be contractor personnel. In other cases, raw data from the stations will be reduced to scientific and engineering terms at contractor-owned and-operated facilities.

Equipment and components	1962	1963	1964
Satellite network.....	$ 3,940,000	$10,500,000	$22,000,000
Manned flight network.....	10,253,000	42,702,000	84,000,000
Deep space network.....	---	7,506,000	10,000,000
Launch area instrumentation.....	892,000	1,400,000	3,000,000
Aerodynamic test range.....	---	710,000	1,000,000
Communications network.....	967,000	2,214,000	4,000,000
Data processing and handling....	300,000	2,700,000	10,000,000
Subtotal, direct R&D costs....	$16,352,000	$67,732,000	$134,000,000
Personnel costs.....	1/	1/	1/
Operation of installations.....	1/	1/	1/
Total costs.....	$16,352,000	$67,732,000	$134,000,000
Total personnel.....	1/	1/	1/

1/ Personnel and operations costs included under Network operations.

Maintenance, improvements and augmentation of tracking and data acquisition equipment and components to meet the requirements of the flight missions are a continuing program requirement. Requirements of each category are discussed below.

Satellite network

The present network is continuously being improved to meet advanced requirements, and will be modified to provide added capacity to handle extremely high data output rates from the newer satellites. This class of satellites, including the Oribiting Astonomical Observatory, Eccentric Geophysical Observatory, Polar Orbiting Geophysical Observatory, Nimbus, Relay and Syncom, must transmit large amounts of data. The conversion of satellite onboard data recording systems from analog to digital techniques will enable the satellites to record and store large amounts of data which will be transmitted to earth at specified stations. This type of operation reduces the number of times that the interrogation of the satellite for data is initiated, but vastly increases the amount, or density, of data that must be received in a given time period.

Basic requirements for improved data acquisition and command capabilities are dictated by increased sophistication of spacecraft telemetry. Optimum operational control of these satellites requires earlier and more reliable acquisition of the telemetry signals and higher power command antennas. To meet this requirement, the network stations are being equipped with tracking antennas capable of quick acquisition of satellite signals and tracking in an automatic mode throughout the pass of the satellite. Slaved to telemetry antennas will be special antennas for transmitting command messages to the satellites. These modifications and additions will result in improved data acquisition and command capabilities for many satellite projects. The addition of self-tracking antennas commences in fiscal year 1963 and it will be carried on throughout fiscal year 1964.

Range and range-rate systems are planned for the network and will be purchased in fiscal year 1964. These are high precision tracking systems needed to determine, within very small limits, spacecraft velocity and location in space while at high apogees. The coherent doppler measurement which is utilized to determine velocity in these systems has a great advantage over pulsed systems. Also, coherent systems allow extreme narrowness of the frequency bands used, thus reducing the power requirements.

Pulse code modulation (PCM) telemetry data handling equipment will be installed in all of the NASA primary data acquisition stations and will become standard operating equipment. The primary characteristic of PCM is its flexibility. It will respond to the wide frequency range and handle the great variety of information patterns required by the flight experiments. It can be programmed to select any one of several predetermined formats and provide outputs in the proper format for direct computer entry or driving "quick-look" and other type displays. It is fabricated in module form and

can be quickly repaired by module replacement.

Additional equipment needed for the support of the various programs planned for fiscal year 1964 includes special purpose RF equipment without which some of the more special satellites would have to fly without complete network telemetry coverage. Mobile telemetry receiving units, assembled in trailers and designed to be air-transportable, permit highly flexible data acquisition operations without requiring the construction of an entire new ground facility. Certain launch and injection conditions require specialized coverage which can best be met in this fashion. Additional data handling, processing and reduction equipment will be purchased and installed at various locations. As the number of satellites covered and the amount of data gathered from each new satellite increases, this new equipment will prevent a breakdown in flow of information to the experimenters. Such equipment includes magnetic tape recorders, both analog and digital; consoles, screens, and associated equipment; simulation equipment; readout equipment; timing equipment and tests and maintenance equipment needed to maintain and operate the various station subsystems.

Manned flight network

The 16-station manned flight network, originally designed to support the 3-orbit Mercury flights, was equipped during fiscal year 1962 to meet the needs of the one-day flights and is being further modified during fiscal year 1963 to meet the Project Gemini requirements. Ten of the stations are being equipped with PCM telemetry receivers, on-site data processors, and new command encoding and transmitting systems. This phase will be completed in fiscalyear 1964 and the major step toward installing the Apollo-required systems will begin.

For lunar capability missions it will be necessary to reverify, or to conduct, vehicle check-outs after insertion into the parking orbit and prior to injection into the lunar transfer trajectory. This verification of the electrical and mechanical condition of the spacecraft and the lunar excursion and injection vehicles is necessary to detect any malfunctions during the launch boost phase of flight that escapes the attention of the astronauts. Such verifications will provide assurance to the flight controller that the mission as planned can be executed or will permit prompt corrective or alternate courses of action to be initiated.

Such in-orbit check-outs must be automated so as to be capable of rapid performance. This is necessary since a large check-out crew will be unavailable and contact time with the ground will be limited. As presently planned, these in-orbit check-out functions will be performed partially by on-board and partially by ground-based systems. The ground-based systems will be developed and located at existing tracking and data acquisition facilities and will consist of expanded and extremely versatile telemetry systems for two-way communication of large amounts of status data and of command functions. In addition, translation equipment will be necessary

at these locations to provide communications into and out of a large-scale electronic data processor. This data processor will be the heart of the ground-based portion of the in-orbit check-out capability. It will provide the automatic control for the spaceborne portions of the system. In addition to these subsystems, extensive display and console control units will be necessary for use of the flight controllers.

Installation of three such automated check-out facilities at existing stations is planned for fiscal year 1964.

Approximately 7 existing stations, as well as 3 ships, will be equipped with an S-band unified tracking and communications system. This will consist of an antenna approximately 30 feet in diameter, an S-band transmitter, two phase-lock receivers, a range modulation and demodulation unit so that range may be measured with the accuracy demanded by the program and various detection, recording and ancillary equipment associated with the system.

Conversion to S-band offers many advantages, one of which is the optimum use of low-noise receivers. The system will allow many of the previous functions requiring several pieces of equipment onboard the spacecraft to be combined into one unit. This is essential for lunar type missions inasmuch as weight is a critical spacecraft factor. Another advantage gained by moving the telemetry frequency from the VHF to the S-band is the increased communication gain in the use of directional antennas onboard the spacecraft. This will aid in getting voice, television, and telemetry data back to the manned flight network from lunar distances. The system is particularly effective in that the network can do orbital tracking and communication in conjuction with a single piece of onboard equipment. The present capabilities of the net stations are not designed for tracking and communications at the S-band frequencies. At the S-band frequencies considerable increase of radio frequency gain will be realized. This will allow for the transmission of data at greater rates which will be a necessity for spacecraft onboard data systems designed around digital techniques. It is estimated that transmission rates of 32 kilobits per second will be required to handle the real-time data flow.

Improved data handling and data processing capabilities will be necessary at the sites. The present communication system will be unable to transfer the heavy concentration of data back to the central computing center. This will necessitate additional on-site data editing, handling, and processing equipment in order to reduce the digital information to the required amount which can be transmitted over the presently installed communication lines.

Instrumentation must be provided to establish the position of the manned space capsule prior to landing and recovery. The necessity of such a system to determine recovery coordinates without regard to velocity does not pose a requirement for high accuracy, but sufficient sophistication is necessary to provide maximum speed of location and recovery. It is planned to use currently available commercial equipment, with only minor modifications, at the various prime and secondary landing areas.

Provision for spares, maintenance, and replacements at each of the sites concerned must be carefully planned. Telemetered and communications data received at each of the stations is of great importance to the successful completion of the mission; therefore, downtime, that is, loss of time due to failure, of any part of the system must be kept to a minimum.

Deep space network

Unmanned lunar and planetary probes are levying an increased requirement for radio tracking, command, telemetry, and data acquisition, which in turn places a demand for expansion and modernization of the deep space network.

During fiscal year 1964, the deep space network will still consist of 3 major sites. The planned increase in capability, however, will enable the network to support simultaneously more than one space probe mission and will provide sufficient flexibility of coverage in both the L-band and S-band frequencies. The flight schedule for fiscal years 1964 and 1965 shows an increase in Ranger launches with onboard equipment operating in the 960-and 2300-megacycle frequency spectrum. The 2300-megacycle frequency is less subject to cosmic noises and, therefore, will increase the network capabilities. During the same period, space probes will be launched toward Mars and Venus, and Surveyor spacecraft will be landed on the moon. Both Mariner and Surveyor trajectory missions will overlap thus requiring multiple S-band frequency channels to allow noninterfering command and transmissions to and from the spacecraft.

To meet the S-band requirement, all deep space network stations must be equipped with compatible data acquistion, tracking, command recording, and processing equipment. Due to the necessity of supporting more than one mission at a time, it will be necessary that duplicate systems be installed and checked out at each site.

The receiving equipment at each site will be modified by the addition of S-band traveling-wave maser amplifiers. This will allow for the tracking and data acquisition of radio frequency signals with lower signal-to-noise ratios. This capability will extend the tracking and data acquisition functions to cover greater ranges of transmission with increased reliability in the quality of data recorded. The S-band maser subsystem requires precision cooling for the proper operation and stability. The use of liquid helium as a coolant requires the utmost cooling system mechanical and structural integrity to constrain the gases. Special types of servicing equipment are required for handling and maintaining the cooling units.

Modifications to the antennas will allow operation with both L-band and S-band cassegrain feed systems. This will allow for an increase in the overall system sensitivity. Since both L-band and S-band will be used, each site must be equipped with proper equipment for the rapid change-over from one frequency to the other. Each S-band cassegrain subsystem consists of a feed, diplexer, filters, switches, microwave circuitry, pressurized refrigeration, cone and subreflectors.

In order for the large antennas to acquire the spacecraft signals, separate acquisition aids operating in the S-band must be provided for each antenna at each site. Special handling equipment will be needed for rapid conversion depending on mission requirements. Each acquisition subsystem consists of feed, switches, microwave circuitry and structure.

Because of the many functions that must be simulated and checked out by each station of the network prior to a spacecraft mission, simulation equipment must be located at each site for proper equipment alignment. This will consist of Mariner-type transponders similar to those flown in the spacecraft operating on S-band frequencies.

To establish accurate tuning of receivers and transmitters, precision reference frequency synthesizer systems will be installed at each station. This will provide for increased sensitivity at ground receivers and spacecraft transponders.

Due to the varied missions scheduled during fiscal year 1964, a mobile station which can be relocated on short notice to cover spacecraft injection will be required. At present, injection coverage is limited due to lack of proper equipment. Therefore, a range and doppler S-band station will be developed to meet specified injection requirement. The equipment will be installed in a trailer that can be relocated with minimum expense and time. This will provide the additional coverage of spacecraft injection points in space as dictated by the mission requirements. The range station will also be equipped with necessary test and alignment equipment. Data handling and communications equipment will be needed to provide the necessary station independence, flexibility, and mobility. Mobile generators will be supplied to provide station power.

The increased volume of data will require that each station have duplicate data recording capabilities. In addition, the S-band conversion will increase the data bendwidth thereby providing for higher data density at any given time. This, plus the simultaneous receiving and transmitting of radio-frequency signals, will necessitate the use of separate tape recording machines. In order to realize maximum use of present tape recorders, modification will be made to units in the field to increase their data recording capability. A complete line of S-band electronic spare parts and components will be stored at each station to minimize operational downtime. The increased volume of data to be recorded will necessitate large supplies of magnetic and paper tape. Provisions for maintenance, spares and replacements for equipment including support items such as generators, pumps, and hydraulic and electrical machinery will be established at each deep space network station.

Launch area instrumentation

The everchanging nature of the programs supporting the various disciplines of space science have resulted in the design of experiments of increasing complexity and requiring not only larger numbers of launch vehicles but also vehicles capable of carrying heavier payloads probing deeper into space.

In addition, there is an increasing demand to flight test numerous components and systems for the manned lunar program as that program gathers momentum. Experiment and vehicle components and subsystems are flown on relatively small, less expensive, vehicles launched from Wallops Island. At Wallops Station and supporting sites on Bermuda, and along the East Coast, the radar and optical tracking systems and telemetry data acquisition and recording systems must be updated with advanced antennas, preamplifiers, frequency diversity and data recording equipment.

On radars it will be necessary to provide: an extension of the pulse synchronization system to include the FPQ-6 radar scheduled for installation in the summer of 1963; data recording systems with magnetic tape formats compatible with improved digital computer input requirements; and a redesigned pulse repetition frequency generator for the MOD II radar to improve the stability of its ranging system.

The telemetry systems will be updated and extended to provide: two new mobile recording vans incorporating additional space and updated equipment compatible with program requirements; pre-detection systems for use with the high-gain multiple frequency telemetry antenna facility; updating of the X-band telemetry system to include a low-noise pre-amplifier; improved design telemetry tape recorders with high frequency response; and updating of existing playback and readout facilities to include changes required by new telemetry systems.

The range safety system will be updated; an all-weather sky screen system provided; and integrated displays installed at the range safety officer's station. The range support ship (USNS Range Recoverer) will be provided with improved meteorological equipment, a surveillance radar, timing equipment, a precise navigation system, and a capability for payload recovery down range.

Aerodynamic test range

The aerodynamic test range operated by the Flight Research Center requires normal maintenance to remain effective in support of the NASA and Air Force aircraft flight projects. For example, the radar at Edwards Air Force Base has been exercised some 2,000 hours, while the one at the Ely station has had to work only about half that much. In order to obtain maximum utilization of this equipment, the Ely instrument's pedestal (the life of this component is the most limiting in the system in that wear on it affects the overall system accuracy) will be removed and exchanged with the pedestal at Edwards which will then be refurbished. This should extend the useful life of both stations at least for another operating year. Routine modifications and improvments to the electronics, communication, and display systems will continue in fiscal year 1964.

Communications network

The continued successes of the NASA flight program reflect directly

on the utilization of the communications network. Communications terminal equipment must be specially designed for satellite projects and automatic circuit handling equipment is now required at switching centers. Channelizing equipment must be purchased to expand the capacity of some circuits for better efficiency of utilization.

The reliability of communications using high-frequency radio is marginal due to the crowding of the spectrum and high-frequency propagation deterioration due to increased sunspot activity. This places the need for greater transmitter power and the updating of terminal equipment. Equipment is required to provide for the addition of voice capability on the transmitters/receivers presently utilizing only teletype. Expansion from one-channel TTY service to multi-channel TTY and voice service into South America requires additional terminal equipment and increased transmitter power.

Mobile communications stations are required to provide for short-term heavy communications loads at established network stations or to carry out the communication functions at remote sites; these are also required to provide for intra-station transmission of wide-band signals where the distances preclude hard line facilities. This situation exists where equipment is located on a remote mountain top, at test sites remotely located from the main station, or a ship anchored in a harbor where docking facilities are not available.

Data processing and handling

With the advent of the larger scientific satellites, it is planned that onboard spacecraft digital systems will be used to supplement the present analog systems. This will allow for storage of many bits of information which cannot be handled with present-day analog systems. This vast increase of data flow from the spacecraft will require expanded data handling facilities to meet the many bits of information which require editing, scaling, print-out, and presentation. It is expected that one large satellite of the Orbiting Astronomical Observatory class will generate several hundred thousand bits of information per orbit. This data flow rate can only be handled by the operation of digital processing and handling equipment that operate at pre-programmed modes in automatic fashion at high speeds.

To satisfy this workload in data handling, it will be necessary that present data handling systems be modified and supplemented with more efficient and expedient data processors which are compatible with the spacecraft onboard digital data acquisition systems. Since data requirements vary considerably for each type of satellite, different types of data handling equipment will be required for the ground systems. The data handling equipment which will tie in the interface problems between the formats of the onboard and ground systems will be of prime concern. This will consist of advanced subsystems to perform more efficiently the necessary steps of signal conditioning, format arranging, data buffering,

speed scaling, intermediate data scaling, print-out, plotting, display, and presentation. This type of equipment will provide the necessary data flow capability that can handle large volumes of data processing at high rates.

The majority of data handling subsystems are designed and tailored to meet specific requirements of data format and peripheral equipment. Therefore, spares and replacements must also meet these unique specifications which are not common to shelf-item replacements. The cost of spares and replacements is, therefore, considerably more than standard replacement and component items.

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