National Aeronautics and Space Administration

BUDGET ESTIMATES

FISCAL YEAR 1965

Volume II

RESEARCH AND DEVELOPMENT

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1965 ESTIMATES

RESEARCH AND DEVELOPMENT

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RESEARCH AND DEVELOPMENT

GENERAL STATEMENT

The research and development program of the National Aeronautics and Space Administration is directed toward achieving and maintaining American supremacy in space. The research and development program designed to achieve these objectives includes the Gemini and Apollo manned space flight projects; a comprehensive program of scientific investigation of the earth, moon, sun, planets and outer space employing unmanned vehicles ranging from sounding rockets to large orbiting observatories and interplanetary probes; an applications program to develop systems and technology for meteorological and communications satellite systems; and an advanced research and technology program designed to provide the base for continuing programs in space.

MANNED SPACE FLIGHT PROGRAMS

About two-thirds of the amount requested for Research and Development for fiscal year 1965 is required for the manned space flight program. The objective of this program is to provide a national 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 within this decade. The program is shaped to lead from one mission to the next in the most logical, safest and most efficient manner. The first phase of this program, the Mercury flights, was completed with Major Cooper's 22-orbit flight on May 16, 1963. Gemini unmanned test flights will begin in fiscal year 1964, with two-man flights scheduled to begin in fiscal year 1965. Gemini achievements in fiscal year 1965 will support Apollo by the development of operational procedures directly applicable to the lunar landing mission. The over-all Apollo program consists of three flight mission phases; (1) unmanned suborbital and earth-orbital flights; (2) manned earth-orbital long-duration flights and earth-orbital rendezvous flights; and, (3) manned lunar flights. The Apollo program is now entering a period of extensive development and test.

SPACE SCIENCE AND APPLICATIONS PROGRAMS

Unmanned scientific flight projects include the geophysical satellites designed to collect data on the earth and its atmosphere; orbiting solar and astronomical observatories; a program of unmanned lunar investigations including lunar orbit missions as well as hard and soft landings on the moon's surface; and the Mariner and Pioneer spacecraft designed for planetary exploration. The TIROS and Nimbus projects reflect NASA support of the Weather Bureau in application of satellite technology to achieve an operational meteorological system with global coverage. Communications satellite projects include Echo and the active repeaters, Relay in low altitude orbit and the Syncom satellite in synchronous orbit. Effort is also planned on development of more advanced satellites as a basis for design of advanced operational systems for communications, meteorological and other applications.

ADVANCED RESEARCH AND TECHNOLOGY

The advanced research and technology effort is aimed at supporting current flight programs and at assuring a capability to undertake future flight missions. The program includes effort in the fields of spacecraft and launch vehicle technology, human factors, electronics, chemical and nuclear propulsion, and space power supplies including both nuclear and non-nuclear systems. In the field of aeronautics, special emphasis will be placed on supersonic transport research.

TRACKING AND DATA ACQUISITION

The critical element in obtaining scientific information recorded during every space flight mission is the world-wide network of tracking and data acquisition stations. In fiscal year 1965, as in prior years, effort will be directed towards supporting planned flights, and towards providing the increased capability necessary to support observatory class satellite projects, Apollo manned space flight missions, and deep space flight projects.

TECHNOLOGY UTILIZATION

The technology utilization program provides forthe identification, collection and dissemination of technical information which has industrial application. Also included are efforts to develop better methods for management of large-scale research and development programs, and to improve our understanding of the implications of the space program.

FINANCING

The FY 1964 program totals $4,067,000,000 of which $3,926,000,000 is covered within the present appropriation and $141,000,000 would be funded by the proposed FY 1964 supplemental appropriation. Expenditures for fiscal year 1964 are estimated at $3,520,000,000 and $3,905,000,000 for 1965.

This volume contains detail narrative justifications supporting the authorization and appropriation request for fiscal year 1965.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1965 ESTIMATES

RESEARCH AND DEVELOPMENT SUMMARY BY BUDGET ACTIVITY

Budget Activities and Programs	Fiscal Year 1963	Fiscal Year 1964	Fiscal Year 1964 Supplemental	Fiscal Year 1965
MANNED SPACE FLIGHT..........	$1,503,583,000	$2,649,800,000	$141,000,000	$3,011,900,000
Gemini.....................	288,090,000	383,800,000	---	308,400,000
Apollo.....................	1,183,965,000	2,243,900,000	141,000,000	2,677,500,000
Advanced missions..........	11,391,000	22,100,000	---	26,000,000
Completed missions.........	20,137,000	---	---	---
SPACE APPLICATIONS...........	$96,958,000	$103,300,000	---	$86,100,000
Meteorology................	54,051,000	67,800,000	---	37,500,000
Communications.............	32,075,000	13,500,000	---	12,600,000
Other applications.........	10,832,000	22,000,000	---	36,000,000
UNMANNED INVESTIGATIONS IN SPACE	$489,951,000	$602,700,000	---	$649,800,000
Spacecraft development and operations...............	384,222,000	477,600,000	---	521,600,000
Launch vehicle development.	105,729,000	125,100,000	---	128,200,000
SPACE RESEARCH AND TECHNOLOGY	$255,962,000	$298,100,000	---	$283,300,000
Launch vehicles and spacecraft...............	88,547,000	111,900,000	---	104,400,000
Propulsion and space power.	167,415,000	186,200,000	---	178,900,000
AIRCRAFT TECHNOLOGY..........	$15,598,000	$22,100,000	---	$37,000,000
SUPPORTING OPERATIONS........	$152,742,000	$250,000,000	---	$313,900,000
Tracking and data acquisition....................	122,142,000	210,000,000	---	267,900,000
Sustaining university program..................	30,600,000	40,000,000	---	46,000,000
TOTAL PLAN..................	$2,514,794,000	$3,926,000,000	$141,000,000	$4,382,000,000

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1965 ESTIMATES

RESEARCH AND DEVELOPMENT SUMMARY
OF BUDGET ACTIVITIES BY PROGRAM

Budget Activities and Programs	Fiscal Year 1963	Fiscal Year 1964	Fiscal Year 1964 Supplemental	Fiscal Year 1965
MANNED SPACE FLIGHT	$1,503,583,000	$2,649,800,000	$141,000,000	$3,011,900,000
Gemini....................	288,090,000	383,800,000	---	308,400,000
Apollo....................	1,183,965,000	2,243,900,000	141,000,000	2,677,500,000
Advanced missions.........	11,391,000	22,100,000	---	26,000,000
Completed missions.......	20,137,000	---	---	---
SPACE APPLICATIONS	$96,958,000	$103,300,000	---	$86,100,000
Meteorology..............	54,051,000	67,800,000	---	37,500,000
Communications...........	32,075,000	13,500,000	---	12,600,000
Other applications.......	10,832,000	22,000,000	---	36,000,000
Advanced technological satellites...........	(8,668,000)	(18,500,000)	---	(31,000,000)
Technological utilization..........	(2,164,000)	(3,500,000)	---	(5,000,000)
UNMANNED INVESTIGATIONS IN SPACE	$489,951,000	$602,700,000	---	$649,800,000
Spacecraft development and operations.........	384,222,000	477,600,000	---	521,600,000
Geophysics and astronomy............	(147,689,000)	(186,200,000)	---	(190,200,000)
Lunar and planetary exploration..........	(222,802,000)	(270,800,000)	---	(300,400,000)
Bioscience..............	(13,731,000)	(20,600,000)	---	(31,000,000)
Launch vehicle development	105,729,000	125,100,000	---	128,200,000
SPACE RESEARCH AND TECHNOLOGY	$255,962,000	$298,100,000	---	$283,300,000
Launch vehicles and spacecraft.............	88,547,000	111,900,000	---	104,400,000
Space vehicle systems..	(43,990,000)	(49,000,000)	---	(38,800,000)
Electronic systems.....	(17,071,000)	(28,700,000)	---	(28,400,000)
Human factor systems...	(9,790,000)	(13,200,000)	---	(16,200,000)
Basic research.........	(17,696,000)	(21,000,000)	---	(21,000,000)

Budget Activities and Programs	Fiscal Year 1963	Fiscal Year 1964	Fiscal Year 1964 Supplemental	Fiscal Year 1965
Propulsion and space power..................	$167,415,000	$186,200,000	---	$178,900,000
Nuclear-electric systems..............	(39,893,000)	(44,700,000)	---	(48,100,000)
Nuclear rockets.......	(69,465,000)	(82,700,000)	---	(58,000,000)
Chemical propulsion...	(49,722,000)	(45,800,000)	---	(59,800,000)
Space power...........	(8,335,000)	(13,000,000)	---	(13,000,000)
AIRCRAFT TECHNOLOGY	$15,598,000	$22,100,000	---	$37,000,000
SUPPORTING OPERATIONS	$152,742,000	$250,000,000	---	$313,900,000
Tracking and data acquisition..........	(122,142,000)	(210,000,000)	---	(267,900,000)
Sustaining university program.............	(30,600,000)	(40,000,000)	---	(46,000,000)
TOTAL.............	$2,514,794,000	$3,926,000,000	$141,000,000	$4,382,000,000

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1965 ESTIMATES

SUMMARY OF RESEARCH AND DEVELOPMENT BUDGET PLAN BY PROGRAM

	Fiscal Year 1963	Fiscal Year 1964	Fiscal Year 1964 Supplemental	Fiscal Year 1965
MANNED SPACE FLIGHT.......	$1,503,583,000	$2,649,800,000	$141,000,000	$3,011,900,000
Gemini..................	288,090,000	383,800,000	---	308,400,000
Apollo..................	1,183,965,000	2,243,900,000	$141,000,000	2,677,500,000
Advanced missions.......	11,391,000	22,100,000	---	26,000,000
Completed missions......	20,137,000	---	---	---
SPACE SCIENCE AND APPLICATIONS................	$615,345,000	$742,500,000	---	$776,900,000
Geophysics and astronomy	147,689,000	186,200,000	---	190,200,000
Lunar and planetary exploration	222,802,000	270,800,000	---	300,400,000
Sustaining university program...............	30,600,000	40,000,000	---	46,000,000
Launch vehicle development..................	105,729,000	125,100,000	---	128,200,000
Bioscience.............	13,731,000	20,600,000	---	31,000,000
Meteorological satellites	54,051,000	67,800,000	---	37,500,000
Communication satellites	32,075,000	13,500,000	---	12,600,000
Advanced technological satellites............	8,668,000	18,500,000	---	31,000,000
ADVANCED RESEARCH AND TECHNOLOGY.............	$271,560,000	$320,200,000	---	$320,300,000
Basic research..........	17,696,000	21,000,000	---	21,000,000
Space vehicle systems...	43,990,000	49,000,000	---	38,800,000
Electronic systems......	17,071,000	28,700,000	---	28,400,000
Human factor systems....	9,790,000	13,200,000	---	16,200,000
Nuclear-electric systems	39,893,000	44,700,000	---	48,100,000
Nuclear rockets.........	69,465,000	82,700,000	---	58,000,000
Chemical propulsion.....	49,722,000	45,800,000	---	59,800,000
Space power.............	8,335,000	13,000,000	---	13,000,000
Aeronautics.............	15,598,000	22,100,000	---	37,000,000
TRACKING AND DATA ACQUISITION............	$122,142,000	$210,000,000	---	$267,900,000

	Fiscal Year 1963	Fiscal Year 1964	Fiscal Year 1964 Supplemental	Fiscal Year 1965
TECHNOLOGY UTILIZATION.....	$2,164,000	$3,500,000	---	$5,000,000
TOTAL PLAN................	$2,514,794,000	$3,926,000,000	$141,000,000	$4,382,000,000

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1965 ESTIMATES

SUMMARY OF RESEARCH AND DEVELOPMENT BUDGET PLAN AS RECONCILED TO FINANCING SCHEDULE

	Fiscal Year 1963	Fiscal Year 1964	Fiscal Year 1964 Supplemental	Fiscal Year 1965
Budget plan:				
Research, development, and operation..........	$2,953,469,000	---	---	---
Research and development.	(2,514,794,000)	$3,926,000,000	$141,000,000	$4,382,000,000
Administrative operations	(438,675,000)	---	---	---
Total..................	$2,953,469,000	$3,926,000,000	$141,000,000	$4,382,000,000
Financing:				
Appropriation............	$2,897,878,000	$3,926,000,000	$141,000,000	$4,382,000,000
Transferred from "Construction of facilities" (76 Stat. 731)..................	+32,602,850	---	---	---
Transferred to: "Administrative operations" (77 Stat. 439).................	---	-16,385,000	---	---
"Operating expenses, Public Buildings Service, GSA (76 Stat. 728)...........	-1,073,723	---	---	---
Appropriation (adjusted).	2,929,407,127	3,909,615,000	141,000,000	4,382,000,000
Prior Year funding applied- Generated by adjustments to prior year budget plans..................	+25,731,873	+1,670,000	---	---
FY 1963 funding applied to FY 1964 budget plan.	-1,670,000	---	---	---
Transfer from prior year "Construction of facilities" funds....	---	+14,715,000	---	---
Total budget plan financing........	$2,953,469,000	$3,926,000,000	$141,000,000	$4,382,000,000

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1964 COLUMN OF FISCAL YEAR 1965 BUDGET ESTIMATES

(Thousands of Dollars)

CONVERSION CHART FOR MANNED SPACE FLIGHT PROGRAM STRUCTURE

PRIOR STRUCTURE		CURRENT STRUCTURE														
		GEMINI				APOLLO										
PROGRAM/PROJECT	Total	Total	Spacecraft	Launch Vehicle	Support	Total	Spacecraft	H-1 Eng	RL-10 Eng	F-1 Eng	J-2 Eng	Saturn I	Saturn IB	Saturn V	Support	Adv Missions Studies
TOTAL	2,649,800	383,800	252,300	110,000	21,500	2,243,900	870,900	11,100	20,000	62,300	56,600	204,200	149,900	689,600	179,300	22,100
MANNED SPACECRAFT SYSTEMS	1,283,900															
Spacecraft technology	18,700					18,700									18,700	
Mercury	-0-															
Gemini																
Spacecraft	273,300	273,300	252,300		21,000											
Launch vehicle procurement	110,000	110,000		110,000												
Apollo																
Spacecraft	798,100					798,100	795,200								2,900	
Launch vehicle procurement																
Little Joe II	6,800					6,800	6,800									
Saturn I	21,500					21,500						21,500				
Saturn IB	3,000					3,000							3,000			
Saturn V	-0-					-0-										
Mission control systems	52,500					52,500									52,500	
LAUNCH VEHICLES AND PROPULSION	1,192,900															
Launch vehicle technology	12,900					12,900									12,900	
Propulsion technology	12,800					12,800									12,800	
Launch operations technology	2,100					2,100									2,100	
Saturn I development	182,200					182,200						182,200				
Saturn IB development	139,400					139,400							139,400			
Saturn V development	657,000					657,000								657,000		
H-1 Engine development	11,100					11,100		11,100								
RL-10 Engine development	20,000					20,000			20,000							
F-1 Engine development	62,300					62,300				62,300						
J-2 Engine development	56,600					56,600					56,600					
Launch instrumentation	17,500					17,500									17,500	
Launch operations	19,000					19,000									19,000	
INTEGRATION, CHECKOUT AND RELIABILITY	125,000					125,000	58,400					500	7,500	32,600	26,000	
SPACE MEDICINE	11,000	500			500	10,500	10,500									
SYSTEMS ENGINEERING	37,000															
Systems	14,900					14,900									14,900	
Advanced studies	22,100															22,100

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1963 COLUMN OF FISCAL YEAR 1965 BUDGET ESTIMATES
(Thousands of Dollars)
CONVERSION CHART FOR MANNED SPACE FLIGHT PROGRAM STRUCTURE

PRIOR STRUCTURE		CURRENT STRUCTURE															
		GEMINI				APOLLO											
PROGRAM/PROJECT	Total	Total	Spacecraft	Launch Vehicle	Support	Total	Spacecraft	H-1 Eng	RL-10 Eng	F-1 Eng	J-2 Eng	Saturn I	Saturn IB	Saturn V	Support	Advanced Missions Studies	Completed Missions
TOTAL	1,503,583	288,090	205,045	79,109	3,936	1,183,965	363,962	6,260	29,645	53,703	46,769	256,887	21,271	343,442	62,026	11,391	20,137
MANNED SPACECRAFT SYSTEMS	722,089																
Spacecraft technology	7,963					7,963									7,963		
Mercury	20,030																20,030
Gemini																	
Spacecraft	208,612	208,612	205,045		3,567												
Launch vehicle procurement	79,109	79,109		79,109													
Apollo																	
Spacecraft	337,816					337,816	337,446								370		
Launch vehicle procurement																	
Little Joe II	6,300					6,300	6,300										
Saturn I	54,270					54,270						54,270					
Saturn IB	-0-																
Saturn V	-0-																
Mission control systems	7,989					7,989									7,989		
LAUNCH VEHICLES AND PROPULSION	721,785																
Launch vehicle technology	6,299					6,299									6,299		
Propulsion technology	9,004					9,004									9,004		
Launch operations technology	2,304					2,304									2,304		
Saturn I development	200,862					200,862						200,862					
Saturn IB development	18,414					18,414							18,414				
Saturn V development	340,853					340,853								340,853			
H-1 Engine development	6,260					6,260		6,260									
RL-10 Engine development	29,645					29,645			29,645								
F-1 Engine development	53,703					53,703				53,703							
J-2 Engine development	46,769					46,769					46,769						
Launch instrumentation	-0-																
Launch operations	7,672					7,672									7,672		
INTEGRATION, CHECKOUT AND RELIABILITY	34,265					34,265	15,123					1,755	2,857	2,589			
SPACE MEDICINE	5,569	369			369	5,093	5,093										107
SYSTEMS ENGINEERING	19,875																
Systems	8,484					8,484									8,484		
Advanced studies	11,391															11,391	

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PROGRAM OBJECTIVES AND JUSTIFICATION:

The Gemini program objectives are to develop an extended operational capability for manned space flight and through this capability to conduct specific experiments and tests which support Apollo, Department of Defense programs and scientific investigations. To accomplish this objective long-duration and rendezvous missions have been planned for a two man spacecraft. During the long-duration missions, the astronauts will control and maneuver the spacecraft thus providing performance data (on both systems and astronaut) after long exposures to space flight. The astronauts will perform a series of experiments generated by NASA, Department of Defense and the scientific community. The first long-duration flight is planned for 1965.

The rendezvous missions begin with the launch of the target vehicle, a modified Agena D, which is boosted into orbit by a standard Atlas launch vehicle. Approximately 24 hours later, the Gemini spacecraft is inserted into orbit where it is positioned close to the Agena. The astronauts then mate the spacecraft with the target vehicle through a docking maneuver. The Gemini spacecraft and Agena target vehicle permit a variety of rendezvous techniques to be explored and provide a test bed for various phases of Apollo mission. Great importance is placed on the intelligence, and piloting ability of the astronauts to accomplish complex missions with the Gemini spacecraft.

Early rendezvous flights will develop optimum techniques and evaluate man's abilities as compared to automatic controls, thus greatly extending the present knowledge of manned space flight technology and operational procedures. As operational proficiency increases and flight techniques are developed, Gemini will simulate situations comparable to future space missions. The simulation of the lunar orbit rendezvous of the Apollo lunar excursion module with the command and service modules is of particular importance; however, Gemini will also provide data for other missions such as rendezvous with a space station or inspection of unmanned satellites. The rendezvous missions are defined in detail and planned to lead logically into the next mission without duplication.

The reentry trajectory is normally controlled by the astronauts by lift force orientation. In contrast to Mercury which could only make a ballistic reentry, Gemini can descend to a chosen recovery zone within an area of several thousand square miles. In addition, the paraglider, which may be introduced later in the program, allows the fine control required for landing at a specific preselected land site.

SUMMARY OF RESOURCES REQUIREMENTS:

	1963	1964	1965
Spacecraft	$205,045,000	$252,300,000	$168,900,000
Launch vehicles	79,109,000	110,000,000	111,300,000
Gemini support	3,936,000	21,500,000	28,200,000
Total costs	$288,090,000	$383,800,000	$308,400,000

BASIS OF FUND REQUIREMENTS:

Spacecraft

	1963	1964	1965
Spacecraft	$205,045,000	$252,300,000	$168,900,000

The two-man Gemini spacecraft, which is the successor to Mercury and draws heavily on proven Mercury technology, reflects major advances in spacecraft design. Mercury demonstrated the feasibility of manned space systems and man's usefulness therein. Gemini is a far more advanced, complex and versatile spacecraft and will provide a transition from the pioneering achievements of Mercury to the lunar program goals of Apollo.

A highly refined and sophisticated design is required to conduct the missions specified for Gemini. Gemini is larger than Mercury and is divided into three basic sections: the reentry, the retrograde and the equipment adapter sections. This arrangement provides a larger spacecraft for the longer and more complex missions while still keeping the reentry section relatively small. Modularized equipment is located in a series of equipment bays around the pressurized cabin to provide for accessibility during testing and checkout, thus minimizing launch delays. Many access doors and external check points are provided for use by the launch crew to quickly locate and service a faulty item. New subsystems have been introduced: fuel cells to replace batteries; ejection seats; on-board spacecraft propulsion for maneuvering in space; and rendezvous radar and an inertial guidance system for rendezvous with the Agena. The inertial guidance system also provides alternate guidance capability during launch in the event of failure of the Gemini launch vehicle's primary guidance system.

The Gemini spacecraft contract was awarded to the McDonnell Aircraft Corporation in December 1961. Over 50 percent of this contract effort is placed with subcontractors. Major subsystems are being supplied by 18 subcontractors in various specialized areas. There are also many other subcontractors, vendors and suppliers performing additional work on the Gemini program. North American Aviation Corporation, as associate contractor, is developing the paraglider for land landing.

Approximately one-third of the total Gemini program funding will be for production of deliverable hardware. Under the McDonnell contract major items being delivered to the Gemini program include: (1) 12 flight spacecraft; (2) 5 non-flying "boilerplate" spacecraft for use in development and qualification testing of subsystems; (3) 4 static articles, non-flying, spacecraft used primarily for various structural, thermal and flotation tests; (4) a complete flight-quality spacecraft for simulated space missions in an environmental chamber (Project Orbit); (5) an electrical systems test unit (for integrated testing of engineering models of electrical and electronic equipment); (6) a compatibility test unit, (a non-flying spacecraft configured so that flight-qualified models of all subsystems can be fully checked for operation and compatibility with the ground equipment before the all-systems test flight); (7) 2 mission simulators; (8) a docking trainer; (9) several systems trainers; (10) 9 docking adapters; and (11) specialized ground equipment, test hardware, and spares.

All of the non-flying spacecraft and related units will be delivered by the end of the current fiscal year. These were funded in fiscal years 1963 and 1964. The first flight spacecraft was delivered to Kennedy Space Center in October 1963; the second is scheduled for delivery in the last quarter fiscal year 1964. Six additional spacecraft, now in manufacturing and assembly, will be delivered in fiscal year 1965 and construction of the remaining four will be started during that year. The major portion of the fiscal year 1965 funding will be for the production, testing, and launch of the spacecraft and its components.

The Mercury program testing requirements dictated that each component, subassembly, assembly, subsystem and system, be carefully and extensively tested to assure a flight-worthy spacecraft. The requirements for reliability and performance dictated by the Gemini missions are even more stringent and the testing program has been increased accordingly. Whenever possible, tests are performed under actual environmental and operating conditions. Components and subsystems undergo exhaustive development testing to certify that the design requirements have been fully met under all anticipated conditions (Qualification Tests). Vendor procured production components must pass a pre-delivery acceptance test before shipment to McDonnell. Every component undergoes a pre-installation acceptance test at McDonnell to re-verify required quality standards.

To assure spacecraft flight readiness, approximately 176 working days (two shifts) are spent in systematically testing and verifying the spacecraft and its many subsystems after completion of manufacturing. This includes 93 working days of testing at McDonnell to insure that the spacecraft components and subsystems are compatible and perform as installed in the spacecraft. Included in these spacecraft tests are several simulated flights, including one in an altitude chamber with an astronaut, to insure that procedures and equipment are flight ready. At Kennedy Space Center an additional 56 working days of testing is performed to insure integrated operation of the spacecraft and the checkout and launch instrumentation. At the launch complex, the spacecraft and launch vehicle are mated and tested to insure their compatibility. A simulated countdown and boost flight phase is performed as a final check for flight readiness. These tests require approximately 27 working days.

During fiscal year 1964, the major portion of the development testing, as well as the qualification testing of all subsystems of the spacecraft will be completed and spacecraft #1 and #2 will be certified as flight ready. In fiscal year 1965, four spacecraft will undergo the four months spacecraft system tests at McDonnell and the three months of testing after delivery to Kennedy Space Center in preparation for flight.

Launch Vehicles

	1963	1964	1965
Gemini....................	$63,709,000	$76,900,000	$66,900,000
Atlas.....................	---	6,300,000	19,500,000
Agena.....................	15,400,000	26,800,000	24,900,000
Total costs...............	$79,109,000	$110,000,000	$111,300,000

The Gemini Launch Vehicle is a Titan II ICBM booster modified for greater reliability and astronaut safety. These modifications "man-rate" the Titan II and include: redundant electrical power and flight control systems for greater reliability; a malfunction detection system to warn the astronauts of launch vehicle failures requiring abort; replacement of the Titan II inertial guidance system by the radio guidance system used successfully in Mercury; and removal of items useful only to the Titan II ICBM. These modifications necessitate an extensive test program. Components used in the Gemini launch vehicle are subjected to more severe test conditions than those of the Titan II (ICBM) since manned flight requires a higher safety standard. In most cases, this requires re-qualification tests of Titan II components and systems. All Gemini-peculiar components and systems will complete the full developmental and qualifications tests by March 1964.

NASA is procuring fifteen Gemini Launch Vehicles through the Air Force Space Systems Division. The Air Force has implemented this procurement program under five major contracts: Martin-Marietta for the Launch Vehicle, Aerojet for the engines; General Electric for the guidance system; Burroughs for the computer; and Aerospace Corporation for technical assistance.

The launch vehicles are subjected to the same type of comprehensive testing after manufacturing as the spacecraft. Prior to delivery to the launching site, functional system tests are conducted at Martin-Marietta in Baltimore on all systems with the complete vehicle installed in the vertical test facility with the same type of ground equipment used at the launch site. All systems are thoroughly tested except for actual engine firing. This provides test procedure experience, comparability of test data and an opportunity to uncover problems early. The first Gemini Launch

Vehicle was tested for five months in the vertical test facility prior to delivery to Kennedy Space Center in October 1963.

Subsequent to delivery to Kennedy Space Center, the Gemini Launch Vehicles undergo comprehensive testing at Launch Complex 19, (this complex has been modified for the Gemini mission) to establish compatibility and to verify flight readiness. This includes the complete systems check-out of the vehicle with the launch complex ground equipment and a static firing of the first and second stage engines. Following these tests, the spacecraft is mated with the launch vehicle and complete space vehicle tests are conducted in preparation for launch. The test period for the first Gemini Launch Vehicle, including the initial check-out of Launch Complex 19, is approximately 113 working days.

During fiscal year 1965, four launch vehicles will be delivered. Each of these vehicles will undergo 55 working days of systems test in the vertical test facility prior to delivery, followed by approximately 60 working days of testing and check-out at the Kennedy Space Center.

The Gemini Launch Vehicle development is benefiting from the Air Force's Titan II program. Over 20 Titan II launchings by the Air Force have provided valuable launch operations experience and flight test data directly applicable to the Gemini Launch Vehicle. The Gemini Launch Vehicle malfunction detection system is being tested on 6 Air Force Titan II flights. Some problems in the Titan II have been encountered primarily with the rocket engines which are of concern to the Gemini Launch Vehicle development. The Air Force has undertaken an improvement program. Design improvements from that program are being incorporated into the Gemini Launch Vehicle. For example, (as of December 1963) the surge chamber fix for a longitudinal oscillation has been tested on 2 Titan II launches. The fix will be installed on Gemini Launch Vehicle #1.

In fiscal year 1965, effort will be largely related to launch vehicle production, testing and launch support. The fiscal year 1965 funding requirement was developed jointly by NASA and the Air Force through detailed analysis of experience with the Titan II program, the launch vehicle contractors, Mercury experience, and the specific work programmed for the budget year. The funding requirement takes into account such factors as the extensive quality control and test effort required to assure man-rating standards.

ATLAS/AGENA

The complete Gemini target vehicle and launching system consists of a modified Agena D and the Atlas standard launch vehicle. Eight Atlas/Agena target vehicle systems are being procured through Air Force Space Systems Division.

Atlas - The Atlas standard launch vehicle is being developed by the Air Force to achieve greater reliability during countdown and flight.

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The experience gained from over one hundred Atlas launchings has been used as a basis for the improvement program. NASA is contributing to the development costs of this program. The first Gemini Atlas is scheduled for delivery in the second quarter of fiscal year 1965. The second will be delivered in the first quarter of fiscal year 1966. Four more Gemini Atlas vehicles will be in fabrication by the end of fiscal year 1965. The fiscal year 1965 funding requirement for the Gemini Atlas is primarily for the fabrication and testing of these vehicles and includes a proportionate share of the standard launch vehicle development and testing cost.

Agena - The modifications to the basic Agena D to make it a Gemini target vehicle provide: (1) additional maneuverability in orbit; (2) command and communications compatible with the Gemini spacecraft and the ground station network; and (3) a docking mechanism. These modifications, to be accomplished by the Lockheed Missiles and Space Division, consist of changes to the electrical power supply, telemetry, spacecraft command recorder and decoder subsystems and major modifications to the propulsion system. The main engine is being given a multiple restart capability so that it may be started as many as five times in orbit for rendezvous and post-rendezvous maneuvers. A secondary propulsion system is also being added to provide small velocity changes and propellant orientation for main engine start. The docking capability is achieved by adding to the Agena an adapter, built by McDonnell, and provided as government furnished equipment to Lockheed.

The Gemini target vehicle modifications make it far different from the Agenas used in other NASA programs or by the Air Force. It is a versatile, orbiting space vehicle, as well as a powerful second stage booster, that requires man-rating of the flight article. The development and qualification testing required is correspondingly severe.

Fiscal year 1964 is devoted to heavy effort in testing. The engines will undergo four months of combined systems hot firing at Lockheed Sunnyvale. The engines also will be subjected to a preliminary flight rating test for four months at Bell Aircraft. Two months of structural tests will be concluded in January 1964. Qualification tests will be completed on the command and control system, the guidance and flight control units, and the pulse code modulation telemetry system.

Systems testing of the first flight vehicle will be conducted in fiscal year 1965. Integrated systems testing will be followed by radio frequency interference tests. Static firing tests of the assembled vehicle will be conducted at the Santa Cruz Test Base in October and November 1964. The first flight article will then be shipped to the Kennedy Space Center for prelaunch test and check-out in mid fiscal year 1965. By the end of Fiscal Year 1965, four Gemini target vehicles will be in various stages of production and test.

Gemini Support

	1963	1964	1965
Gemini Support................	$3,936,000	$21,500,000	$28,200,000

Gemini support includes funds for the conduct of perations and for supporting development. Operations encompasses the areas of flight and crew operations while supporting development includes those activities directly supporting the Gemini Program, but not contained within the spacecraft, launch vehicle or target vehicle contracts.

Operations

The budget for Gemini Operations is divided into Flight Operations and Crew Operations.

Flight Operations includes the planning, support, and actual flight test of manned space systems from lift-off to recovery. Three main functional areas are included: Flight Control and Mission Planning; Recovery; and Test and Evaluation.

Recovery funds in fiscal year 1965 will support the Department of Defense recovery forces and Weather Bureau services required for four Gemini flights. These services include deployment of ships, aircraft and rescue personnel; airlifting of medical and communications equipment; providing a capability of spacecraft location in the event of contingency landings; and worldwide weather information coverage. Funds are required for procurement and maintenance of retrieval and location equipment issued to Department of Defense recovery forces. Additional funds are included in fiscal year 1965 for the completion of the test and evaluation of this retrieval and electronic location equipment.

A typical Gemini recovery force includes approximately 18 ships, and 100 aircraft and is comparable to the number used for a Mercury mission. A modification in recovery force employment concept has permitted the use of a comparable force size even though Gemini mission complexity has increased.

Four Gemini flights will require funds for flight control in fiscal year 1965. These funds will be used for: continuation of the contractor support personnel required for flight monitoring and remote site operation; flight controller training; purchase of auxiliary equipment for flight controllers; and development of flight control procedures.

Fiscal year 1965 funds for mission planning will continue the development of real time computer programs required for each mission, booster closed loop guidance equations and the highly sophisticated mathematical techniques required for trajectory programs and mission analysis begun in fiscal year 1964.

Fiscal year 1965 funding for Crew Operations includes those monies necessary to conduct the required space crew training. This funding will pay for the operation and modification of the various training and simulation devices, such as the Gemini Mission Simulator, the Part Task Trainer, and the Docking Trainer as well as for academic, acceleration and survival training. In addition, a Launch Vehicle Abort Simulator will be purchased and placed into operation.

Supporting Development

Supporting Development consists of essential activities used in conjunction with the spacecraft or launch and target vehicle contracts and is conducted under separate contract or in-house at the various NASA field centers. In fiscal year 1965, the major portion of pilot support systems and components will be delivered. This is comprised of pressure suits; food and waste management systems; various bio-instrumentation devices, including electrocardiogram instruments, oral temperature devices, impedance pneumographs, blood pressure devices and bio-medical recorders. The fiscal year 1965 funding will also support development of extra vehicular equipment. Reimbursement to the Department of Defense for support is also in the fiscal year 1965 estimates. These support activities consist of such items as aircraft and facilities for the parachute and paraglider development program and facilities for conducting ejection seat sled tests.

OFFICE OF MANNED SPACE FLIGHT — APOLLO PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The ultimate objective of the manned space flight program is to provide the capability for a broad program of exploration which will achieve and maintain a position of space leadership for the United States. A specific goal in acquiring this capability is the landing of men on the Moon and returning them safely to Earth; this goal will be realized through the Apollo program.

The overall program requires three flight phases: (1) unmanned suborbital and Earth-orbital flights; (2) manned Earth-orbital, long-duration flights and Earth-orbital rendezvous flights; (3) manned lunar flights.

Unmanned suborbital flights will qualify the spacecraft abort propulsion landing systems, and test the lunar excursion module (LEM) propulsion systems. Unmanned Earth-orbital flights of the command module and service modules and the LEM will qualify spacecraft systems and structure in the actual space environment. Manned Earth-orbital flights and LEM rendezvous flights will follow the unmanned spacecraft qualification phase of the program. The manned long-duration missions will verify the system endurance capabilities and will develop operational techniques essential for the conduct of lunar missions. Rendezvous missions, utilizing the command and service modules and the LEM to simulate the lunar orbit rendezvous phase of the lunar mission, will extend the experience gained in the Gemini program and flight qualify the systems for the lunar mission.

Lunar missions may include manned circumlunar and lunar-orbital flights to develop operational techniques in the lunar environment and to conduct scientific experiments in the cislunar space. Lunar landing missions will be made to explore the Moon's surface and to conduct scientific experiments.

Funds requested in fiscal year 1965 for the Apollo program will initiate the delivery of spacecraft and launch vehicles in support of the "all-up" concept of flight testing. This concept emphasizes the flight testing of the flight weight structures consisting of the complete spacecraft and launch vehicle systems that will duplicate subsequent equipment to be used for lunar missions. The Apollo program presented in this justification for fiscal year 1965 is based on the assumption that the funds received in fiscal year 1964 will include a supplemental appropriation of $141 million.

SUMMARY OF RESOURCES REQUIREMENTS:

Project:	1963	1964	1964 Supplemental	1965
Spacecraft......	$363,962,000	$870,900,000	$31,000,000	$945,800,000
H-1 Engine......	6,260,000	11,100,000	---	9,800,000
RL-10 Engine....	29,645,000	20,000,000	---	17,900,000
F-1 Engine......	53,703,000	62,300,000	---	64,100,000
J-2 Engine......	46,769,000	56,600,000	---	61,600,000
Saturn I........	256,887,000	204,200,000	---	120,600,000
Saturn IB.......	21,271,000	149,900,000	---	260,100,000
Saturn V........	343,442,000	689,600,000	110,000,000	988,400,000
Apollo support...	62,026,000	179,300,000	---	209,200,000
Total costs...	$1,183,965,000	$2,243,900,000	$141,000,000	$2,677,500,000

BASIS OF FUND REQUIREMENTS:

Spacecraft

	1963	1964	1964 Supplemental	1965
Command and service modules	$269,450,000	$508,300,000	$19,000,000	$520,500,000
Lunar excursion module.........	13,000,000	144,500,000	12,000,000	189,900,000
Guidance and navigation.....	31,846,000	91,500,000	---	83,800,000
Instrumentation and scientific equipment......	2,380,000	5,600,000	---	7,500,000
Spacecraft support........	47,286,000	121,000,000	---	144,100,000
Total costs...	$363,962,000	$870,900,000	$31,000,000	$945,800,000

Command and Service Modules. In December 1961, the Space and Information Systems Division of the North American Aviation Corporation (NAA) was selected as prime contractor to design, develop, and fabricate the command and service modules of the Apollo spacecraft. In addition, NAA was assigned responsibility for design and fabrication of the spacecraft - launch vehicle adapter, integration of test, scientific, and other government-furnished equipment into the spacecraft, assembly and test of the spacecraft, and support of spacecraft preparation for flight tests.

During fiscal year 1964, development hardware for command and service module components and subsystems will be fabricated and subjected to extensive testing. All major command and service module subsystem contracts will be definitized.

In the ground and flight testing program both developmental and production flight-configuration spacecraft will be used. During fiscal year 1964, 3 developmental spacecraft will be delivered for the ground test program, which includes static, dynamic and thermal structural tests, and operational and environmental testing of the spacecraft with all its subsystems installed.

Ground testing will continue on 6 developmental spacecraft, delivered in prior years, to improve the water recovery and handling capabilities; to develop the Earth-landing impact attenuation provisions; to improve the reliability of the parachute recovery system; and to verify the dynamic stability of the command and service module with a prototype Saturn I launch vehicle.

During fiscal year 1964, 3 developmental spacecraft will be delivered to the White Sands Missile Range and 3 to Kennedy Space Center for flight tests. Flight test activity at the White Sands Missile Range (WSMR) will use pad abort and Little Joe II launch facilities. One of these spacecraft was used to successfully test the launch escape system and Earth-landing system in August 1963. Another of the developmental spacecraft delivered to WSMR will be used with a Little Joe II launch vehicle in a high dynamic-pressure abort test. The third developmental spacecraft will be used for high-altitude abort tests on a Little Joe II. Two of the developmental spacecraft, delivered to Kennedy Space Center, will be used for launch environmental tests on the Saturn I (SA-6 and SA-7). The third spacecraft combined with a micrometeoroid experiment will be the payload for the SA-9, Saturn I flight.

At the close of fiscal year 1964, 3 additional developmental and 10 production spacecraft will be in various stages of manufacture.

In fiscal year 1965, the majority of testing on developmental spacecraft will be completed, and manufacture and qualification testing of production flight-configuration spacecraft will be underway. All major subsystems for the command and service modules will be in the final stages of reliability and qualification testing.

The ground test program will be implemented in fiscal year 1965 with the delivery of 6 production spacecraft for propulsion system tests, vibration and acoustics tests, environmental proof tests, complete static structural tests, thermal tests on structures, and a verification of the water impact and flotation capabilities derived from previous developmental tests.

During fiscal year 1965, 3 developmental spacecraft for flight tests will be delivered. One spacecraft will be flight-tested at Kennedy Space Center carrying micrometeoroid and scientific experiments. A high-altitude abort test will be conducted at White Sands Missile Range with the second spacecraft. The third spacecraft will be delivered to Kennedy Space Center for structural qualification tests. In fiscal year 1965, 4 production spacecraft for flight test will be completed. Two of these spacecraft will be delivered to White Sands Missile Range to qualify the critical launch escape system. The other two production spacecraft will be delivered to Kennedy

Space Center for launch on Saturn IB. These flights will initiate the "all-up" test concept. At the end of fiscal year 1965, 12 production spacecraft will be in various stages of construction. Each of these spacecraft will be equipped for "all-up" systems tests.

Lunar Excursion Module. The lunar excursion module (LEM) has been under development by the Grumman Aircraft Engineering Corporation. This contract, let in December 1962, is managed by the Manned Spacecraft Center. The LEM will have the capability of separating from the command and service modules and performing lunar descent, landing, ascent, and rendezvous and docking with the mother spacecraft which will remain in lunar orbit.

During fiscal year 1964, preliminary design of the lunar excursion module will be completed and the detailed design and development effort will be under way. Grumman will complete contracting for all major subsystems and will begin the fabrication of 4 ground test LEMs and one flight test LEM. In fiscal year 1964, the first mockup was delivered and manufacturing was initiated on 4 other mockups. These mockups, used extensively for design and operational studies, contribute uniquely to the development of the LEM. Tests of landing stability have been made on scale models. In addition, 4 LEM test models were fabricated to determine crew mobility, to conduct thermal and antenna radiation tests, and to study the interface between the descent and ascent stage. For propulsion system tests, fourteen test rigs were manufactured for development tests at Rocketdyne, Bell Aerospace Systems, Space Technology Laboratories, the Arnold Engineering Development Center, and the White Sands Missile Range.

By the end of fiscal year 1965, ground based qualification tests of the ascent engine will be complete, and qualification testing of the descent engine at Arnold Engineering Development Center and the contractor's plant will be approximately 80 percent complete. The LEM ground test programs, on the mockup and test models, will be 90 percent complete.

In fiscal year 1965, 3 lunar excursion module articles will be delivered for use in subsystems integration tests, structural tests, and dynamic tests. Fabrication will be complete on the first LEM to be used for an unmanned propulsion development flight. Four LEM's for propulsion development flights will be in manufacture in fiscal year 1965 and delivered in fiscal year 1966. In fiscal year 1965 Grumman will initiate the system integration test program with LEM test article No. 1. Vibration testing on the Saturn V vehicle will be under way at the Marshall Space Flight Center with LEM test article No. 2 and dynamic and static tests will be in process at Grumman on LEM test article No. 3.

Guidance and Navigation. 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 during all phases of the flight development effort and finally for the flight to the Moon and Earth return.

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

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

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

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

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

This team of contractors will provide guidance and navigation equipment for both the command module and the lunar excursion module. To a large degree, identical types of equipment will be used in both modules.

During fiscal year 1964, sub-components of the command module's guidance and navigation system will be extensively tested and qualified. Five of the functional guidance and navigation systems will be completed and will undergo a variety of mechanical, electrical, thermal, and vibration tests. Two additional systems will be delivered for integration and checkout in Apollo spacecraft.

In fiscal year 1965, development, qualification, and reliability testing of the guidance and navigation hardware for the command module will be completed. Fourteen command module guidance and navigation systems, including four flight qualified systems, will be delivered in support of the developmental ground and flight testing programs.

Contract negotiations for the LEM's guidance and navigation systems will be completed in fiscal year 1964. During this time, designs for LEM equipment will be finalized and construction of experimental and developmental models of its guidance and navigation system will be started.

Developmental and functional guidance and navigation systems for the LEM will be delivered in fiscal year 1965. The sub-components will undergo reliability and environmental testing and the first pre-production systems will be delivered.

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Instrumentation and Scientific Equipment. Funds requested for instrumentation and scientific equipment will be used to develop and procure the specialized flight research and test instrumentation equipment required during the spacecraft developmental flight testing. (The development and procurement of scientific equipment for in-space and lunar scientific experiments is funded in the Space Sciences budget and is not included as a part of the Manned Space Flight requirement.) Typical instrumentation includes signal conditioners, sensors, transducers, telemetry transmitters, transmitting antennas, and ground support equipment. (Typical scientific equipment includes special cameras, magnetometers, seismographs, and radiation measuring devices.)

During fiscal year 1964, emphasis was on the design, procurement, fabrication, test and qualification of instrumentation (and scientific equipment) needed for 8 Apollo spacecraft tests, including spares. Deliveries of instrumentation hardware were made to North American Aviation for installation and checkout in developmental spacecraft.

Fiscal year 1965 funds will be employed to design, procure, fabricate, and test additional flight research and development instrumentation for 5 Apollo spacecraft flight tests, 6 Apollo spacecraft ground tests, and 3 LEM ground tests.

Spacecraft Support. Spacecraft support for Apollo includes the requirement for Little Joe II launch vehicles, supporting development, pre-flight automatic checkout equipment (PACE) and aerospace medicine.

The Convair Division of the General Dynamics Corporation was selected in May 1962 to design, develop, and fabricate six Little Joe II launch vehicles. In June 1963, 2 additional Little Joe II vehicles were added to the contract, bringing the total to eight vehicles. Fabrication of the first 4 vehicles will be completed in fiscal year 1964, as will development and flight testing of the Little Joe II attitude control system. The Little Joe II provides the capability to obtain necessary flight test data on the spacecraft abort and propulsion systems at much lower cost than using the full-scale Saturn. The funds required in fiscal year 1965 will complete production of the eight Little Joe II launch vehicles and will purchase rocket motors and attitude control systems for all tests now planned.

Funds are also required for utilization of other government installations and for special test equipment at NASA installations in direct test support of the spacecraft development effort. The funds will also cover hardware development and technical effort in direct support of the spacecraft not funded in the prime contract. Also included are funds for propellants for the various spacecraft engine development tests and the special tooling required to support the subcontractors' manufacturing effort.

The spacecraft checkout (pre-flight) program includes engineering studies conducted by General Electric and other qualified contractors for the Apollo program office at NASA Headquarters and related Centers. The fiscal year 1964 and fiscal year 1965 funding program also includes funds required to procure or fabricate the checkout hardware for 9 Pre-Flight Automatic Checkout Equipment (PACE) stations.

Aerospace medicine support for Apollo includes test and evaluation of specific items of hardware or systems, developed or proposed for use, which are related to the maintenance, protection, and effective performance of the astronauts before, during, and following a space mission. The following tasks will be supported with funds allocated to this area in fiscal year 1965:

(1) Effort will be continued on the manned testing of complete command module and LEM environmental control (life support) systems, as well as testing of individual components. Current problems involve extending mission time, providing automatic controls, and increasing the reliability of the system within the given weight limitations.

(2) Prototype Apollo space-suit assemblies for use in the first manned Apollo mission and for the lunar landing mission will be produced. This effort includes establishment of design requirements for the extra-vehicular and lunar suit assembly, qualification and evaluation programs, and validation of the suit to assess its capability to meet total mission requirements. Apollo biosensors will also be developed, with the primary development objectives of miniaturization and a standard clinical approach. In addition, a study will be initiated on visual problems associated with activity on the lunar surface and with critical maneuvers, such as rendezvous. Glare and distortion in the space environment will be the primary variables investigated and preventive measures or aids will be developed as necessary.

(3) The Apollo mission requires the ability to identify the effects of radiation on crew members. Development will be initiated on sensitive and reliable indicators of radiobiological effects and methods of measuring progress in medical recovery from radiation.

(4) Medical operations activities include the implementation of the medical recovery plan and the medical selection of the astronauts, their training in the physiological bases for the life support systems, and the reduction and analysis of medical data obtained from training and simulation programs, in the same manner as the Mercury data, to provide a consistent base for comparison and analysis with data obtained in flight.

H-1 Engine

	1963	1964	1965
Engine development.............	$5,610,000	$9,100,000	$8,200,000
Propellants....................	650,000	2,000,000	1,600,000
Total costs..................	$6,260,000	$11,100,000	$9,800,000

The H-1 engine, which is being developed by the Rocketdyne Division of North American Aviation, is used in the first stage of Saturn I and Saturn IB vehicles. Eight of these engines are used in the stage. This engine uses liquid oxygen and RP-1 (kerosene) as propellants to produce up to 200,000 pounds of thrust.

Development of a 165,000-pound thrust H-1 engine was initiated by the Department of Defense in September 1958 as an improved version of Thor-Jupiter engines. Responsibility for development of this engine was transferred to NASA in 1960. The engine has been used successfully in the first four Saturn I launches. A 188,000-pound thrust version will be used in the remaining six flights of Saturn I. A 200,000-pound version will be developed and used in all Saturn IB vehicles. Although the H-1 has been flown successfully at the 165,000-pound thrust level, certain components required modification to assure reliable performance at higher thrust levels. In particular, the nickel thrust chamber tubes have been replaced by stainless steel tubes to compensate for the reduced service life caused by the increase in thrust chamber pressure required by the up-rating of the engine.

Development of a 200,000-pound thrust version of the engine for the Saturn IB is necessary to insure attainment of the required payload capability. This additional development effort will begin in fiscal year 1964 and continue in fiscal year 1965. The fiscal year 1964 effort will include a complete stress analysis for critical engine components at increased flight loads created by the higher engine thrust operating level and a program of engine system tests to determine operating limits. Only those components found to be marginal during stress analysis and 200,000-pound thrust level testing will be redesigned. The fiscal year 1965 up-rating effort will consist of a development and testing program to complete engine qualification at the 200,000-pound thrust level by the end of the second quarter of fiscal year 1965. The development program will continue to provide support to the Saturn I/IB flight program.

RL-10 Engine

	1963	1964	1965
Engine development............	$22,436,000	$16,000,000	$13,900,000
Propellants...................	7,209,000	4,000,000	4,000,000
Total costs.................	$29,645,000	$20,000,000	$17,900,000

The RL-10 A-3 engine is being developed by Pratt and Whitney for use in a cluster of six in the second stage of the Saturn I vehicle, (and a slightly modified version of the engine in pairs in the second stage of the Centaur vehicle). Each engine, using liquid hydrogen and liquid oxygen as propellants, develops 15,000 pounds of thrust.

Development of the RL-10 A-3 engine, the responsibility of the NASA in 1961, followed the RL-10 A-1 engine program initiated by the Air Force in

1958. The RL-10 A-3 successfully completed its Preliminary Flight Rating Tests (PFRT) in July 1962 and is ready for flight use. The first ground test firing of a cluster of 6 RL-10 A-3 engines was made in January 1963. A pair of engines was flown successfully in the Centaur vehicle in November 1963. The qualification testing program for the RL-10 A-3 engine will continue into fiscal year 1965.

During the fiscal year 1965, approximately 900 ground tests will be performed. The test program will require the rebuilding of 7 engines and the fabrication of 6 new engines during the year. Developmental effort will also continue in the following areas: Saturn and Centaur vehicle flight support, production support and product improvement.

Accomplishments in fiscal year 1965 will include completion of qualification of the pressurant heater and the increased expansion nozzle, completion of the evaluation of the hastelloy chamber, and completion of the propellant utilization valve contamination test.

F-1 Engine

	1963	1964	1965
Engine development.............	$50,082,000	$55,300,000	$55,100,000
Propellants....................	3,621,000	7,000,000	9,000,000
Total costs..................	$53,703,000	$62,300,000	$64,100,000

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

Development of the F-1 engine was begun in January 1959 when NASA awarded a contract to Rocketdyne for development, through Preliminary Flight Rating Tests (PFRT), of a 1,500,000-pound thrust LOX-RP-1 rocket engine. In June 1961, the test firing of the first F-1 engine was accomplished. Since that time, F-1 engines have achieved rated thrust and duration (150 seconds) many times. During the latter part of 1962, a developmental problem of combustion instability reached serious proportions. This instability problem has been attributed to difficult detailed design problems associated with extremely large injectors and turbopumps. A task force composed of NASA, Department of Defense, University and Industry experts was assigned to attack this problem and recommend solutions. As a result of this activity, several injector designs were evolved which produce stable combustion. However, a substantial program of testing must still be accomplished to prove that other engine requirements such as performance, durability, and pressure drop are not compromised by an injector of satisfactory stability. The final release of the design of the PFRT engine was made in the first quarter of fiscal year 1964, and testing is scheduled for completion in the third quarter of the same fiscal year. The design for the qualification engine will be released in fiscal year 1965.

During fiscal year 1965, 300 separate engine ground tests will be performed. These tests are part of the 1,289 planned engine system tests that will be performed to qualify the engine for manned flight. Major test effort programmed for fiscal year 1965 includes:

(1) Demonstration of highly improved pump performance;

(2) Completion of the engine flight-rating tests;

(3) Demonstration of the engine's ability to recover from rough (unsteady) combustion without harm;

(4) Initiation of testing of the engine under simulated flight-environment conditions.

Four new engines will be built and 12 engines will be rebuilt during the budget year as part of the total test program.

J-2 Engine

	1963	1964	1965
Engine development.............	$38,779,000	$48,350,000	$47,600,000
Propellants....................	7,990,000	8,250,000	14,000,000
Total costs..................	$46,769,000	$56,600,000	$61,600,000

The J-2 engine is being developed by the Rocketdyne Division of North American Aviation at Canoga Park, California, for use in upper stages of the Saturn IB and Saturn V vehicles. The engine is designed to develop 200,000 pounds of thrust, using liquid oxygen and liquid hydrogen propellants. One J-2 engine will be used in the second stage of the Saturn IB vehicles. In the Saturn V vehicle, a cluster of five J-2 engines will be used in the second stage and a single engine in the third stage.

Development of the J-2 engine began in September 1960 with the award of the development contract to Rocketdyne. By October 1962, the engine achieved its first full-thrust (250-second duration) run. The first 500-second duration run as required for the S IV B stage of the Saturn V was successfully conducted on November 27, 1963.

In fiscal year 1965, 500 of the total of 1,470 engine system tests currently planned to complete the J-2 engine qualification, will be conducted. During the year, the engine will complete its flight rating test and will be qualified for unmanned flight. Testing for qualification of the fuel turbopump, gas generator, LOX turbopump, engine controls and engine flight instrumentation will be started in the budget year. In the process of accomplishing these tests, seven new engines will be built and fourteen engines will be rebuilt during fiscal year 1965.

Saturn I

	1963	1964	1965
S-I stage......................	$103,850,000	$59,000,000	$20,600,000
S-IV stage.....................	64,667,000	82,100,000	55,400,000
Vehicle instrument unit........	20,862,000	14,200,000	3,600,000
Ground support equipment.......	17,766,000	4,400,000	3,700,000
H-1 engine procurement.........	9,561,000	3,200,000	---
RL-10 engine procurement.......	14,950,000	4,900,000	---
Vehicle support................	25,231,000	36,400,000	37,300,000
Total costs..................	$256,887,000	$204,200,000	$120,600,000

The Saturn I is a two-stage, multi-purpose launch vehicle. The first stage, S-I, is being developed and produced by the Marshall Space Flight Center and the Chrysler Corporation. Chrysler is manufacturing this stage at the Michoud Plant of the NASA. A cluster of eight H-1 engines, using kerosene and liquid oxygen propellants, gives the S-I stage a capability of 1,500,000 pounds of thrust. The H-1 engines are being developed and produced by the Rocketdyne Division of North American Aviation. The second stage, S-IV, is being developed and produced by the Douglas Aircraft Company and will be powered by a cluster of six RL-10 liquid oxygen and liquid hydrogen engines with a total thrust of 90,000 pounds. The RL-10 engines are produced by Pratt and Whitney Aircraft.

The Saturn I development program has advanced into the second phase of hardware development which involves flight testing with live second stages. Four successful launches of the first stage, "Block I" configuration, have been conducted. Flight tests with "Block II" vehicles, composed of live first and second stages, will commence in fiscal year 1964 with the launching of SA-5 and SA-6. The remaining "Block II" launches are scheduled for fiscal year 1965.

Saturn I development has contributed significantly to the development concurrently in progress on the Saturn IB launch vehicle. The first stages of both of these vehicles have similar basic structural configurations with the exception of redesigned tail fins and the supporting structure for the Saturn IB's larger second stage (S-IVB). The first stages of both vehicles are powered by eight Rocketdyne H-1 engines with similar accompanying propellant feed and pressurization systems. Propellant tanks on the Saturn IB first stage (S-IB) have been lengthened to increase propellant capacity, however, tooling and assembly methods have remained the same. An improvement in the thrust of the H-1 engine for the Saturn IB is planned with a minor change in engine design. Virtually all the support equipment for the first stages can be utilized on either vehicle.

S-I Stage. By the end of fiscal year 1964 fabrication of all stages will be in process or completed. The funds required in fiscal year 1964 reflect the heavy ground testing workload at the Marshall Space Flight Center and heavy manufacturing and ground testing workload at the Michoud Plant. Fiscal year 1965 will be the peak year, to date, for Saturn I launches and the majority of the funds requested will be used in the completion and preparation of stages for launch. Funds are also included for reduction of post-flight data, support of the housekeeping contractor at Michoud, and support of the Slidell Computer Facility.

S-IV Stage. The first live S-IV stage will be launched in fiscal year 1964. This flight test will be the first of two flights planned for the fiscal year. Four S-IV stages will be flown in fiscal year 1965. Funding prior to fiscal year 1964 was used for development engineering, fabrication of ground test stages and early flight stages, an extensive ground test program, and long lead-time stage procurement. Fiscal year 1964 funds support a major fabrication, assembly, and testing program affecting all stages to be used for the flight program. Fiscal year 1965 represents the culmination of manufacturing of S-IV stages and funding is geared to the completion and delivery of the four remaining stages to Kennedy Space Center for pre-launch checkout with the entire launch vehicle. As with the S-I stage, funds are provided for reduction of post-launch data and propellants for testing the stages.

Vehicle Instrument Unit. The Saturn I instrument unit, under development by the Marshall Space Flight Center, includes an inertial guidance system, a flight control system, a tracking system and a telemetry and measuring system. The major electronic components are being provided by Bendix and International Business Machines Corporation (IBM). In fiscal year 1964, basic development for all instrument units to be used in the Saturn I vehicle was essentially completed. In addition, fabrication and checkout of the four remaining instrument units for the Saturn I project will take place. As part of this effort, a new nonpressurized instrument unit (the design to be used on the Saturn IB and V), to be flown on the last three Saturn I vehicles, will be assembled and tested. Procurement of hardware for the ST-124 inertial platform, the guidance computer, and the guidance signal processor will be completed. Fiscal year 1965 funds will also support the cost of materials, tooling and special test equipment, and parts necessary to assemble the four remaining instrument units.

Ground Support Equipment. Ground support equipment (GSE) is non-facility hardware required to handle, operate, and checkout assembled vehicles. In fiscal year 1964, the initial GSE development for Launch Complexes 34 and 37 at the Kennedy Space Center and procurement and delivery of major sets of GSE were essentially completed. Fiscal year 1965 funds will be used to provide for maintenance of electrical support equipment, handling equipment, and other vehicle - GSE associated with the launch complexes.

H-1 Engine Procurement. The last H-1 engines required for Saturn I development were procured with fiscal year 1963 funds. Fiscal year 1964 funds were for support hardware, spares, and support services. No procurement funds are required in fiscal year 1965.

RL-10 Engine Procurement. Procurement of RL-10 engines required for Saturn I development will be completed in fiscal year 1964 with the delivery of 20 engines. No procurement funds are required in fiscal year 1965.

Vehicle Support. Vehicle support funds are required to provide research analysis, equipment, combined system testing, and other various services that are common to more than one stage or system of the vehicle. Fiscal year 1964 funding includes computer systems analysis; wind-tunnel tests; hardware standardization tests, tooling and special test equipment; quality assurance and inspection services; propellant testing; barge and air transportation services and equipment, and component testing. In fiscal year 1965, effort will continue in these areas, and funding will include special equipment for liquid hydrogen testing; tooling and special equipment for improvement of advanced checkout techniques applicable to Saturn IB and V operations; critical vehicle component testing; instrumentation of the dynamic vehicle; electronic computer hardware parts for special modification and interfaces of equipments; transportation of all stages and payloads; launch support services at the Kennedy Space Center in support of Saturn I launches including refurbishment of the pad after launch, and post-launch vehicle analysis; personnel training; systems analysis and studies; documentation; and propellant for launches.

Saturn IB

	1963	1964	1965
S-IB stage......................	$4,745,000	$39,200,000	$79,100,000
S-IVB stage.....................	4,500,000	21,600,000	57,000,000
Vehicle instrument unit.........	311,000	14,200,000	28,400,000
Ground support equipment........	6,926,000	33,000,000	31,500,000
H-1 engine procurement..........	1,700,000	8,000,000	12,400,000
J-2 engine procurement..........	2,050,000	6,400,000	11,000,000
Vehicle support.................	1,039,000	27,500,000	40,700,000
Total costs..................	$21,271,000	$149,900,000	$260,100,000

The Saturn IB is essentially an uprated version of the Saturn I vehicle and is required as a test bed for Saturn V components and to provide the capability for Earth-orbital flight testing of the Apollo spacecraft. The first stage, the S-IB, is a modified version of the S-I stage of the Saturn I vehicle and is being developed by the Chrysler Corporation Space Division. It will be powered by an uprated set of eight H-1 engines capable of developing a sea-level thrust of approximately 1.6 million pounds. The second stage, the S-IVB, is being developed by the Douglas Aircraft Company. Its basic design characteristics are common to the S-IV stage of the Saturn I vehicle.

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The significant differences between the S-IV stage and the S-IVB stage are increased propellant capacity and replacement of a cluster of six RL-10 engines with a single J-2 engine. With some modifications, the S-IVB will also be used as the third stage of the Saturn V vehicle.

S-IB Stage. Development of the S-IB stage was started in fiscal year 1963. Fiscal year 1963 funding provided for stage redesign required to reduce structural weight and to accommodate a new interface with a larger diameter second stage, the S-IVB. Fiscal year 1963 funds also provided for necessary long lead-time procurement of stage hardware. In fiscal year 1964, S-IB design and fabrication activity increases greatly. The first two flight stages will be in manufacturing; and long lead-time hardware will be procured for the first four stages. During fiscal year 1965, the first flight stage (S-IB-1) will be assembled and static tested. Fabrication and assembly of S-IB-2 and S-IB-3 will be completed and assembly of the S-IB-4 will be under way. At the same time component testing as a check on systems reliability will be increased. In addition, long lead-time hardware required for S-IB-5 through S-IB-9 will be procured.

S-IVB Stage. The primary developmental effort for the S-IVB stage is being funded in the Saturn V project. Funds requested for the S-IVB stage include the engineering design effort and modifications required to adapt the stage for use in the Saturn IB; the actual hardware used in the project; and the cost of accelerating development to make the stage available for the Saturn IB flight schedule. A relatively low level of effort was maintained in fiscal year 1963 and consisted for the most part of preliminary design work on the stage and associated ground support equipment. In fiscal year 1964, considerable progress is planned for major tooling, fabrication, and stage tank structural testing. Battleship and structural testing will start late in the fiscal year. Fabrication of stages for the dynamic, all-systems, structural, and facility checkout ground tests will be in process and production of the first two flight stages will be under way. In fiscal year 1965, the fabrication, assembly, and checkout of the remaining ground test stages will be completed. Structural tests will be completed and all-systems tests will be under way. The first flight stage will be completed and a static test firing will be conducted. Structural fabrication, assembly, and checkout of the second flight stage will be completed and fabrication and assembly of the third and fourth flight articles will be under way. Procurement of long lead-time items for S-IVB-5 through S-IVB-9 will be funded.

Vehicle Instrument Unit. Fiscal year 1964 instrument unit funds provide for continuing design and development of Saturn IB-peculiar equipment, procurement of long lead-time items for the first four Saturn IB units (S-IU-1 through S-IU-4), and the start of fabrication of the first flight unit. During fiscal year 1965, incremental funding of the first four flight units will continue. The first flight unit will be completed and assembled; fabrication of the second one will be completed and assembly will be started; fabrication of subsystems for the next two instrument units will be initiated. In addition, long lead-time procurement will begin for five additional units.

Ground Support Equipment. In March 1963 it was decided to provide an automatic checkout system for the Saturn IB as a test unit for Saturn V checkout procedures. Fiscal year 1963 funding initiated the development of a checkout prototype (breadboard) for this purpose. Funding of the prototype will be essentially complete by the end of fiscal year 1964. The design effort will be intensified and procurement will be initiated during fiscal year 1964. Additional engineering development and component testing for computers and associated equipment will be required during fiscal year 1965. Two computers for the breadboard and two for Launch Complex 37 at the Kennedy Space Center will be delivered during the budget year and procurement of the instrument unit checkout station will be completed. Outfitting of the west side of the static test stand at Marshall Space Flight Center will be finished. In addition, provision is made for maintenance of Saturn IB test and checkout equipment.

H-1 Engine Procurement. Fiscal year 1964 funding provides for 12 engines that will be delivered in fiscal year 1964 and for procurement of long-lead hardware deliveries in fiscal year 1965. The fiscal year 1965 estimate includes 42 engines to be delivered in fiscal year 1965, and procurement of long-lead hardware for 38 engines to be delivered in fiscal year 1966. Estimates for both fiscal years include support hardware, services, and propellants for acceptance testing of the engines to be delivered.

J-2 Engine Procurement. Fiscal year 1964 funding provides for procurement of long-lead hardware for deliveries in fiscal year 1965. The current request covers 8 engines to be delivered in fiscal year 1965 and procurement of long-lead hardware for 7 engines to be delivered in fiscal year 1966. Estimates also include requirements for support hardware and services.

Vehicle Support. Vehicle support includes funds necessary to provide studies, services, or equipment that are common to more than one stage or system of the vehicle. Fiscal year 1964 funding includes system analysis of the Saturn IB vehicle and associated ground support equipment (GSE). Other areas of investigations are performance, weight control, stage and payload separation, emergency detection studies, wind tunnel testing, reliability testing, and vehicle control and simulative tests. Also included are a pro-rated share of computer services used by all Saturn-class vehicles, and engineering support services not specifically identified with individual stages or vehicle units. In fiscal year 1965, funds are required for the maintenance, logistic support, addition to ground telemetry equipment; procurement of instrumentation, an RF system, telemetry and GSE measuring equipment; direct engineering support in such areas as test program preparation and test analysis; additional wind tunnel and dynamic testing; and transportation.

Saturn V

	1963	1964	1964 Supplemental	1965
S-IC stage...........	$129,388,000	$218,300,000	$31,100,000	$271,600,000
S-II stage...........	95,088,000	134,600,000	30,500,000	189,900,000
S-IVB stage..........	51,359,000	95,600,000	20,400,000	126,800,000
Vehicle instrument unit...............	12,045,000	69,900,000	---	78,100,000
Ground support equipment..........	6,425,000	25,800,000	---	70,100,000
F-1 engine procurement...............	14,601,000	45,000,000	11,200,000	67,400,000
J-2 engine procurement...............	14,450,000	24,900,000	16,800,000	45,300,000
Vehicle support......	20,086,000	75,500,000	---	139,200,000
Total costs........	$343,442,000	$689,600,000	$110,000,000	$988,400,000

The Saturn V is a three-stage launch vehicle with the capability of placing into low Earth orbit a payload in excess of 120 tons and providing for escape trajectories for payloads of about 45 tons. The Saturn V project was approved in January 1962, following an extensive series of studies on vehicle configurations for the manned lunar landing. The Boeing Company, Aerospace Division, was selected as contractor for the first stage (S-IC); North American Aviation, Inc., Space and Information Division, for the second stage (S-II); and the Douglas Aircraft Company, Missiles and Space Division, for the third stage (S-IVB). Work was initiated with North American in October 1961, with Douglas in December 1961, and with Boeing in February 1962. F-1 and J-2 engines, produced by the Rocketdyne Division of North American Aviation, are provided as government furnished equipment to the stage contractors. Major contractor effort has been reoriented to include the recent decision to adapt the "all-up" concept of flight testing. On the first launch of the flight test program all stages will be live.

S-IC Stage. The Marshall Space Flight Center, with Boeing's assistance, will assemble and test the first ground test stages at Huntsville, Alabama. During fiscal year 1962 and continuing into fiscal year 1963, major effort was placed on design, facility planning, research studies, and acquisition of tooling and test equipment. Component testing was started in fiscal year 1963 and fabrication was initiated on the first ground test stages. Fiscal year 1964 will complete the major portion of fabrication and assembly of the all-systems stage and will mark the start of fabrication and assembly of the dynamic test stage. The fabrication and assembly of some structural test components will be completed and fuel tank testing will begin. Long lead-time hardware for the last ground test stage and the first flight stage will be funded. In fiscal year 1965, the dynamic test stage will be completed and all-systems and structural tests will be started. In addition, the facility checkout and the first flight stage, S-IC-501, will be assembled and fabrication of succeeding flight stages, S-IC-502 and S-IC-503, will be started. Long lead-time hardware procurement for the fourth flight stage, S-IC-504, will also begin.

S-II Stage. In fiscal years 1962 and 1963, the major S-II efforts were concerned with preliminary and detailed designs, procurement of special tooling and test equipment, procurement of components for design verification and qualification testing, and long lead-time hardware procurement for early stages. During fiscal year 1964, fabrication of the battleship stage and the structural stage continued. In addition, fabrication and assembly of the all-systems dynamic, and facility checkout stages were initiated. Procurement of long lead-time hardware for the first two flight stages began. In fiscal year 1965, major stage testing, such as battleship and structural testing, will be initiated. The all-systems stage fabrication and assembly will be completed and checkout will be inaugurated. Both the dynamic and facility checkout stages will be partially assembled. Fabrication of four flight stages will be in progress and long lead-time procurement will be initiated on the fifth flight article.

S-IVB Stage. The S-IVB stage is a modified version of the S-IV. Although it will be used also in the Saturn IB, the basic development costs are being charged to the Saturn V. As with the S-IC and S-II stages, funding in fiscal years 1962 and 1963 was used to provide design, facilities planning and tooling, and procurement of long lead-time hardware. Qualification testing of components was also started during this period. Initiation of major stage testing, including battleship and structural tests, was provided for in fiscal year 1964. During fiscal year 1964, the Douglas Aircraft Company began the fabrication and assembly of the all-systems, dynamic and facility checkout stages. Long lead procurement of hardware and fabrication for the first flight stage was also started. Ground testing will be intensified in fiscal year 1965 and the last ground test stage, the facility checkout stage, will be delivered. Fabrication of the first flight stage will continue and long lead procurement for the next flight stages will be initiated.

Vehicle Instrument Unit. The vehicle instrument unit includes an all-inertial guidance system, a control system, and telemetry and measuring capabilities. It is being developed and assembled by the Marshall Space Flight Center. The major electronic components are provided by the Bendix and IBM corporations. Fiscal year 1962 and 1963 funds provided for initial design, component testing and a continuance of guidance system research and development, based on experience with the Saturn I project. In fiscal year 1964, the design and engineering of components will continue and the first two ground test units vibration and structural, will be delivered. Structural testing will be performed. During fiscal year 1965, the procurement, fabrication, and acceptance testing of components will continue and the procurement of long lead-time items for SA-501 and SA-502 will be started. The remaining four ground test units (the breadboard, facility checkout unit, dynamic unit, and flight systems unit) will be delivered. Vibration testing will be completed and the dynamic and flight systems tests will begin.

Ground Support Equipment. Ground support equipment (GSE) is non-facility hardware required to handle, operate, and checkout the assembled vehicles. Fiscal year 1964 funds were used almost exclusively for the development of automatic checkout equipment to facilitiate pre-launch countdowns and to improve launch reliability. Fabrication of a prototype set of equipment (breadboard) was also started and procurement was initiated for equipment to be installed in Launch Complex 39 facilities. The Saturn V breadboard will be completed in fiscal year 1965 and procurement actions will continue to provide the minimum checkout equipment essential for the first facility checkout and launch of a Saturn V vehicle. Fiscal year 1965 funds will also be used to develop and procure special test equipment and components.

F-1 Engine Procurement. The fiscal year 1964 funding provides for 2 engines to be delivered in the current year, and procurement of long-lead hardware for 19 engines. The fiscal year 1965 estimate provides for engines to be delivered in fiscal year 1965, and procurement of long-lead hardware for 30 engines. Funds in both fiscal years provide for procurement of support hardware and services and propellants for acceptance testing.

J-2 Engine Procurement. The fiscal year 1964 estimate provides for 11 engines to be delivered in the current year and procurement of long-lead hardware for 26 engines to be delivered in fiscal year 1965. Fiscal year 1965 funding provides for engines to be delivered in fiscal year 1965 and procurement of long-lead hardware for 41 engines to be delivered in fiscal year 1966. Funds in both fiscal years also provide for support hardware, support services and propellants for acceptance testing of the engines.

Vehicle Support. Vehicle support funds are required to provide services and equipment that are common to more than one stage or system of the vehicle. Fiscal year 1964 funding includes instrumentation, recording, and data reduction equipment for the Saturn V dynamic test stand; development of transportation capabilities, such as modifications of marine vessels for stage transportation; use of a special airplane, the "Pregnant Guppy," for emergency movement of out-sized cargo; a pro-rata share of computer services used by all Saturn vehicle projects; range safety devices and tracking beacons for use during Saturn V flights; and engineering support. In fiscal year 1965, these basic activities will be continued. Fiscal year 1965 funding includes special tooling and fabrication of test hardware and fixtures; procurement of special test equipment for calibration and support of component testing; expansion of wind tunnel testing to determine acoustical environment, pressure distribution, static stability, vehicle flutter analysis and heat transfer; a cryogenic flow calibration stand, hybrid simulation facilities; real time digital simulation equipment; an analog flight simulator; data reduction equipment; control system hydraulic simulation equipment; dimensional and non-destructive testing equipment for assembly and quality verification; vehicle propellant blast hazard testing; activation and operation of dynamic test stand.

Apollo Support

	1963	1964	1965
Systems engineering............	$20,425,000	$40,900,000	$46,000,000
Launch operations and instrumentation..............	7,672,000	36,500,000	51,300,000
Mission control systems........	7,989,000	52,500,000	41,400,000
Apollo space operation.........	370,000	2,900,000	21,600,000
Supporting technology..........	25,570,000	46,500,000	48,900,000
Spacecraft technology........	(7,963,000)	(18,700,000)	(20,200,000)
Launch vehicle technology....	(6,299,000)	(12,900,000)	(13,000,000)
Propulsion technology........	(9,004,000)	(12,800,000)	(12,200,000)
Launch operations technology.	(2,304,000	(2,100,000)	(3,500,000)
Total costs..................	$62,026,000	$179,300,000	$209,200,000

Apollo support consists of the supporting technology and engineering effort related to total mission requirements, including space vehicle reliability and development and maintenance of the launch and flight operations necessary for the accomplishment of the Manned Lunar Landing program.

Systems Engineering. This activity provides for the program-wide technical support needed for the successful accomplishment of Apollo. It is designed to provide assurance that the functional and performance requirements placed upon all elements of the program are compatible with each other and with the mission objectives. Studies undertaken in early fiscal year 1963 reaffirmed the selection of the lunar orbital rendezvous (LOR) mode for the Apollo mission. Recent systems engineering activities include development of specifications for Apollo that insure that each subsystem element will be developed in accordance with the overall system requirement. Fiscal year 1964 funding provided for the initiation of studies concerning mission description and planning, test objectives and integration, systems specifications, guidance and navigation, communications and tracking networks, checkout effectiveness, and documentation. Systems engineering receives principal support from both Bellcomm and General Electric. Fiscal year 1965 funding provides for an extension of most of the analyses now under way and initiation of new efforts, where required, as the program advances. There will be some shift of emphasis to reliability studies, including mission safety analysis, mathematical model development, and failure effects analysis.

Launch Operations and Instrumentation. The funds in this category provide for the launch instrumentation necessary to measure and record the launch performance of space vehicles used in the Manned Lunar Landing program; the support provided by range contractors and the Air Force; basic equipment, supplies and stock material required by the range contractors or the Air Force in support of the program; and the maintenance and necessary alteration of facilities in the Merritt Island Launch Area and at Launch Complexes 34 and 37 at the Kennedy Space Center. The division of responsibilities between NASA and the Air Force were delineated in an agreement between the Administrator and the Secretary of Defense on January 17, 1963.

Mission Control Systems. Mission control systems activities include development, operation, and maintenance of the Integrated Mission Control Center (IMCC) at the Manned Spacecraft Center and associated interface equipment at the Kennedy Space Center. It also provides for the technical integration of the IMCC with the world-wide manned space flight network.

The IMCC building is nearly complete and beneficial occupancy is scheduled for March 1964. Implementation of the real-time computer complex by IBM has progressed rapidly. Three of the four large digital computers required are temporarily in a rented building and are being used for preparation of computer programs and operational planning. The balance of the technical systems within the IMCC, under contract to Philco, are being developed and procured and all major equipment is scheduled to be available by the end of fiscal year 1964. Integrated testing of the IMCC with the manned space flight network will be conducted in fiscal year 1965. Fiscal year 1965 funds are needed for the completion of the IMCC and for operation and maintenance of the IMCC. Also included is the Apollo launch data system, consisting of equipment at Kennedy Space Center for data format conversation and signal conditioning prior to transmission to the IMCC at the Manned Spacecraft Center.

Apollo Space Operation. Apollo space operations required for the support of flight missions can be classified into three major categories: Pre-flight, flight, and crew.

Pre-flight operations include the effort required to check-out the spacecraft at the launch area prior to launching. Fiscal year 1965 funds will be utilized to carry on the effort initiated in the fiscal year 1964. These funds will provide for the contractor services required for collecting, recording and evaluating the checkout telemetry data; the connecting of the ground support equipment to the facilities; the engineering and design effort required for connecting the ground support equipment; the cryogenic and hypergolic consummables required for testing and flight loading the spacecraft; and the common-use spacecraft consummable spares utilized by Apollo contractors.

Flight operations includes the planning, support and actual accomplishment of manned missions from lift-off to recovery. Flight operations may be divided into three distinct areas: Mission planning; flight control; and operational support.

Fiscal year 1964 funding for mission planning supported development of real time computer programs, booster closed-loop guidance equations, mathematical techniques for trajectory programs, and the procurement of a hybrid computer to provide an analytical capability for the development of real time computer programs for mission analysis and support. Fiscal year 1965 funds will be used to continue the support of these mission planning functions.

The fiscal year 1964 funds allocated for flight control were used to provide contractor support personnel for flight monitoring and remote site operation, flight controller training aids, and accessory and auxiliary equipment for flight controllers. Fiscal year 1965 funds will be used to continue support of the above items and, in addition, provide engineering studies of flight control techniques.

Fiscal year 1965 funds will be used to continue studies begun in fiscal year 1964 on recovery operation techniques, tests of spacecraft landing and recovery systems, and procurement of handling and retrieval equipment for Apollo.

Crew operations provides for crew training and integration of crew activities with the engineering design and development of Apollo spacecraft and with flight mission planning and training. The equipment requirements for crew training include a free-flight lunar lander, a crew procedures development trainer, in-flight test systems hardware, and centrifuge cockpit equipment.

Fiscal year 1964 funds provide for astronaut academic, survival, and mission training. Fiscal year 1965 crew operations funding will provide for fabrication and testing of the crew procedures development trainer and will continue crew training commensurate with trainer availability.

Supporting Technology. This is a project of individually selected engineering tasks primarily supporting the broad Apollo program. The project includes studies and hardware developments which will provide increased assurance of meeting the performance and reliability requirements of the Apollo program. This effort includes investigations of improved or alternate systems, subsystems, components and materials which can be phased into the present Apollo program in a timely fashion as required.

The tasks fall into four general categories -- spacecraft, launch vehicles, propulsion, and launch operations.

Apollo spacecraft technology deals with materials and structures, flight systems development, and human factors. Alternate structural subsystems will be designed and evaluated under the specific launch and flight environments to be encountered by the spacecraft. Effort will be continued to improve spacecraft seals and sealing techniques. Improved protective systems will be investigated to provide flight crews with an environment which is as safe and comfortable as can be provided. Development of alternate hardware, based on new technology will be started, to make improved equipment available on a timely basis.

In the launch vehicles category, primary emphasis is being placed on the improvement of structures and propulsion systems, and the integration of the engines into the launch vehicles. Problems associated with vehicle aerodynamics, and guidance and control requirements will be investigated. Recent advances in the state-of-the-art will be applied to alternate approaches for the mainstream hardware development.

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Propulsion technology effort is directed toward current development problems as well as improved engine system components. Investigations will be continued into the problems of combustion instability and propellant pump stalls during start up. Effort is also being directed into the area of pulse-operated reaction control engines, on tankage and components for small pressure-fed systems, and on propellant performance for application to spacecraft propulsion systems.

In the launch operations, tasks relating to the fueling system, for the handling of liquid oxygen and kerosene, hypergolic fuels and oxidizers, and the simultaneous handling of liquid oxygen and liquid hydrogen will be studied. Ground support equipment and techniques, will also be studied in an effort to reduce the time required for checkout.

OFFICE OF MANNED SPACE FLIGHT — ADVANCED MISSIONS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

From the experience and technological advancement gained to date with Mercury, Gemini, and Apollo missions, advanced manned space flight mission concepts are examined through advanced studies designed to determine the logical extension of the national space capability. Development of the capability for manned lunar landing and return provides to the nation the scientific and technical knowledge of the space and lunar operations necessary to undertake long-term Earth-orbiting satellite missions, scientific exploration of the Moon, and ultimately, exploration of the planets. Planning of this type is essential to provide information upon which to base future program decisions.

SUMMARY OF RESOURCES REQUIREMENTS:

	1963	1964	1965
Advanced studies................	$11,391,000	$22,100,000	$26,000,000

BASIS OF FUND REQUIREMENTS:

	1963	1964	1965
Advanced studies................	$11,391,000	$22,100,000	$26,000,000

The objectives of the advanced studies are to analyze present hardware systems for growth potential; to develop requirements for future systems; to provide guidance for research and technology activity; and to provide information upon which future program decisions can be based.

This activity will enable the NASA to advance technology in required areas, provide a sound basis for future programs, and permit near optimum scientific and technical programs. Advanced planning is necessary and essential to enable full consideration of the foregoing factors and of the resource requirements for future missions.

Advanced studies involve the continuing effort leading to the definition and preliminary design and specification of possible future manned space flight missions, based on the fact that exploration of the Moon is but the first major step in manned exploration of space. Specific areas of investigation include manned satellites, manned lunar missions, and manned planetary missions.

Manned Satellites

During the past, studies have been directed toward (1) the demonstration of the technical feasibility of manned Earth-orbiting satellites, (2) establishment of the characteristics of orbiting manned laboratories, and (3) definition of major subsystems, such as life support system, power supplies, scientific and experimental instrumentation, data processing equipment, and stabilization systems. In addition, studies have been initiated to analyze logistic requirements for operational maintenance of manned satellites. This included launch facility requirements, refueling, resupply and emergency rescue methods, and configuration requirements for ferry and supply vehicles.

The fiscal year 1965 effort for manned satellites studies will place emphasis on optimization, specification preparation and preliminary plans for design of the various subsystems and configurations. The results of this effort will permit a detailed appraisal of the requirements for such a program beyond the approved military effort and will provide a sound basis for a hardware development program decision if required in the future.

Manned Lunar Missions

The prime objective of the Apollo program is to place two men on the lunar surface and to return them safely within this decade. This achievement will constitute the beginning of lunar exploration. Therefore, the principal emphasis of the manned lunar studies is to identify and define the most effective systems to support lunar exploration missions following the initial Apollo landings.

Studies are now underway involving systems to support initial surface reconnaissance operations in the immediate post-Apollo period and systems suited to more extensive lunar operations and scientific exploitation of the moon.

Systems being investigated for use in the period following the initial landing include the Apollo Logistic Support System (ALSS) and the Stay Time Extension Module (STEM). The ALSS would consist of an unmanned Apollo Lunar Excursion Module (LEM) descent stage, modified to be capable of landing approximately 7,000 pounds on the lunar surface, to include an appropriate family of surface equipment. This equipment would include surface vehicles and shelters to extend the mobility, stay time, and capability of Apollo astronauts. The STEM would consist of a modified Apollo LEM capable of providing modest extension of lunar surface stay time for the astronauts beyond that presently provided.

The principal system being investigated for subsequent, more extensive operation is the Lunar Exploration System for Apollo (LESA), a flexible system which in its growth capability could provide a lunar base. LESA is conceived as a modular set of lunar surface hardware which can be quickly tailored to support a wide range of lunar exploration missions. The system includes surface vehicles, shelters, nuclear power plant, appropriate support equipment, and regenerative systems to reduce resupply requirements. From the family of LESA modules, sets of equipment could be assembled to meet the needs of either small or large groups of astronauts (up to 18 men) for lunar surface missions of either short or long duration.

Emphasis in the lunar study program is on laying a sound base for development of the ALSS, the most probable system for support of early lunar exploration missions. Following program definition studies during fiscal year 1964, it is anticipated that preliminary engineering work will be initiated in fiscal year 1965. This will include essential supporting development, detail design, preliminary mockups, and test articles.

Manned Planetary Missions

Considerable scientific and technical interest has centered around manned planetary missions; however, it is too early to define in detail either mission concepts or schedules. Primarily, the fiscal year 1964 studies are directed toward a better understanding of such a program.

In fiscal year 1965, the manned planetary mission effort will place primary emphasis on analysis of system feasibility and concept. Studies of scope, objective, schedules and cost will be necessary to select the most promising mission profiles for detailed engineering analysis in later years.

OFFICE OF SPACE SCIENCE AND APPLICATIONS GEOPHYSICS AND ASTRONOMY PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The fundamental objective of the Geophysics and Astronomy Program is to extend our knowledge and understanding of the space environment of the Earth, the Sun and its relationships to the Earth, the geodetic properties of the Earth, and the fundamental physical nature of the universe. Much of the space research accomplished under this program has been devoted to understanding the environment of the Earth. Sounding rockets, balloons, aircraft, and Explorer class satellites have been used for exploration of the Earth's upper atmosphere and ionosphere. Investigation of the Earth's magnetosphere and the great radiation belt have been conducted with Explorer-class satellites and large sounding rockets. These spacecraft will continue to be used together with Geophysical Observatories in an effort to obtain a comprehensive picture of the Earth's environment and to determine its variations with changes in solar activity. This basic understanding of the Earth's environment is important to the operation of manned and unmanned spacecraft and contributes to our knowledge of meteorology and communications. We also gain knowledge which will help us understand what we measure in the exploration of other planets.

Studies of the Earth's space environment have demonstrated the controlling effect that the Sun has on this environment, and they provide many important clues to the nature of the Sun. However, a comprehensive study of the Sun requires the use of astronomical instruments pointed at the Sun. Since much of the electromagnetic radiation emitted by the Sun is absorbed or distorted by the Earth's atmosphere, sounding rockets and Solar Observatories are being used to place the instrumentation above the atmosphere. To complement these observations, Explorer spacecraft are being launched into highly elliptical Earth orbits which take them into interplanetary space to monitor the arrival of solar protons, measure the solar wind, and explore the interplanetary magnetic field. These observations, together with the information on the space environment near Earth, will contribute to a vastly improved understanding of the Sun as a star, as a controlling influence on life here on Earth, and as a hazard to man's survival in space.

Through accurate tracking of satellites, it is possible to obtain data on the figure and structure of the Earth and to study the nature of the Earth's gravitational field and its interactions with the gravitational fields of nearby celestial bodies. These data are needed to develop a reference basis for all measurements of positions and maps of the Earth. They also provide a basis for calculation of orbits and trajectories of manned and unmanned spacecraft. Data from various satellites and space probes have been used to give improved calculation of the figure and structure of the Earth and its gravitational potential. The accuracy of these data is vastly improved when satellites are specifically instrumented to facilitate accurate tracking. Explorers will be flown with such instrumentation in a program which will continue the work initiated by the Department of Defense under Project ANNA.

While the preponderance of the space program is concerned with our own solar system, some of the most interesting and potentially most important discoveries await us in our investigation of the rest of the universe. The Sun is the only star which is close enough so that it can be studied in great detail, but observation of other stars and interstellar material can tell us much about the nature, evolution and natural laws of the universe that we cannot learn from the study of a single star, our Sun. Here again astronomical observations are hindered by the Earth's atmosphere; so sounding rockets, balloons, aircraft, and satellites are used to carry instrumentation up through the atmosphere. Astronomical Observatories represent our major effort in this area; but work with sounding rockets, balloons, aircraft, and Explorers have already demonstrated that observations in the ultraviolet, X-ray, gamma ray, and radio regions of the electromagnetic spectrum can give us much information that cannot be obtained from the largest Earth based telescopes.

SUMMARY OF RESOURCES REQUIREMENTS:

	1963	1964	1965
Supporting research and technology....................	$13,581,000	$15,100,000	$14,800,000
Solar observatories.............	10,900,000	18,800,000	22,100,000
Astronomical observatories......	39,250,000	47,700,000	51,000,000
Geophysical observatories.......	39,634,000	53,300,000	55,400,000
Explorers.......................	32,811,000	34,200,000	31,900,000
Sounding rockets................	11,513,000	17,100,000	15,000,000
Total costs..................	$147,689,000	$186,200,000	$190,200,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1963	1964	1965
Solar physics...................	$1,633,000	$2,200,000	$2,200,000
Astronomy.......................	2,087,000	2,600,000	2,600,000
Geophysics......................	9,065,000	8,800,000	8,500,000
Interdisciplinary...............	796,000	1,500,000	1,500,000
Total costs..................	$13,581,000	$15,100,000	$14,800,000

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 Science and Applications. The program includes theoretical and laboratory research, ground based observations, aircraft and balloon flight experiments, and advanced work leading to the development of satellite and rocket borne instrumentation. Data which have been obtained from various flight projects and ground based observation are correlated under this program to take advantage of all available information in arriving at conclusions. The cataloging and preservation of such data are also funded under this program.

In the field of solar physics, ground based monitoring is financed in conjunction with the work done by the National Bureau of Standards to complement the observations made with sounding rockets and Solar Observatories. Development of advanced instrumentation for future Orbiting Solar Observatories (OSO) and Advanced OSO spacecraft is also funded under this program. Laboratory and theoretical studies are conducted to interpret the data obtained and to provide a basis for solar flare predictions.

Astronomical research and technology efforts have consisted mostly of work directed at the development of instruments for future Explorer and Observatory flights. Observations from balloons and from the X-15 aircraft have also been funded from this program. The X-15 has been equipped with a three axis gyroscopically stabilized platform capable of pointing instruments at a predetermined portion of the sky. Ultraviolet photography experiments will be flown on this platform. This program also supports theoretical studies in geodesy, celestial mechanics, and stellar astrophysics. Some advanced work toward gravitational and relativity experiments is also funded.

The geophysics portion of the program covers a range of scientific disciplines supporting the study of the Earth's environment. It provides for theoretical and laboratory studies and instrumentation development in planetary atmospheres, space chemistry, meteoroids and micrometeoroids, energetic particles, magnetodynamics, and ionospheric and radio physics. The flight program has produced a considerable amount of data in these fields. The university groups, NASA field centers, and other research organizations participating in this program are correlating these data and incorporating the knowledge obtained in the planning and development of future flight experiments.

Interdisciplinary efforts include support of the Space Science Board, the National Data Center, and development of instrumentation useable in more than one of the scientific disciplines. The National Data Center will serve as a national repository for data resulting from world wide atmospheric and space research.

Solar Observatories

	1963	1964	1965
Orbiting Solar Observatory:			
Spacecraft......................	$3,824,000	$5,400,000	$4,700,000

	1963	1964	1965
Experiments.....................	$3,387,000	$5,300,000	$5,600,000
Ground operations...............	---	300,000	100,000
Delta launch vehicles...........	2,289,000	3,700,000	2,700,000
Subtotal costs (OSO)............	$9,500,000	$14,700,000	$13,100,000
Advanced Orbiting Solar Observatory:			
Spacecraft......................	$1,400,000	$4,100,000	$7,000,000
Experiments.....................	---	---	2,000,000
Subtotal costs (AOSO)...........	$1,400,000	$4,100,000	$9,000,000
Total costs.....................	$10,900,000	$18,800,000	$22,100,000

OSO I, launched in 1962, was the first of the observatory class of satellites. It provided the first monitoring of the Sun's extreme ultraviolet and X-ray radiation for a period of several rotations of the Sun. Seven similar spacecraft are scheduled for launch at approximately nine month intervals beginning in early 1964 and extending through 1968.

The spacecraft points an experimental package at the Sun to an accuracy of one minute of arc. Other experiments are carried in the spinning wheel which stabilizes the spacecraft. These experiments look at the Sun once with each revolution of the wheel.

Fiscal year 1963 and prior year funds provided for development of the first spacecraft and its experiments, for most of the development of the second spacecraft and its experiments, and for major development work on the third spacecraft and its experiments.

Fiscal year 1964 funds provide for final analysis of data from the first flight and for final preparations to launch the second spacecraft and analyze the data from its experiments. They provide for continuation of the development of the third observatory. Work is being initiated on the spacecraft and experiments for the fourth and fifth observatories.

Fiscal year 1965 funds will complete the analysis of data from the first two observatories and provide for final preparations for launch of the third and fourth. Major development work will be continued on the fifth observatory and development of the sixth observatory will be initiated. Long lead-time development of experiments for the seventh observatory will also be funded.

Fiscal year 1963 and prior year funds provided for procurement of the Delta launch vehicles for the first three observatories except for the final preparations for launch of the second and third. These preparations and the funding of the fourth vehicle are provided in fiscal year 1964. Fiscal year 1965 funds provide for the fifth launch vehicle.

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The total of eight observatories, including launch vehicles, will cost about $76,000,000 of which $10,705,000 was funded prior to fiscal year 1963. These observatories will provide the primary means of space flight research in solar physics until Advanced Orbiting Solar Observatory (AOSO) becomes operational.

AOSO is scheduled for its first flight in 1968. This observatory which is now in its initial stage of development will be capable of much more detailed observation of the Sun than OSO. While OSO looks at the Sun as a whole with limited capability to identify radiation from specific parts of its atmosphere, AOSO will have a capability for detailed study of solar activity pinpointed to specific areas of the Sun. It is being designed to point on command to within five seconds of arc of any desired point on the Sun and to track that position with a precision of one second of arc. The greater focal length of its instruments will greatly improve the resolution of the cellular structure of the Sun. It will point all of its instruments at the Sun, and its polar orbit will place it in continuous sunlight for most of its useful life.

Fiscal year 1962 funds provided for preliminary studies by three firms, leading to detailed proposals for development of the AOSO spacecraft. Fiscal year 1963 and fiscal year 1964 funds finance the contract for detailed design, program definition, and construction of breadboard models of critical subsystems by Republic Aviation Corporation. Fiscal year 1965 funds provide for initiating hardware development of subsystems for the spacecraft and for initiating design and breadboard of flight experiments.

This observatory is expected to make a major contribution to our understanding of the nature of the Sun, to the determination of its effects on the environment of the Earth, and to the ability to make long range predictions of its hazard to man's survival in space.

Astronomical Observatories

	1963	1964	1965
Spacecraft.....................	$32,325,000	$30,400,000	$31,100,000
Experiments.....................	5,569,000	9,400,000	6,500,000
Atlas Agena vehicles............	1,356,000	7,900,000	13,400,000
Total costs..................	$39,250,000	$47,700,000	$51,000,000

The Orbiting Astronomical Observatory (OAO) was initiated in 1960 provide a stabilized platform above the Earth's atmosphere capable of pointing astronomical observing equipment at any selected region of the sky with extreme accuracy and for extended periods of time. Such a platform makes it possible to view the stars, nebulae, interstellar matter, and the planets in regions of the electromagnetic spectrum which are obscured by the Earth's atmosphere. It also eliminates the interference caused by the distortion of light by the Earth's atmosphere and the light of the night sky caused by reflection of light by particles in the atmosphere.

The first spacecraft, scheduled for launch in 1965, will carry two astronomical measurement assemblies. One will map the sky in the ultraviolet portion of the spectrum, recording emissions from up to 50,000 stars and large nebulae in four ultraviolet spectral bands. The other assembly will be used to determine the stellar energy distribution and measure the emission line intensities of diffuse nebulae in about the same spectral region.

The second spacecraft will carry a 36-inch telescope to make absolute spectrophotometric measurements of stars and nebulae in the ultraviolet. It can be used for a variety of astronomical problems and to observe any celestial object except the Sun, Venus, Mercury, or objects fainter than 11th magnitude.

The third spacecraft will carry a telescope designed to make studies of interstellar gas and dust clouds from which stars are believed to be formed. Since most of the interstellar atoms absorb only in the far ultraviolet, this instrument will provide information in a field which cannot be studied successfully by ground based observations.

The third spacecraft will also carry a small experiment designed to study X-ray emission of a wide assortment of celestial objects and to obtain information on interstellar absorption of helium and the heavier elements. This experiment is being developed through the University College, London.

Experiments for the fourth and fifth spacecraft have not yet been selected. Consideration will be given to observations in other regions of the electromagnetic spectrum as well as adaptation of ultraviolet instrumentation to the solution of new astronomical problems.

OAO spacecraft are scheduled for launch at one year intervals beginning in 1965. Fiscal year 1963 and prior year funds provided for development of the spacecraft components and initiated assembly of the prototype spacecraft. They provided for the major development work on experiments for the first two spacecraft. Also funded was the initial development effort on the primary experiment for the third spacecraft.

Fiscal year 1964 funds provide for completing the construction of the first two spacecraft and for integrating the flight experiments and testing the complete systems. They also provide for initiating the procurement of the third spacecraft and for major development work on its primary experiment. In addition, initial funding is provided for advance development of experiments for future flights.

Fiscal year 1965 funds provide for the final preparations to launch the first spacecraft and for integration and test of the second spacecraft and its experiments. Work will be continued on the construction of the third spacecraft and its experiments, and the construction of a fourth spacecraft and its experiments will be initiated.

Two Atlas Agena vehicles with modifications to accommodate the size and weight of the OAO are being procured. Funding for the first vehicle will be completed in fiscal year 1965 while final preparation of the second vehicle will be funded in fiscal year 1966. Procurement of the third vehicle will be initiated in fiscal year 1966.

The development and operation of the OAO including spacecraft, experiments, and launch vehicles for five flights is estimated to cost about $282,000,000. The cost of the project prior to fiscal year 1963 was $43,434,000. The experiments to be conducted under this project have the potential of providing data which may completely change our present scientific theory on the nature, evolution, and processes of the universe.

Geophysical Observatories

	1963	1964	1965
Spacecraft......................	$23,969,000	$35,000,000	$22,700,000
Experiments.....................	6,987,000	9,100,000	19,900,000
Ground operations...............	1,422,000	1,400,000	1,900,000
Atlas Agena vehicles............	4,890,000	4,800,000	5,200,000
Thor Agena vehicles.............	2,366,000	3,000,000	5,700,000
Total costs...................	$39,634,000	$53,300,000	$55,400,000

The Orbiting Geophysical Observatory (OGO) project was initiated in 1960 to develop and operate a series of satellites capable of supporting a large number of diversified but correlated scientific and technological investigations within the Earth's upper atmosphere, the magnetosphere, and cislunar space. These investigations will provide a portion of the scientific base for a better understanding of the Earth as a planet, Sun-Earth relationships, hazards to manned and unmanned space flight, and the complex phenomena of our solar system.

OGO spacecraft will be launched into two general types of orbits: one, highly eccentric orbit passing through the magnetosphere, and the other, a near circular orbit which will pass over the polar regions at relatively low altitudes to obtain data on the upper atmosphere and ionosphere. Later spacecraft may be placed in highly eccentric polar orbits to facilitate correlation of the radiation belt and magnetic field phenomena with conditions in the polar atmosphere and ionosphere. Atlas Agena launch vehicles are required for the highly eccentric orbits. Thor Agena launch vehicles will be used for circular orbit missions.

The first spacecraft, which is scheduled to be launched into a highly eccentric orbit in mid 1964, will carry twenty scientific experiments. The largest portion of this payload will obtain data associated with magnetic fields and energetic particles. There are included, however, a number of experiments for studying phenomena in the disciplines of astronomy, solar physics, the atmosphere and the ionosphere.

The second OGO spacecraft, scheduled for launch in 1965, will also carry twenty experiments. This low altitude polar mission is primarily oriented toward obtaining data relating to the Earth's atmosphere and ionosphere. Subsequent launchings are scheduled at an average rate of two per year throughout the decade, to provide coverage of changing conditions throughout a solar cycle.

Fiscal year 1963 and prior year funds provided for spacecraft and ground system development and construction of a prototype and three flight spacecraft, A through C. They also provided for the development and construction of experiments for the first four flights.

Fiscal year 1964 funds provide for completion of the integration and testing of spacecraft A and for most of the work to prepare B and C for launch. They provide for analysis of data from the first flight and for continued preparation of experiments for B, C, and D. Fiscal year 1964 funds also provide for initiation of the procurement of spacecraft D, E, and F and for initial development of experiments for E.

Fiscal year 1965 funds will continue the preparation of spacecraft D, E, and F and continue the preparation of experiments for C, D, and E. They will initiate development of experiments for F and G and provide for analysis of data from B and C.

Procurement of the first two Atlas Agena vehicles was initiated in fiscal year 1962 and will be completed in fiscal year 1965. Procurement of the first Thor Agena vehicle was initiated with fiscal year 1963 funds. Fiscal year 1965 funds provide for completion of this procurement and initiation of the procurement of one more vehicle of each type.

The project, including launch vehicles, is estimated to cost about $370,000,000. This will provide for eleven flights and will conduct over 200 individual experiments. Costs will average about $50,000,000 per year through fiscal year 1968.

Explorers

	1963	1964	1965
Atmosphere and ionosphere Explorers......................	$5,467,000	$7,700,000	$5,300,000
Magnetosphere and interplanetary Explorers......................	5,190,000	5,600,000	6,800,000
Astronomical and astrophysical Explorers......................	---	1,500,000	7,000,000
Delta launch vehicles............	14,100,000	11,700,000	7,500,000
Scout launch vehicles............	4,954,000	6,600,000	4,300,000
Thor Agena launch vehicles.......	3,100,000	1,100,000	1,000,000
Total costs...................	$32,811,000	$34,200,000	$31,900,000

Explorers are small 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 leadtime and can be launched by Delta and Scout launch vehicles. This class of satellites is also employed in international cooperative programs because their relatively simple design enables a cooperating country with little or no experience to participate in the program.

Explorer class satellites fall into three general categories on the basis of the types of missions they perform.

Atmosphere and Ionosphere Explorers. These satellites are launched to low altitude orbits to obtain as much coverage as possible of the Earth's atmosphere and ionosphere. Successful satellites in this category have included Explorer VIII which made direct measurements of ion and electron temperature and pressure in the ionosphere, Explorer IX and XIX which were used to measure atmospheric density, Ariel I which carried experiments of the United Kingdom to correlate ionosphere measurements with measurements of solar radiation, the Canadian Alouette I which made the first topside soundings of the ionosphere, and Explorer XVII which made the first comprehensive measurements of atmospheric composition and also made comprehensive direct measurements of atmospheric temperature, pressure, and density.

Presently ready for launch are (1) an ionosphere Explorer which will perform topside soundings of the ionosphere using six fixed frequencies, (2) a beacon Explorer which will transmit signals to be received by ground stations in 24 nations to study ionospheric propagation, and (3) a second United Kingdom satellite which will record galactic noise, the vertical distribution of ozone in the atmosphere, and the quantitative particle flux of micrometeoroids. Fiscal years 1964 and 1965 funds provide for preparing these spacecraft for launch and for analysis of data. Two spacecraft of each type have been built. The launch schedules for the second spacecraft in each case will be dependent on the results of the first.

A cooperative effort with Italy was initiated with fiscal year 1963 funds to launch a series of satellites from a floating platform in the Indian Ocean. These satellites, launched into an equatorial orbit, will explore the equatorial regions of the atmosphere and ionosphere.

Fiscal year 1964 funds provide for initiation of a cooperative effort with France to study the ionosphere in the very low radio frequencies. They also provide for continuation of efforts with Canada, the United Kingdom, and Italy as well as additional flights of the Explorer IX and Explorer XVII types of spacecraft.

Fiscal year 1965 funds do not provide for any new and different spacecraft in this area of research, but they provide for analysis of data and for support of the cooperative launchings with the United Kingdom, Italy, and France. They also provide for a continuing program with Canada to monitor the ionosphere with launchings at the rate of one flight per year throughout the decade. Additional Explorers are expected to be launched to monitor the atmosphere during the latter part of the decade.

Magnetosphere and Interplanetary Explorers. 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. Explorers XII and XIV, which traversed the Earth's magnetosphere out to about 11 and 15 Earth radii,respectively, provided information on the great radiation belt and the Earth's magnetic field. Explorer XV was launched to study the artificial radiation belts created by the high altitude nuclear explosions. Another satellite of this type is to be launched in 1964, to continue to follow the decay of the artificial belt. The first of a series of interplanetary Explorers was successfully launched on November 26, 1963. These satellites will monitor the arrival of solar protons in the interplanetary medium between the Earth and the Moon's orbit, measure the solar wind, and explore the interplanetary magnetic field. The series will provide data needed for Apollo and extend our knowledge of energetic particles and magnetic fields in interplanetary space. Fiscal year 1964 funds provided for the development of two Injun Explorers by the State University of Iowa to measure the downward flux of solar corpuscular radiation into the Earth's atmosphere. Additional Explorers for which funds are provided in fiscal year 1964 and fiscal year 1965 are planned to be designed by other university groups to study interactions of the atmosphere with magnetic and radiation phenomena. About four satellites per year are planned for these areas of research through the decade.

Astronomical and Astrophysical Explorers. A radio astronomy receiver flown on a sounding rocket has demonstrated the feasibility of obtaining useful data on the Sun, the planets, the stars, and interstellar matter using radio receivers and relatively small antennae which can be deployed from small spacecraft. Fiscal year 1964 and fiscal year 1965 funds provide for the development of a radio astronomy Explorer. They also provide for instrumentation of Explorer spacecraft for geodetic missions to continue the work initiated by the Department of Defense under Project ANNA. This effort is planned under a joint working group to meet the requirements of the Department of Defense and the Department of Commerce as well as those of NASA. Fiscal year 1965 funds also provide for work on the extension of astronomical observations into the X-ray region of the electromagnetic spectrum using a small telescope on an Explorer. About three Explorers per year are planned for astronomical and astrophysical investigations throughout the decade.

Launch Vehicles. Scout and Delta launch vehicles will be used in the foreseeable future to launch Explorer satellites. The Delta vehicles will continue to be required for spacecraft in the 500 pound class and for the more highly eccentric orbits. Scout launch vehicles will be used for the smaller spacecraft and lower orbits. Between the two vehicles, 9 or 10 launchings per year are planned throughout the decade. The cost of the program beyond fiscal year 1965 including spacecraft, support and launch vehicles will average about $39,000,000 per year.

Sounding Rockets

	1963	1964	1965
Experiments.....................	$4,348,000	$9,000,000	$6,000,000
Rocket procurement...............	2,884,000	2,900,000	3,400,000
Attitude control systems.........	763,000	1,600,000	1,700,000
Rocket development...............	300,000	300,000	400,000
Engineering support..............	480,000	600,000	500,000
Instrumentation..................	2,738,000	2,700,000	3,000,000
Total costs....................	$11,513,000	$17,100,000	$15,000,000

Sounding rockets are small unguided vehicles which are used to make vertical profile measurement of the Earth's atmosphere, ionosphere and magnetosphere; to conduct chemical experiments in the upper atmosphere; to recover meteorite samples for laboratory study; to make short duration observations of the Sun, stars, and planets; and to test instrumentation and techniques in a space environment for later use on satellites. Sounding rocket experiments can be prepared with short leadtime. They also provide a means of exploring that part of the upper atmosphere which lies between maximum balloon altitude and minimum satellite altitudes. Their vertical profiles complement the orbital paths of satellites in completing the complex picture of the environment of the Earth. Instrumentation and techniques proved out on sounding rockets provide a test of feasibility for satellite experiments and greatly improve the chances of obtaining useful data.

The fiscal years 1964 and 1965 budgets support a level of about 115 flights each as compared with 78 flights supported by the fiscal year 1963 budget. In addition to the greater number of flights, greater use will be made of larger vehicles as more emphasis is placed on flights with astronomical instruments and geophysical experiments designed to correlate two or more measurements.

In studies of the atmosphere, flights are planned using spectrometers to analyze the composition of the atmosphere and the chemical reactions caused by the interaction of solar radiation with the atmosphere. Rocket payloads designed to collect cosmic dust and upper atmospheric gases are being developed. Studies of atmospheric structure will be continued, employing chemical releases and small spheres. Chemical releases will also be used to induce chemical reactions as a basis for studying the composition of the atmosphere and to simulate the reactions caused by natural phenomena.

Flights will be made to study the quiet ionosphere during solar minimum as a part of the International Quiet Sun Year. Rockets will be launched containing two capsules to demonstrate the feasibility of obtaining ionospheric measurements by transmissions between two closely spaced spacecraft.

Studies of the sun will be made with spectrographs, coronagraphs, and spectroheliographs. These flights are closely associated with the development of instrumentation for OSO and AOSO.

Astronomical observations of the stars, planets, and interstellar matter will be made in the ultraviolet, X-ray, and radio regions of the electromagnetic spectrum. These flights will provide useful preliminary information for experiments to be flown on planetary spacecraft, the OAO, and radio astronomy Explorers.

Sounding rockets will continue to be used throughout the decade in conjunction with satellite observation to obtain a comprehensive picture of the environment of the Earth during the rise of the solar cycle and as an aid in the development of astronomical instrumentation. The cost of the program is expected to average about $17,000,000 per year.

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PROGRAM OBJECTIVES AND JUSTIFICATION:

The objective of lunar and planetary exploration is to obtain significant scientific data from the moon, other bodies of the solar system and from interplanetary space. In the area of lunar exploration, an immediate objective of the program is to obtain scientific information and design data required for manned lunar landings. By acquisition of more general knowledge, the program seeks to explain the origin, early history, and mechanisms of development of the solar system. Determination of the interplanetary and planetary space environments and the development of spacecraft capable of carrying scientific payloads are prime objectives providing the means to accomplish the scientific objectives of the flight program.

Lunar Program

A principal scientific objective of the lunar program is the exploration of the moon and its environs for information on the surface structure, physical properties of the surface, and mechanisms of formation of the surface features. Information pertaining to the history of the earth-moon system and perhaps on the origin of other planetary bodies may be uncovered from the study of lunar surface. The moon, lacking in atmosphere, has not been subjected to the erosions of wind and water and may, therefore, preserve a record of the early history of the solar system which may be lost forever on extraterrestrial bodies which have appreciable atmospheres.

Ground-based observations and research are continuing in the areas of lunar mapping, environmental data collection, and preparation of scientific models primarily for manned systems engineering and operations planning. Four Ranger flights planned for the present calendar year will yield greatly improved lunar topographical data with television pictures from 1,000 miles distance through to lunar impact. Following Ranger, the Surveyor series of lunar landing spacecraft are planned for 1965 and 1966 to obtain a variety of detailed information from the surface of the moon such as surface physical and chemical properties, texture and hardness, lunar seismic activity and meteorite environment. The Lunar Orbiter series of spacecraft is planned to yield high resolution photography of the lunar surface and to provide data on the mass distribution of the moon in 1966.

Planetary Program

With the success of the Mariner II mission to Venus in 1962, the United States achieved an unqualified "first" in space exploration. Many useful scientific data were obtained as the Mariner II spacecraft flew by the planet. A Mariner fly-by mission to Mars is planned for 1964 with a 500-pound spacecraft to obtain television pictures of the planet and attempt to detect atomic oxygen and hydrogen in the Martian atmosphere. Work is currently underway leading to an improved fly-by mission to Mars in 1966 using the Centaur launch vehicle. Pioneer missions are planned to commence in 1965 to measure interplanetary phenomena at great distances from the earth.

SUMMARY OF RESOURCES REQUIREMENTS:

	1963	1964	1965
Supporting research and technology	$ 22,205,000	$ 19,000,000	$ 18,100,000
Manned space science	---	4,200,000	11,000,000
Ranger	88,816,000	52,200,000	10,800,000
Surveyor lander	66,386,000	98,600,000	136,000,000
Lunar orbiter	4,000	20,000,000	49,300,000
Mariner	42,777,000	59,100,000	54,100,000
Pioneer	2,614,000	17,700,000	21,100,000
Total costs	$222,802,000	$270,800,000	$300,400,000

BASIS OF FUND REQUIREMENTS

Supporting Research and Technology

	1963	1964	1965
Lunar and planetary science	$13,039,000	$12,300,000	$11,500,000
Advanced technical development	6,097,000	4,400,000	4,100,000
Advanced studies	3,069,000	2,300,000	2,500,000
Total costs	$22,205,000	$19,000,000	$18,100,000

Supporting research and technology provides the lunar and planetary programs the capability to carry out vital work not specifically a part of currently approved flight missions.

Much of the supporting scientific research involves exploring the moon and planets with equipment based on Earth. In many areas information on the solar system can be gathered more readily in this way than from flight missions. Earth-based research complements the flight programs by providing additional data for comparisons of experimental results. The combined attack on the mystery of Venus by Mariner II and infrared measurements at

Palomar is a good example of how basic scientific research complements flight experiments. This work is of further value in isolating those areas where flight missions are necessary to obtain data which cannot be obtained by earth measurements.

Supporting research provides the background information around which flight experiments are designed. Promising experiments receive their initial funding under the program and many eventually become flight experiments. The Mariner II magnetometer which discovered that Venus did not have an appreciable magnetic field originated in the supporting research and technology program, as did the plasma probe and magnetometer for the calendar year 1964 Mars fly-by missions and the lunar seismometer and alpha-particle scattering experiments selected for soft-landing missions on Surveyor.

Recent ground-based investigations have led to the conclusion that the Martian atmosphere may be far more tenuous than was previously expected. This problem must be solved before entry capsules can be designed to enter the Martian atmosphere and successfully report conditions on the surface.

The advanced technical development program focuses on three areas where improvements in the engineering arts will most increase the probability of successful planetary missions: communications, guidance and control, and sterilization of planetary spacecraft and entry capsules. Maintaining communications over 100 million mile distance requires very powerful transmitters and very sensitive receivers on earth, and a sensitive yet durable system aboard the spacecraft. Communications can be maintained only if the guidance and control system of an interplanetary spacecraft functions properly to hold the spacecraft in the proper attitude. The system must operate without failure and without repair over periods approaching nine months in order to assure success of missions to Mars.

One of the major objectives of NASA is the search for extraterrestrial life. Spacecraft to be landed or impacted on the planets must be more than surgically sterile to prevent contaminating the planets with earthly organisms. One of the most difficult problems encountered has been sterilizing electronic components without reducing their reliability and useful lifetime. Sterilization technology must improve significantly before planetary landing missions are attempted.

The advanced studies effort is essential to future lunar and planetary mission planning. Studies of space flight mechanics and planetary trajectories establish favorable launch opportunities and the energies required. Comparing these energy requirements with launch vehicle performance yields control weights for spacecraft planning. Missions studied in fiscal year 1963 included a spacecraft to examine the Sun from inside the orbit of Mercury, and Voyager, a spacecraft which would orbit Mars or Venus and land a capsule there.

Under the overall direction of the Office of Space Science and Applications, this work is carried out in universities, industrial research laboratories, and NASA field centers. Funds requested for fiscal year 1965 will support a continuation of about the same level of effort being carried out in the current fiscal year.

Manned Space Science

	1963	1964	1965
Supporting research and technology....................	---	$1,200,000	$2,100,000
Manned satellite science........	---	900,000	3,100,000
Manned lunar science............	---	2,100,000	5,800,000
Total costs....................	---	$4,200,000	$11,000,000

Manned space science supporting research and technology will provide scientific data for the engineering and operational development of manned spacecraft systems, especially Apollo. This continues environmental data collection activities previously funded under the manned spacecraft program and certain activities previously funded as a part of the unmanned lunar program. Work will be conducted to evaluate the hazards of solar flares, radiation, and micrometeoroids as they may effect astronauts and manned spacecraft on lunar missions. Efforts leading to the determination of suitable lunar landing sites for Apollo flights, including estimation of lunar surface bearing strength, will be continued. These supporting research activities include the conduct of ground-based research, coordination of data collection efforts on unmanned flight projects, and the preparation of scientific models, charts, and maps for engineering and operations planning.

Manned satellite science and manned Lunar science projects provide for planning and development of scientific investigations to be performed by man in space. The experience of the Office of Space Science and Applications in the field of scientific experiment development is being utilized through the management of this project to assure that the maximum scientific benefit is realized from man's unique capabilities as a scientific observer. Specific experiments will be developed through the various field centers both in-house and by contract.

Fiscal year 1964 funds are being used for the design, development and procurement of experiments and scientific equipment for early Gemini and Apollo flights and for the scientific training of the current astronauts. The Gemini experiments include investigations of the Earth and its upper atmosphere in which the human observer can make a unique contribution. The increased capability of the Gemini spacecraft will permit expansion of the experimental work accomplished in project Mercury. Experiments in the fields of astronomy and biology are also under development for Gemini. By the close of fiscal year 1964 the preliminary selection of promising scientific experiments for project Apollo will have been made and development will be underway on those investigations that will require several years to prepare for conduct in space.

The fiscal year 1965 funds are required to continue development of Gemini scientific apparatus and to procure flight hardware. Background training to be provided in the various scientific disciplines will enhance the effectiveness of the astronauts as scientific observers on both Gemini and Apollo missions. The procedures for conducting investigations will be ground tested by the astronauts in mission simulation sequences. Design and development of Apollo scientific equipment will be well underway and procurement of prototype and long lead time flight equipment will be initiated. Since astronaut stay-time on the lunar surface will be limited, a wide variety of light-weight, portable, and highly refined equipment is planned to permit optimum observation of surface phenomena and the collection and preservation of samples of surface features. Long-life instruments, equipped for Moon-to-Earth data transmission, will be developed for emplacement by astronauts at points of interest near the landing site. Consistent with recommendations of the Space Science Board of the National Academy of Sciences, NASA will, through this project, develop criteria for the selection of scientist astronauts for lunar missions. A very small level of effort is planned to continue definition of scientific investigations appropriate for extended missions near Earth and on the Moon.

Ranger

	1963	1964	1965
Spacecraft......................	$32,100,000	$29,100,000	$ 7,000,000
Experiments.....................	14,500,000	5,700,000	1,400,000
Ground operations...............	9,800,000	6,200,000	400,000
Launch vehicles.................	32,416,000	11,200,000	2,000,000
Total costs..................	$88,816,000	$52,200,000	$10,800,000

The specific objective of the next four Ranger flights (Rangers A-D) is to obtain television pictures of the lunar surface which will benefit both the scientific program and the United States manned lunar program. These pictures should be at least an order of magnitude better in resolution than any available earth-based photography.

The failure of Ranger V, which was launched in October 1962, led to an extensive redesign and retest effort in order to increase the probability of success on future flights. This effort, which caused the launch schedule for Ranger A to slip to the first quarter of 1964, has now been completed and test results on the current spacecraft have been very encouraging, indicating that the objectives of the redesign have been attained.

Instead of the hard-landing capsule and bus experiments of the early Rangers, the payload for the next series will consist of six television cameras mounted in a "tower" on the bus. Improvements have been incorporated into the bus to attain high reliability. The television system will begin operation at approximately 1,000 miles above the lunar surface and will continue until impact, with the quality of the last pictures sufficient to identify an object a few feet in diameter.

Five additional flights beyond the ninth were planned but have been cancelled in the interest of economies in the total NASA program. This series of flights was planned to impact the lunar surface with survivable capsules.

The Office of Space Science and Applications, NASA Headquarters, is responsible for the overall management of the Ranger program. Responsibility for project management is assigned to the Jet Propulsion Laboratory. The spacecraft was designed by the Jet Propulsion Laboratory and is being fabricated by the Laboratory as an in-house effort. The television system is being procured from the Astro-Electronics Division of Radio Corporation of America.

Fiscal year 1963 funds were used primarily to conduct the extensive redesign and retest effort on the Ranger A-D series and to initiate procurement of long lead time flight equipment. In addition, some of the funds were used to complete and launch Ranger V and to develop a prototype hard-landing photographic capsule. Fiscal year 1964 funds are being used for the assembly, test and launching of Rangers A-C and were used for six months of effort on five impacters prior to cancellation. The fiscal year 1965 funds will be used for final testing and launch of the ninth Ranger and for post launch data evaluation.

Surveyor Lander

	1963	1964	1965
Spacecraft......................	$45,386,000	$57,200,000	$64,400,000
Experiments.....................	4,021,000	4,700,000	11,600,000
Ground operations...............	3,079,000	4,700,000	6,000,000
Launch vehicles.................	13,900,000	32,000,000	54,000,000
Total costs..................	$66,386,000	$98,600,000	$136,000,000

The Surveyor spacecraft is being developed to accomplish the first soft landings on the Moon. On the lunar surface, it will survey various landing areas of interest as possible sites for later manned landings and make measurements to improve our understanding of the nature of the Moon. Landed Surveyors will transmit to Earth a variety of data, such as high-resolution television pictures of the lunar terrain and surface texture, measurements of the surface hardness and other physical and chemical properties, lunar seismic activity, and the meteorite environment near the surface.

The Surveyor mission requires the development of a technology far more advanced than that employed in the Mariner II and Ranger spacecraft. Not only must Surveyor navigate through the space between the Earth and the Moon, but it must land softly on the Moon, essentially by backing down a multi-stage rocket to a landing 240,000 miles and 66 hours removed from the launching site.

The Surveyor spacecraft system is being developed for NASA by the Hughes Aircraft Company under contract to the Jet Propulsion Laboratory. Major contractors are Thiokol/Elkton for the main retro-rocket, Thiokol Reaction Motors Division for the vernier propulsion system, and Ryan Electronics for the attitude and velocity-sensing radars.

Current year funds have been primarily devoted to developmental testing and refinement of components and subsystems, system testing of the proof-test spacecraft, and hovering and drop tests from a balloon which simulate the final landing on the Moon.

Fiscal year 1965 funds will be used for completion of system functional testing, environmental testing (thermal-vacuum, shock, and vibration), mission-simulation testing, field crew training by mock operations, and tests of dynamic models on Centaur development flights. Development of the basic Surveyor spacecraft system is expected to be essentially completed and test flights started during fiscal year 1965.

Lunar Orbiter

	1963	1964	1965
Spacecraft......................	$4,000	$20,000,000	$31,600,000
Ground operations...............	---	---	2,200,000
Launch vehicles.................	---	---	15,500,000
Total costs.....................	$4,000	$20,000,000	$49,300,000

The primary mission of the Lunar Orbiter is to conduct photoreconnaissance of the Moon. From its orbit, the satellite will make scientific measurements of the Moon and its environs in addition to its photographic mission. Analysis of the Lunar Orbiter's orbit will help determine the mass distribution of the Moon. Only a lunar satellite can provide this information on mass distribution which is central to any discussion of the origin of the Earth-Moon system, and is relevant to reconciliation of the conflicting theories of the origin of the solar system. Irregularities in lunar mass distribution are closely linked with questions of the seismic activity of the Moon, its radioactivity, and the character of the lunar surface. The Orbiter data will be very valuable in evaluating and correlating the scientific observations made by the Surveyor Lander. The Orbiter photography will be used to screen out obviously undesirable sites in which to place the Surveyor and then to team with the landed Surveyor in the verification of suitable sites for the Apollo landings.

Early planning for a lunar orbiter had considered an Atlas-Centaur launched spacecraft. In 1963, advances in spacecraft technology and the growth in payload capability of the Atlas-Agena launch vehicle made a lunar orbiter in the 800 pound class feasible. Consequently, the decision was made to design a spacecraft for the Atlas-Agena launch vehicle. The first orbiter is planned to be launched early in calendar year 1966 with following flights at the approximate rate of one each quarter.

Project management responsibility has been assigned to Langley Research Center and launch vehicle systems management to Lewis Research Center. Proposals for design and fabrication of the Orbiter spacecraft were requested from industry in October 1963, and the Boeing Company was selected in December 1963.

Funds provided in fiscal year 1964 are being utilized to initiate the spacecraft development contract and will carry the spacecraft through design and prototype fabrication. Fiscal year 1965 funding will provide for fabrication of flight hardware and the initial payment on Atlas-Agena launch vehicles. The ten-flight program is estimated to cost about $225 million.

Mariner

	1963	1964	1965
Spacecraft........................	$29,802,000	$27,300,000	$25,100,000
Experiments.......................	1,333,000	8,100,000	8,600,000
Ground operations.................	6,830,000	10,000,000	9,500,000
Launch vehicles...................	4,812,000	13,700,000	10,900,000
Total costs.......................	$42,777,000	$59,100,000	$54,100,000

Mariner is the United States' program to explore the planets. Flights to the planets are extremely difficult space missions because existing launch vehicle systems are strained to the utmost by energy requirements, and the state of the art of spacecraft technology by flight duration. System lifetimes on the order of nine months must be attained, yet redundancy which is desirable for reliability must be minimized due to weight limitations. Planetary exploration will proceed in three phases: fly-by missions, fly-by missions with landing capsules or probes, and spacecraft which include both a landing module and an orbiting module.

Launch vehicle capability has restricted the early Mariners to fly-by missions. The Atlas-Agena launch vehicle which provided 447 pounds for the highly successful Mariner II in 1962, has been improved so that over 500 pounds are available for the 1964 Mars mission. Mariner spacecraft are attitude stabilized, relying on Earth, Sun, and star sensors for orientation, and on solar panels for power. The spacecraft measures micrometeoroid impacts, fields, and particle fluxes in interplanetary space enroute. The 1964 Mariner will take television photographs of the Martian surface as it flies by and attempt to detect atomic oxygen and hydrogen in the atmosphere.

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Development of the Centaur launch vehicle to operational status will permit a greatly improved fly-by mission in 1966, which will build on data from the earlier flights through the use of more sophisticated instrumentation.

The Jet Propulsion Laboratory is responsible for management of the Mariner program and will build the spacecraft in-house. Lewis Research Center has responsibility for procurement of both the Atlas-Agena and Centaur launch vehicles used in the Mariner program.

There have been reports of ten attempts to fly spacecraft to the planets by the Soviet Union and two by the United States. The Russians succeeded in ejecting only two from Earth orbit into interplanetary trajectory, and these both failed before they reached their objectives. The United States achieved the world's only planetary success when Mariner II's microwave radiometers made their measurements on Venus on December 14, 1962. The funds appropriated for fiscal year 1963 paid for the final test and checkout of Mariners I and II, and started work on the two 1964 flights to Mars.

The fiscal year 1964 funds will complete parts procurement, functional and type approval tests, fabrication of the spacecraft, and systems tests for the 1964 Mars launches, as well as preliminary design and long lead time procurement for the 1966 mission. The fiscal year 1965 requirement is for the final assembly, test, checkout, and launch of the two Mars spacecraft in late calender year 1964. Tracking will continue after launch for nine months until encounter. The balance of the fiscal year 1965 resources will be applied to the design and development of the spacecraft for the calender years 1966 and 1968-1969 missions.

Pioneer

	1963	1964	1965
Spacecraft......................	$1,839,000	$11,000,000	$ 7,900,000
Experiments.....................	725,000	2,300,000	4,200,000
Ground operations...............	50,000	300,000	900,000
Launch vehicles.................	---	4,100,000	8,100,000
Total costs..................	$2,614,000	$17,700,000	$21,100,000

Pioneer missions will use small spacecraft, with long lifetimes, designed to measure interplanetary phenomena. In conjunction with the Interplanetary Monitoring Probe, which measures the near-Earth environment and the planned Mariner missions, Pioneer will enable the United States to obtain simultaneous scientific data at widely separated points in space, measuring magnetic fields, solar plasma, cosmic rays, radio propagation, and interplanetary dust during the International Quiet Sun Year and beyond. Correlation with similar measurements made in near-Earth orbit will enable us to understand better these phenomena and their interrelation.

In addition, Pioneer will monitor solar phenomena near the low point of solar activity, and will make measurements during the buildup of activity, and as the maximum approaches. These data will contribute to scientific knowledge of the origin of the sun; its dynamics, composition, and effect on the Earth's environment. An immediate use for this knowledge will be research directed toward developing a method for predicting solar flares which would be a hazard to manned space flight.

Pioneer takes advantage of recent and planned improvements in the reliable Delta launch vehicle. Thrust augmentation will add to the existing capability of the Delta, and it is planned that a spacecraft of about 140 pounds will be injected into an interplanetary orbit. The first four Pioneer missions will alternate between orbits which close to within 75,000,000 miles of the Sun and orbits which go outside Earth's orbit to 110,000,000 miles from the Sun. The expected lifetime will be at least six months, so that a reasonable launch rate will permit simultaneous measurements from two Pioneers, as well as comparison of Pioneer data with Interplanetary Monitoring Probe, and occasionally with Mariner spacecraft. Relatively simple design will ensure high reliability in the Pioneer spacecraft, which will be largely a refinement of existing technology.

Responsibility for project management rests with Ames Research Center. Under the technical direction of Ames, Space Technology Laboratories will build the spacecraft under a fixed price, incentive fee contract. The Jet Propulsion Laboratory will provide tracking and data acquisition services, while Goddard Space Flight Center is responsible for systems management of the launch vehicle procured from the Douglas Aircraft Company.

Fiscal year 1963 funds were used for spacecraft design and system development. Fiscal year 1964 funds are being used to initiate procurement of the first four spacecraft and launch vehicles. During 1964 the prototype will be developed, tested, integrated with the scientific experiments and qualified for flight.

The fiscal year 1965 request completes purchase of the first four launch vehicles and almost all of the spacecraft. Final qualification of the first flight spacecraft should be completed early in 1965 and the initial launch should occur in the second quarter of calendar year 1965. These funds will also pay for possible design modifications to the Pioneer spacecraft and selection and development of new experiments to fly on the second block of three spacecraft, the last of which would fly in 1967. The total program of seven flights is estimated to cost about $70 million.

OFFICE OF SPACE SCIENCE AND APPLICATIONS — SUSTAINING UNIVERSITY PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

With its establishment, NASA was charged with expanding human knowledge of phenomena in the atmosphere and space and preserving the role of the United States as a leader in aeronautical and space-related science and technology. As would be expected in any undertaking of this complexity and sophistication, the need for knowledge of almost infinite variety was immediately recognized, and it soon became apparent that the existing sponsored research activities could not utilize fully the abilities of our universities. Accordingly, the Sustaining University Program was planned and initiated in fiscal year 1962 to increase university participation in aeronautical and space science and engineering endeavors and to broaden NASA's sponsored research activities.

Universities are the traditional source of both new knowledge and highly trained manpower. Only through a carefully designed program can the supply of scientific talent and the development of significant and relevant research capabilities keep pace with the demands of the national space effort. The Program objectives are to: (1) increase the future supply of scientists and engineers required in space-related science and technology; (2) build laboratories urgently needed for space research in selected universities; and, (3) improve the universities' role in support of NASA by encouragement of creative multidisciplinary investigations, development of new capabilities, and consolidation of space-oriented activities. These three aspects of the Sustaining University Program are complementary to project sponsored research and to each other.

The training aspect produces skilled manpower, research scientists, technicians and instructors. By September 1964, about 2,000 future scientists and engineers will be in training in the NASA program at a cumulative cost through fiscal year 1964 of nearly $36 million. Adequate facilities are essential if the scientists' already difficult undertakings are not to be hampered further by unsuitable environments. Acquisitions initiated through this aspect of the program and funded in fiscal year 1964 and prior years are intended to add approximately 855 thousand square feet of laboratories at a cumulative cost, of about $29 million. Additionally, by supporting high quality research at selected institutions not currently participating in the space program, the number of universities and scientists involved in attacking some of the fundamental problems facing NASA has grown significantly. Through this portion of the program, some $18 million at 70 institutions will have been invested by the end of fiscal year 1964 to obtain research results which will help to determine the long-range course of space technology.

SUMMARY OF RESOURCES REQUIREMENTS:

	1963	1964	1965
Training......................	$14,145,000	$20,000,000	$25,000,000
Facilities....................	10,249,000	12,000,000	10,000,000
Research......................	6,206,000	8,000,000	11,000,000
Total costs..................	$30,600,000	$40,000,000	$46,000,000

BASIS OF FUND REQUIREMENTS:

	1963	1964	1965
Training......................	$14,145,000	$20,000,000	$25,000,000

The rapid development of the space program continues to place increasingly severe demands on the supply of highly trained scientists and engineers. The demand is in two general directions: those technical personnel required to participate directly in the solution of immediate problems confronting current space activities and those required to conduct future research, teach new students in order to replenish the manpower pool, and evaluate and organize the vast amounts of scientific data acquired through increasing space experimentation.

The predoctoral research training program is designed to produce 1,000 Ph.D's annually. This type of program has been strongly recommended by the President's Science Advisory Committee as necessary and reasonable. The Committee stated that a special effort must be made if the supply of highly trained scientists and engineers is to keep pace with the demand. It was further determined that there are adequate numbers of qualified students available who would not enter graduate research training unless new opportunities were made available. The Committee recommended that the annual output of Ph.D.'s should reach at least 7,500 by the year 1970, an increase of 4,000 Ph.D.'s over the present annual rate.

NASA's predoctoral training program was started with grants to ten universities for the support of ten graduate students at each university for a period of three years, and at a total cost of approximately $2 million. In fiscal year 1963, 786 trainees at 88 universities, which included second grants to the first ten institutions and grants to 78 new institutions, were added at a total cost of about $14 million. Presently, only 886 students are in training, but approximately 1,100 more new students are to be added at a cost of about $20 million from fiscal year 1964 funds. Subsequently, additions of 1,250 students in 1965, 1,300 to 1,400 in 1966 and again in 1967 will be made to attain a level of nearly 4,000 students in training. In spite of this emphasis on training, the first graduates will not become available until 1965. It should be noted that no amount of money injected at some later date will produce scientists or engineers in six months to ease some suddenly recognized manpower crisis.

The training program provides three-year predoctoral opportunities to selected graduate students at qualified 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 individual competence. At the end of this training, the student may remain at a university, carrying out long-range research and teaching the "next generation" or he may participate directly in current research activities of immediate importance to the space program at the university, in industry, or within NASA.

Individual trainees are selected at the university by senior faculty members who may supervise the research training of the students, and are thus in the best position to evaluate the capabilities of the candidates. The stipends granted are comparable to those offered by other sources, and the grants are made through the university to minimize movement of the student. The grant also includes an allowance to the university to strengthen its program in space-related science and technology. It may include such items as small amounts for minor specialized equipment, a modest amount for course-content improvement, an appropriate share of special faculty augmentation, as well as similar items normally covered by income from tuition and fees.

Specialized training for selected students offers the students 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 also engaged in space research activities. The students thus have a relationship with NASA through contact with scientists and experiments generated by experienced senior investigators. Such close ties will provide the trainee with additional motivation for the continuation of studies and participation in the national space effort. A by-product of these traineeships is the incentive they provide to undergraduates who look forward to similar participation.

The predoctoral training grants are aimed directly at alleviation of a most critical manpower deficiency. The training program also includes related activities such as postdoctoral conversion of scientists desiring to enter space-related fields, enhancement of the utility of people possessing unique capabilities, and summer seminars for carefully selected students with outstanding potential.

	1963	1964	1965
Facilities....................	$10,249,000	$12,000,000	$10,000,000

Research and training in space-related science and technology at non-profit scientific and educational institutions in support of NASA's mission are often impeded by inadequacy or complete lack of existing laboratory space. Although some research scientists need only limited facilities in order to pursue their theoretical studies, it is an increasingly frequent requirement that first-line space research of the type needed by NASA necessitates the use of more elaborate equipment, such as computers, electronic testing devices, and environmental simulators. Sufficient laboratory space must be provided for this equipment as well as for the faculty, graduate students, other research personnel and supporting services.

Besides relieving the critical shortage of working space for groups now heavily involved in research pertinent to the NASA mission, these new facilities will make possible the development and assembly of new multidisciplinary research groups which can more effectively respond to NASA's needs than can innumerable dispersed smaller groups. During the next five years a total of some 75 universities heavily engaged in NASA's programs are expected to require over three million square feet of laboratories to accommodate research and training in space-related work. Acquisitions initiated through fiscal year 1964 for this project are adding approximately 855 thousand square feet of laboratory space at a cost of nearly $29 million. A continued, orderly and deliberate acquisition rate to help fulfill part of the remaining needs requires $10 million for construction of an additional 275 thousand square feet of laboratory space. Thus the universities will be in a position to undertake the work of which they are capable and which is required if already established national goals in space are to be realized.

	1963	1964	1965
Research......................	$6,206,000	$8,000,000	$11,000,000

The support of broad programs of space and aeronautical research, specifically tailored to the individual characteristics of each university, affords the maximum opportunity for balancing and strengthening existing work, and for stimulating the development and growth of new ideas and talent. In this manner, the space program obtains the most vigorous, productive and creative contributions a university can provide.

Many of the scientific and technological problems facing NASA require an understanding of the behavior of large and complex systems that resist piecemeal attack, and their solution demands the concerted and cooperative effort that universities can provide by bringing together their many specialists from the varied technical and scientific disciplines. Additionally, by supporting quality research at selected institutions not currently participating in the space program, the number of universities attacking some of the fundamental problems facing NASA is permitted to grow and thus broaden the base of the nation's research capability. By providing new opportunities to these institutions to participate, many excellent research programs have already emerged and new talents and skills have been developed. Through this portion of the program, some $18 million at 70 institutions will have been invested through fiscal year 1964 to obtain research results which will help to determine the long-range course of space technology.

For the continuation and orderly growth of this special-purpose research in fiscal year 1965, approximately sixty projects will be supported at a cost of $11 million. Forty of these grants will be for the continuation of projects supported in fiscal year 1964, and the remaining 20 will be to universities participating in this research program for the first time.

OFFICE OF SPACE SCIENCE AND APPLICATIONS — LAUNCH VEHICLE DEVELOPMENT PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The purpose of the launch vehicle development program is to provide reliable and economical launch vehicles for NASA unmanned flight projects. This is accomplished by (1) an active research and technology effort for the systems, components and techniques that may be required for future projects; (2) developing such launch vehicles as are required to support these projects; (3) procuring launch vehicles to meet the requirements of approved projects; and (4) modifying and improving the existing stable of vehicles and ground systems to support these projects.

The supporting research and technology area, initiated for launch vehicle development in fiscal year 1963, is progressing to fill the need for advanced studies of vehicle technology required for unmanned missions. Effort in fiscal year 1963 was concentrated in special vehicle systems studies. Fiscal year 1964 funds provide for studies of the use of flourine for future vehicles, and on the behavior of liquid fuels in zero gravity condition.

The Scout and Delta vehicles, developed by NASA, are now operational. Development of these vehicles was completed in fiscal year 1963.

Development of the Centaur will continue in fiscal year 1965, with the first operational mission to be accomplished early in calendar year 1965. The second attempted launching of the Centaur vehicle on November 27, 1963, was entirely successful.

The FLOX development project, initiated in fiscal year 1964, will be completed in fiscal year 1966. This project will initially provide a large increase in payload capacity for the Atlas-Centaur and Atlas-Agena vehicles. Later, other launch vehicles which now use liquid oxygen should benefit significantly.

SUMMARY OF RESOURCES REQUIREMENTS:

	1963	1964	1965
Supporting research and technology	$ 1,598,000	$ 1,900,000	$ 4,500,000
Centaur development	90,600,000	108,100,000	92,000,000
Scout development	3,648,000	---	---
Delta development	2,183,000	---	---
FLOX development	---	1,900,000	17,500,000
Operational vehicle support	7,700,000	13,200,000	14,200,000
Total costs	$105,729,000	$125,100,000	$128,200,000

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BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1963	1964	1965
Fluid behavior studies....	$ ---	$ 500,000	$ 500,000
Solid state technology research................	---	200,000	500,000
Vehicle system studies....	995,000	900,000	1,500,000
Instrumentation...........	---	---	200,000
Propulsion systems technology	603,000	300,000	1,800,000
Total costs.............	$1,598,000	$1,900,000	$4,500,000

The purpose of this supporting research and technology effort is to generate current information on launch vehicle components, sub-systems, and systems to meet the requirements of unmanned missions. This effort also includes development of certain components, sub-systems, and techniques peculiar to launch vehicles used for unmanned missions.

The launch vehicle supporting research and technology program utilizes data available from the NASA Offices of Advanced Research and Technology and Manned Space Flight Programs, the Department of Defense, the Atomic Energy Commission, and industry to determine the nature and desirability of changes to those launch vehicle systems for which this office has cognizance. Similarly, the needs of planned or tentative flight projects are evaluated to determine the extent to which existing vehicles can be employed or show where modifications or additional development may be required.

Selected components and sub-systems are developed when a clear need, based on the advanced studies, is demonstrated. Design criteria for launch vehicles are developed and updated, and studies are carried out to achieve the most economical use of vehicles.

Fiscal year 1963 funds provided for studies of launch operations analysis, system optimization review techniques, high energy propellants, Titan II/Centaur capability, addition of fluorine to the oxidizer in the Atlas booster (FLOX), and the addition of a third stage to the Saturn IB. These studies have been completed or are progressing satisfactorily. Fiscal year 1964 funds are supporting continuation of the launch operations analysis and system optimization review technique studies. Studies for launch vehicle planning, zero gravity fuel behavior, a kick stage, cryogenic propellants, explosive welding, fluorine-hydrogen technology, spin motor technology, and solid state devices have been or will be initiated.

A major portion of these studies will be continued in fiscal year 1965. New studies intended to be initiated in fiscal year 1965 include improved engine starting techniques, insulation technology, flight instrumentation, sounding rocket systems, and feasibility of achieving high vehicle performance.

Centaur Development

	1963	1964	1965
Vehicle development....	$71,652,000	$ 91,600,000	$86,400,000
Engine development.....	4,340,000	2,000,000	300,000
Support services.......	12,295,000	10,400,000	2,600,000
Propellants............	2,313,000	4,100,000	2,700,000
Total costs..........	$90,600,000	$108,100,000	$92,000,000

The primary purpose of the Centaur Development project is to provide a high performance launch vehicle for the NASA unmanned Lunar and Planetary exploration projects which are beyond the capabilities of the Atlas-Agena launch vehicle. This project is centered around the development of the Centaur stage which is a high energy upper stage utilizing liquid hydrogen and liquid oxygen. The first stage of this launch vehicle is a modified Atlas. This project also includes the development of a light weight inertial guidance system and other light weight sub-systems for the Centaur stage to permit maximum payload capacity. The Atlas-Centaur can launch a payload of over 2,100 pounds to the moon.

The Office of Space Science and Applications has assigned management of the Centaur project to the Lewis Research Center. Development of the RL-10-A-3 engine is being directed by the Office of Manned Space Flight and the Marshall Space Flight Center. Integration of this engine with the Centaur vehicle is under the direction of the Lewis Research Center. Atlas vehicles which are modified to be the first stage of the Atlas-Centaur are purchased by the Lewis Research Center through the United States Air Force. Prime contractor for the Centaur project is General Dynamics/Astronautics of San Diego, California. Pratt and Whitney Aircraft Corporation of East Hartford, Connecticut and West Palm Beach, Florida acts as an associate contractor in the development and fabrication of the liquid hydrogen-liquid oxygen engine. These engines are also used in the Saturn S-IV stage. Minneapolis-Honeywell of St. Petersburg, Florida is the principal subcontractor to General Dynamics for the development of the Centaur guidance system.

The Centaur development project was initiated by the Advanced Research Projects Agency of the Department of Defense in 1958 as a relatively small scale development project to investigate liquid hydrogen technology. It was transferred to NASA in 1959 and has been increased in scope until it is now a major launch vehicle development program.

After the first attempted launch of the Centaur on May 8, 1962, an intensive investigation was made which resulted in a thorough ground testing program along with changes to the design and reliability concepts.

This intensive review resulted in significant changes in the structural design of the vehicle; changes in the guidance and propulsion systems were also initiated.

The second test flight of the Atlas-Centaur vehicle was made on November 27, 1963 and was a complete success.

Funding in fiscal year 1965 is intended to complete the development of the single burn capability for the Centaur vehicle and to carry on the development of the two burn capability for later missions. The first operational Centaur is to be launched in fiscal year 1965 as part of the Surveyor project. Other launches are scheduled in fiscal year 1965 for development of a two burn capability, and additional Surveyor flights.

The Centaur Development project is expected to be completed in fiscal year 1966.

Scout and Delta Development

	1963	1964	1965
Scout development.......	$3,648,000	---	---
Delta development.......	2,183,000	---	---
Total costs...........	$5,831,000	---	---

The Scout and Delta development projects were completed in fiscal year 1963. Although the Delta development project was expected to be completed using fiscal year 1962 funds, reorientation of the program required a re-programming action in fiscal year 1963. Technical direction and management of the Scout vehicle is assigned to the Langley Research Center, and of the Delta vehicle to the Goddard Space Flight Center.

FLOX Development

	1963	1964	1965
Engine and engine testing	---	$1,000,000	$7,500,000
Vehicles and vehicle testing................	---	900,000	7,000,000
Ground support equipment and services...........	---	---	1,500,000
Propellants..............	---	---	1,500,000
Total costs...........	---	$1,900,000	$17,500,000

NASA began investigating the addition of fluorine to the Atlas propellant system in early calendar year 1963. At that time very preliminary studies indicated that the addition of 30 percent fluorine by weight to the Atlas oxidizer would increase Atlas performance markedly, and require no major modifications to the vehicle or engine system.

The purpose of the FLOX feasibility study was to insure that FLOX was in fact compatible with the Atlas systems without committing the large funding required for a flight program. This study has satisfactorily demonstrated the feasibility of the concept. Results from selected engine components tests indicate no major modifications to the vehicle are required.

Preliminary effort conducted in 1963 indicates this propellant mixture will increase payload capability of the Atlas-Centaur for the Surveyor mission approximately 30%. A similar increase is expected to be realized on the Atlas-Agena missions, such as the Lunar Orbiter and the Advanced Technological Satellite. The Saturn and Thor boosters may also benefit from this technology.

Effort initiated in fiscal year 1964 and sustained in fiscal year 1965 is expected to permit engine component tests to be completed in the fourth quarter of 1964, vehicle component tests completion in the first quarter of 1965, engine tests in the third quarter of 1965, and the first test launch in the first quarter of 1966.

Operational Vehicle Support

	1963	1964	1965
Product improvement and production testing......	$6,458,000	$ 6,500,000	$ 7,800,000
Maintenance of ground support equipment.......	939,000	3,600,000	2,900,000
System engineering........	303,000	3,100,000	3,500,000
Total costs.............	$7,700,000	$13,200,000	$14,200,000

Product Improvement

Modifications to improve a launch vehicle system have frequently been required as a result of experience, failures, development breakthroughs in other programs, and improved fabrication techniques. The correction of the system deficiencies for otherwise ready vehicles is reflected hereunder.

Operational vehicle support was initiated in fiscal year 1963. Significantly, in fiscal year 1963, changes were made in the Atlas-Agena vehicle configuration through the development of a standard Atlas vehicle by Department of Defense for use both by the NASA and the Department of Defense. NASA participated in this improvement effort. Improvements to the Agena guidance system and the Agena vehicle itself were made. National Aeronautics and Space Administration's most reliable operational vehicle, the Delta, was also improved in fiscal year 1963.

The fiscal year 1964 estimates reflect continued support of the standard Atlas development, improvements to the Agena, the Agena guidance system, and improvements in the Scout system. To be able to launch improved and heavier spacecraft, National Aeronautics and Space Administration is utilizing a Department of Defense Thrust Augmented Thor booster with the Delta. Costs of developing the Thrust Augmented Thor booster were borne by the Department of Defense, however, certain other costs necessary to adapt this development to National Aeronautics and Space Administration operational vehicles are reflected in this operational vehicle support account.

The product improvement estimates for fiscal year 1965 are intended to provide additional modifications required in the Scout vehicle, to continue upper stage improvement for the Delta and to provide the National Aeronautics and Space Administration share of the costs estimated for completion of the standard Atlas development. Other improvements for guidance systems, solid propellant motors, inertial reference packages, and sensors will be funded.

Maintenance of Ground Support Equipment

These funds will provide for the periodic routine maintenance, modification, and replacement of damaged or worn out equipment at National Aeronautics and Space Administration launch complexes as required to maintain the launch capability for operational vehicles. The ground support equipment maintained under this account is peculiar to specific launch vehicle needs. In many instances equipment presently in use was developed by the prime contractors as a part of the respective development programs. Modifications to this equipment improve the reliability and assure the compatibility of the ground support systems with the launch vehicle.

Funds in fiscal year 1965 are required for support of the Scout launch facilities at the Pacific Missile Range and at Wallops Island. Delta ground support requirements consist of replacement of umbilical masts and uprating the instrumentation console at Cape Kennedy. Procurement and modification of ground support equipment at Pad 12 for both Agena B and Agena D capability is to be funded to adequately support the planned launch schedule. Also provided is the acquisition of spares 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:

Each launch of an operational vehicle is monitored by a team consisting of the vehicle contractor and National Aeronautics and Space Administration to ascertain the reliability of vehicle sub-systems and components. The analysis performed after each launch is reviewed, together with similar analysis of previous launches, for erratic performance and failure modes.

The engineering talent required for these reliability studies and system coordination, as well as the cost of computer usage and such other equipment as required, are contracted for on an annual basis. This capability is necessary throughout the operational lifetime of a vehicle system to insure satisfactory vehicle performance.

Other efforts initiated in fiscal year 1964 include standardization of Scout equipment and procedures and studies for better prediction of rocket performance. Fiscal year 1965 plans include continued vehicle data reduction and analyses, range safety documentation, additional standardization effort, preparation of handbooks and manuals for inspection procedures, and other studies to improve vehicle accuracy and reliability.

The system engineering effort on Delta consists of performing studies of the third stage vehicle destruct system, analysis of the first and second stage telemetry measurements, and effort to maintain reliability. The Agena effort under this project in fiscal years 1964 and 1965 provides for mission parameter studies and systems analysis.

OFFICE OF SPACE SCIENCE AND APPLICATIONS — BIOSCIENCE PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The primary objectives of the Bioscience program are (1) the detection and study of extraterrestrial life, (2) study of the biological effects of space environmental factors on living organisms, and (3) basic studies related to support of manned space flight. A program of basic and applied research is being conducted in each of these areas, proceeding from ground-based laboratory investigations to flight experimentation in the space environment and on Mars and other planetary bodies.

Biological studies are an essential part of the national space program. Experiments are conducted to increase biological knowledge in the unique environment of space and the results are pertinent to the future manned exploration of space. The search for life on other planets and the sterilization of spacecraft to be landed on Mars or other planets are also goals being purposefully pursued by the biologists today.

Experiments which are being readied for flight in the Biosatellite will determine, in the space environment, the effects of weightlessness and radiation singly and combined with each other, and the effect of the lack of a day and night cycle upon animals and plants. These experiments are solicited from the scientific community through the Biosciences Subcommittee of the Space Sciences Steering Committee.

The Supporting Research and Technology program provides the necessary background of theoretical and laboratory research to define the experiments to be carried out in space, to devise the techniques and instruments, and to enable the biologists to interpret the space flight data. The Supporting Research and Technology program uses the facilities of NASA centers, universities, industry and other government agencies. Of the research projects currently sponsored outside of the NASA organization about 50 percent are conducted by universities, 30 percent by industry, and 20 percent by other government agencies.

SUMMARY OF RESOURCES REQUIREMENTS:

	1963	1964	1965
Supporting research and technology....................	$11,772,000	$12,100,000	$11,800,000
Flight program (Biosatellite)...	1,959,000	8,500,000	19,200,000
Total costs..................	$13,731,000	$20,600,000	$31,000,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1963	1964	1965
Exobiology (including sterilization)	$5,565,000	$5,200,000	$5,000,000
Environmental biology	2,307,000	2,900,000	2,800,000
Behavioral biology	1,849,000	2,100,000	2,100,000
Physical biology	2,051,000	1,900,000	1,900,000
Total costs	$11,772,000	$12,100,000	$11,800,000

Exobiology. The search for extraterrestrial life and life-related organic compounds is considered to be one of the prime objectives of the space program. Remote sample collectors and life detectors are being developed using a variety of concepts and methods. Studies are being carried out on the origin and synthesis of living systems and the development of significant steps in early evolution. With the use of a variety of energy sources, most of the fundamental building blocks of living systems have been synthesized from simple non-living matter under conditions similar to those prevailing on this planet several billion years ago. This work is being carried out by the Ames Research Center.

Indirect evidence of the presence of water and carbon dioxide on Mars has been obtained at the Jet Propulsion Laboratory by means of special methods employing ground-based observatories and through the use of the National Aeronautics and Space Administration Stratoscope II flight in March 1963. Further studies by infrared spectroscopy during fly-by of the planets is planned to determine the presence of life-related compounds, and the further development of a high-resolution infrared spectroscope necessary for such studies is planned.

Sampling of the upper air for microorganisms has resulted in the knowledge that it is improbable that life "spills out" into space. This upper air microbiological sampling is continuing and meteor fragments are also being analyzed for the presence of life and organic materials.

A spacecraft sterilization program is underway to develop methods and procedures for reducing the number of microorganisms to a minimum on probes to the moon and Venus and for sterilizing capsules destined for a Martian landing. The techniques developed must permit optimum performance of the instrument and must produce no decrement to the reliability of the mission.

Environmental Biology. The biological effects of space environmental factors on living earth organisms are being studied. All space factors are studied on earth except such unique factors as weightlessness, cosmic radiation, and removal from the effects of the earth's rotation. A biological satellite (Biosatellite) program is designed to study the effects

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of these factors and their role in establishing and maintaining normal organization and biological rhythms in living organisms.

The limits of existence of life in extreme environmental conditions are being studied and the extreme parameters of environmental factors in supporting life are being defined. Plants and animals are also being subjected to simulated planetary conditions to determine which organisms could grow on other planets.

Various biological organisms are being studied to develop their application and use in space: (1) in bioregenerative life support systems, (2) as test organisms on other planets, (3) for modifying planetary atmospheres, and (4) for inducing reduced metabolic activity in various specimens.

Behavioral Biology. The effect of the space environment on orientation, behavior, and biological rhythms or organisms is being studied. Neurophysiological, biochemical, and behavioral analyses are being carried out to define brain-behavior relationships of importance to the organism in dealing with stress-producing environmental factors. The molecular basis of acquisition, processing, storage, and retrieval of information on living systems is being studied together with inter-and intra-species communication of intelligent information. Research is in progress on the effects of prolonged confinement in small spaces and other types of environments which produce complex behavioral problems.

Physical Biology. This area is concerned with basic studies of molecular species. Investigations are sponsored in such areas as the mechanism by which freezing and drying affects living cells; structural and functional cellular physiology; physical modeling; major internal physiological systems; molecular organization and differentiation of cells; and behavior of biological systems under controlled space-environmental conditions. Physical biology also embraces studies of energy exchange and nutrition including the development and stability of improved chemically-defined synthetic diets for man, and also for animals which might be utilized in Biosatellite experiments. In this area, 18 volunteer subjects have remained on an all-chemical sustaining diet for three months with no adverse effects. In the area of bioinstrumentation, new and sophisticated instruments are being developed and refined to measure biological, biochemical and biopsychological processes. Research is also being conducted into new methods of biological data processing, storage, and analysis using standard computers, modifying portable digital computers and developing new concepts in computers such as the use of photoconductor phenomena. General support is given to the other Bioscience programs by the sponsorship of conferences, symposia and related communications media.

In the Supporting Research and Technology areas described above, a total of $5,762,000 was expended in the years prior to fiscal year 1963. Most of these funds were spent at Headquarters for research in various biological areas. The balance was spent at the Ames Research Center and the Jet Propulsion Laboratory. The fiscal years 1964 and 1965 efforts include continuing research in the four basic research areas described above, with special emphasis on exobiology. A portion of the exobiology funds are required for investigations into optimum procedures and methods for the effective sterilization of spacecraft. While the major portion of the funds will be expended through the Headquarters office, important work will be performed at the Ames Research Center and the Jet Propulsion Laboratory. In addition, a small sum will be provided the Goddard Space Flight Center to initiate a few selected tasks of importance to the Bioscience program.

Flight Program (Biosatellite)

	1963	1964	1965
Study contracts..................	$300,000	---	---
Spacecraft......................	---	$6,000,000	$10,200,000
Experiments.....................	1,659,000	2,500,000	2,300,000
Ground support..................	---	---	200,000
Launch vehicles.................	---	---	6,500,000
Total costs..................	$1,959,000	$8,500,000	$19,200,000

The Biosatellite program is designed to study the unique environmental factors of space, which include the biological effects of zero gravity or weightlessness, and the effects on biological rhythms of removal of living organisms from the earth's rotation. The effects of weightlessness, combined with a known source of radiation, will be studied to determine what effects, if any, result from this combination. It will then be possible to extrapolate to conditions in deeper regions of space from the great amount of ground-based data on biological effects of radiation.

The Biosatellite experiments include studies at the cellular, tissue, organ, and organism levels as well as studies on fundamental phenomena such as biochemical reactions, protoplasmic streaming, fertilization, embryological development, and growth experiments at the tissue level. The experiments involving organisms would include physiological (including fluid transport), behavioral, reproductive, genetic and overall performance studies. They will include experiments with a wide variety of plants and animals from single cellular organisms to higher plants and animals including primates.

About 175 biological experiments have been submitted by scientists from universities, government, and industry. Panels of scientists have reviewed these experiments, about 40 experiments have been rated as high priority, and many are now being readied for flight. The Ames Research Center is cooperating with experimenters to determine the engineering, life support and telemetry requirements. Breadboard layouts are being made and integration of experiments is being studied.

The experiments are divided into six categories, including (1) primates; (2) mammalian (non-primate); (3) animal, cellular, and egg; (4) plant morphogenesis, photosynthesis and growth; (5) biorhythm, and (6) radiation. The primate experiments include cardiovascular studies involving implants, neurological studies with deep brain probes, the measurement of skeletal calcium loss, and the effects of weightlessness on urinary and gastrointestinal systems or performance. Pigtail, Rhesus, and squirrel monkeys will be used in orbital flights of from three to thirty days duration.

Six Biosatellites will be flown, with the first flight in late 1965 and additional flights at roughly three-month intervals. The launches will be from the Atlantic Missile Range in a 250 statute mile circular orbit. The spacecraft will weigh from 1,000 to 1,300 pounds and will have a payload capacity of 150 to 200 pounds. The internal atmosphere supplied to the biological specimens will be a mean earth atmosphere, that is, composed of 20 percent oxygen and 80 percent nitrogen at 14.7 pounds per square inch to prevent any effects of unusual atmosphere. Certain experiments will be supplied with specialized temperature or other environmental conditions.

The satellite will be tracked while in orbit by existing networks. Both engineering and experimental data will be telemetered to the ground stations for the biologists to monitor, or to enable the ground personnel to command recovery. The recovery operation is currently under investigation. The two possibilities are air snatch recovery by the Air Force aerial recovery group with back-up by ship-based helicopters, or surface retrieval by surface recovery ships. Aerial recovery is preferred because of the need for rapid access to experimental specimens. The Ames Research Center has been assigned primary responsibility for the Biosatellite project, with support to be supplied by Goddard Space Flight Center for the launch vehicles and for the command and control.

Expenditures in years prior to fiscal year 1963 for work connected with the Biosatellite project total $399,000. The major portion of these funds was expended for the BIOS (Biological Investigation of Space) flight project whose objectives were similar to those of the present Biosatellite project. Funding for fiscal year 1963 provided for the initiation of the Biosatellite project through study contracts with three industrial corporations that subsequently resulted in selection of the General Electric Company, Missile and Space Division as prime spacecraft contractor. Funding for fiscal year 1964 will provide for the initiation of design, fabrication and testing of the spacecraft. Funding for fiscal year 1965 will provide for the continuation of the fabrication and testing of the spacecraft, incremental funding for the development of the experiments to the flight-ready state, and partial funding of the Delta launch vehicles. Total funds required for completion of the Biosatellite project in fiscal year 1967 are estimated at $57.6 million.

OFFICE OF SPACE SCIENCE AND APPLICATIONS — METEOROLOGICAL SATELLITES PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Meteorological Satellites program uses space science and technology to contribute to both the scientific and applications aspects of meteorology. In the scientific aspect, NASA is providing the data required for research which will improve the understanding of the relationship between the earth's weather and events in and beyond the upper atmosphere. NASA, in the applications aspect, is developing weather satellite systems, including spacecraft, and the ground control and data acquisition equipment that effectively contribute to the Weather Bureau's execution of its national weather service function, and the weather dependent operations of the Department of Defense. Thus, specific objectives of the NASA Meteorological Program are: (1) to develop and improve space technology, including sensors and subsystems, which will provide data for use by meteorologists; (2) to carry out flight tests as required to test, calibrate and prove the applicability of the instrumentation; (3) to fulfill special data requirements of the atmospheric science community which can be provided uniquely by satellite instrumentation; and (4) to participate in the operational meteorological satellite systems as required to assist the Weather Bureau in the conduct of the operational system.

The eight TIROS satellites have provided almost continuous cloud cover surveillance since April 1, 1960. The first of the advanced Nimbus spacecraft is being readied for launch early in calendar year 1964, and new TIROS configurations and experiments are being completed for launch in mid-1964 and thereafter.

Data from meteorological sounding rockets have shown that in the altitude region from twenty to sixty miles temperatures and winds change in a manner indicating the vital part that this region plays in linking extraterrestrial events to the earth's weather.

The data to be obtained from operational satellites have known application, but work will continue by the research community on determining additional significance for the data. It is expected that all meteorological data from an operational weather satellite will be useful in the scientific study of the atmosphere. New areas of research have already been opened up in such areas of the atmospheric sciences as the detection and tracking of tropical storms, the heat budget of the earth, infrared radiation characteristics of cloud systems, etc.

SUMMARY OF RESOURCES REQUIREMENTS:

	1963	1964	1965
Supporting research and technology....................	$4,877,000	$6,900,000	$6,600,000
Synchronous meteorological satellite experiments.........	---	---	3,200,000
TIROS..........................	19,176,000	16,800,000	5,800,000
Nimbus.........................	28,561,000	41,200,000	18,900,000
Meteorological sounding rockets......................	1,437,000	2,900,000	3,000,000
Total costs..................	$54,051,000	$67,800,000	$37,500,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1963	1964	1965
Synchronous meteorological satellite.....................	$300,000	$300,000	---
Advanced meteorological system component development.........	2,070,000	2,900,000	2,000,000
Advanced meteorological sensor development..................	1,111,000	1,500,000	$1,900,000
Meteorological systems research.	1,396,000	2,200,000	2,700,000
Total costs.................	$4,877,000	$6,900,000	$6,600,000

The objectives of the supporting research and technology effort continue to be: (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 new concepts or applications of meteorological systems for feasibility and value to the program.

In past years, supporting research and technology has supplied the initial work leading to the improved sensors to be flown aboard the TIROS and Nimbus spacecraft. The supporting research and technology effort may be categorized as follows:

Advanced Meteorological System Component Development. This effort developes the supporting equipment for recording and transmitting the information, for providing suitable power, and for stabilizing or aiming, and geographically referencing the position of the sensors' observations.

Advanced Meteorological Sensor Development. This effort leads to sensors which make the physical measurements used to supply meteorological data.

Meteorological Systems Research. This research has as its goal the determination of what physical measurements will provide the meteorological data needed by the research or operational users, what technical developments are necessary to make such measurements feasible, and what data handling will be required prior to transmission to the user.

Fiscal year 1963 funds were applied to continue the developments initiated in fiscal year 1962, and to initiate new studies and developments in the following major areas: synchronous meteorological satellite system studies, satellite radiation studies, day-night TV sensors, studies for satellite system data analysis and transmission, and various component developments such as attitude controls and video recorder systems. Fiscal year 1964 funds are being used to continue these activities and to start work in component and systems development for the synchronous meteorological satellite experiment, for rocket wind measurements, sferics studies, and for studies leading to an interrogation and recording subsystem which will be useful in collecting oceanographic and meteorological data from remote instrumented stations. Also work has started with the fiscal year 1964 funds for digital TV component development. The fiscal year 1965 funds are planned to continue the work in the above areas.

Synchronous Meteorological Satellite Experiments

	1963	1964	1965
Experiments....................	---	---	$3,200,000
Total costs..................	---	---	$3,200,000

The TIROS and Nimbus efforts are aimed at fulfilling the requirements for complete global coverage by meteorological satellite data on a detailed, periodic basis. However, the requirement remains for a system which can provide continuous monitoring of short-lived storms such as squall lines, tornadoes, etc. The feasibility of such a system will be investigated as part of the Advanced Technological Satellite project which will place a satellite in a 22,300 mile orbit so that it appears to be stationary at a given location over the equator. From such a position, a satellite can view tropical and temperate latitudes. With such a satellite instrumented to obtain meteorological data, continuous surveillance can be undertaken of a particular storm as it moves over the surface of the earth.

Several areas requiring technological development have been selected for flights of applicable experiments prior to proceeding to flight project status. Thereby test results will contribute to the definition of the flight project. Experiments are planned for required operating modes of the optical system, in the wide range of light values to be observed, and in the other optical problems involved. The effects of sensor motion on spacecraft stabilization and station keeping will also be studied.

System studies were begun in fiscal year 1963 and completed in fiscal year 1964 under the supporting research and technology funding. Studies and hardware development for experiments are proposed for fiscal year 1965 so that these experiments will be ready for flight aboard spacecraft beginning in calendar year 1966. Total cost to completion of these experiments is estimated at $16.5 million. Direction of this proposed work will be assumed by the Office of Space Science and Applications of NASA Headquarters with Goddard Space Flight Center implementing the effort.

TIROS

	1963	1964	1965
Spacecraft......................	$7,905,000	$9,800,000	500,000
Ground support..................	1,071,000	3,200,000	$2,000,000
Launch vehicle..................	10,200,000	3,800,000	3,300,000
Total costs..................	$19,176,000	$16,800,000	$5,800,000

The engineering and scientific feasibility and the desirability of meteorological satellites has been demonstrated repeatedly by TIROS. In addition, TIROS continues to provide data toward the accomplishment of the additional project objectives which are: (1) to provide maximum interim operational data for use in weather analysis and forecasting prior to availability of data from operational systems, (2) to provide research and development toward advanced meteorological satellite systems, (3) to measure emitted infrared and reflected solar radiation in selected spectral regions, and (4) to observe cloud cover and patterns, and measure the earth-atmosphere heat balance.

The eight attempted launches have all been successful. Data for operational use have been provided since the first TIROS launch, April 1, 1960. TIROS has achieved a useful lifetime in orbit more than triple the original design lifetime of about four months. These satellites have discovered seventeen hurricanes and typhoons during project operations since July, 1961.

Research based on TIROS data has produced significant results in: (1) determining generally the relationships of the cloud patterns to the field of motion, (2) the genesis and life cycles of tropical storms, (3) identifying areas associated with severe local storms (such as tornadoes) from satellite pictures, (4) identifying and correlating cellular convective cloud patterns with the basic atmospheric parameters, and (5) utilization of satellite pictures in surveillance of ice packs and snow fields and cover.

The successful launch of TIROS VIII on December 21, 1963, with the Automatic Picture Transmission (APT) system aboard, is providing direct local readout to relatively inexpensive ground stations.

During fiscal year 1965, the ninth spacecraft in this series designated TIROS I, the "wheel" configuration, will be tested for providing earth oriented pictures from the spin-stabilized TIROS spacecraft. It is this configuration which when tested is expected to replace the earlier TIROS configuration in the Interim Operational Meteorological Satellite (IOMS) being funded by the Weather Bureau. These Interim Operational Meteorological Satellite launches are planned to begin in fiscal year 1965.

TIROS J will be launched into a low eccentric orbit in fiscal year 1965 to provide data at various altitudes and picture resolutions which will contribute to the technology required for advanced meteorological systems. The last TIROS launch (TIROS K) planned for fiscal year 1965 will be placed into a highly eccentric orbit with apogee at approximately synchronous altitudes. In fiscal year 1966, TIROS L will include one standard TV camera and one automatic picture transmission system for direct readout.

The fiscal year 1963 funds were used to purchase 4 Delta vehicles for TIROS VI, VII, VIII and "I" and an incremental payment for "J". Funds were also used to purchase spacecraft VII and an incremental payment was made on VIII. Also funds for Ground Operations and Support were used for TIROS V, VI, and VII.

The fiscal year 1964 funds provide complete funding for the "J" launch vehicle, an incremental payment for the TIROS "K" and "L" launch vehicles and spacecraft, and will complete the funding of TIROS VIII, "I" and "J". Also, funds are provided for Ground Operations and Support of TIROS VII and VIII. Fiscal year 1965 funds are planned to complete payment on spacecraft and the vehicles for "K" and "L", and to complete funding of Ground Operations and Support for TIROS VIII, "I" and "J".

The direction of the TIROS project is the responsibility of the Office of Space Science and Applications at NASA Headquarters. The project implementation is accomplished at Goddard Space Flight Center. The major contractor is the RCA Astro-Electronics Division.

In the TIROS project, especially as applicable to the operational aspects and development of operational systems, NASA and the Weather Bureau work closely together. The projects costs through fiscal year 1963 were $36,778,000. The project cost to completion including the next four launchings is estimated to be $60,193,000.

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Nimbus

	1963	1964	1965
Spacecraft A, backup and B.......	$24,016,000	$30,800,000	$8,900,000
Ground support....................	3,345,000	9,400,000	6,600,000
Launch vehicle....................	1,200,000	1,000,000	3,400,000
Total costs....................	$28,561,000	$41,200,000	$18,900,000

The basic objectives of the Nimbus project are: (1) to develop a significantly improved meteorological satellite to provide data for use by meteorologists; (2) to carry out flight tests to prove the applicability of the instrumentation; (3) to fulfill special data requirements of the atmospheric sciences research community which can be provided uniquely by this instrumentation, functioning as a space meteorological observatory; and (4) to provide the basis for further significant technological advances in meteorological satellites.

The Nimbus spacecraft embodies major steps forward, beyond the basic TIROS, in four areas: (1) Orientation - Nimbus is designed to point down at the earth at all times; (2) Coverage - The satellite has the capability to provide complete global cloud cover data daily; (3) Night Time Cloud Cover Data - Specially developed high resolution infrared radiometers will be used to obtain experimental night cloud cover; and (4) Direct Local Readout - Users equipped with relatively simple, inexpensive ground stations can receive cloud cover pictures of their local area directly from the satellite. (This system is being tested in orbit on TIROS VIII.)

The Nimbus scheduled for launch in the first quarter of calendar year 1964 weighs about 750 pounds, stands ten feet high and is five feet across the sensory ring at the base. The sensory system will include three vidicon cameras, the automatic picture transmission system for direct local readout, and the high resolution infrared radiometers (HRIR) for providing night time cloud cover data. Should it be required, a backup (duplicate) spacecraft for the first Nimbus will be available for launch in fiscal year 1965 (third quarter of calendar year 1964).

The Nimbus B will be ready for launch in fiscal year 1966 and will incorporate redundant advanced vidicon cameras (two sets of these cameras), a redundant automatic picture transmission system, a single high resolution infrared system, and an advanced medium resolution infrared radiometer (MRIR). The greater weight resulting from these additional sensors will require the use of the thrust augmented version of the Thor-Agena launch vehicle.

It is expected that the experience resulting from the Nimbus will play a vital role in the development of operational meteorological satellite systems. Of immediate use will be the broad coverage (near global) day and night cloud cover data available from Nimbus flights.

Fiscal year 1963 funds were used to complete payment for the Thor-Agena "B" vehicle for Nimbus A and an incremental payment was made on the second vehicle. An incremental payment was made on 3 spacecraft and on the associated ground equipment (command data acquisition stations in Alaska and at Goddard plus other accessorial equipment).

In fiscal year 1964 an incremental payment is provided for the second vehicle. The funding for the Nimbus A spacecraft will be completed and an incremental payment on the backup and "B" spacecraft. The Ground Operations and Support funds are to complete the funding of ground equipment, the training of operating personnel and checkout of the ground systems, and for operations and maintenance subsequent to the launch of Nimbus A.

In fiscal year 1965 the funding will be completed for the second launch vehicle and completion of the backup spacecraft. Additional incremental payment will be made for the Nimbus B spacecraft. The fiscal year 1965 funding also provides for Ground Operations and Support for Nimbus A and pre-launch modification and checkout of the ground equipment for the Nimbus B launch.

The cost through fiscal year 1963 has totaled $61,236,000. The estimated cost to completion for the program through Nimbus B as outlined is $130,000,000.

Meteorological Sounding Rockets

	1963	1964	1965
Development of small meteorological sounding rocket system...	$147,000	$1,100,000	$1,100,000
Large meteorological sounding rocket project................	1,290,000	1,800,000	1,900,000
Total costs....................	$1,437,000	$2,900,000	$3,000,000

For the large meteorological sounding rocket project the objectives are to develop and improve sensors and techniques for measuring the basic meteorological parameters in the region from 40 to 60 miles. The launch sites for these large rockets are located at several different latitudes. This distribution contributes to determining the magnitude and extent of the dynamic and thermodynamic variations of the atmospheric properties in the upper stratosphere and mesosphere.

In fiscal year 1963 fifteen large sounding rockets were launched using three experimental techniques; accoustical grenades, pitot tubes, and sodium vapor. These launches showed the applicability of the measurement techniques, and revealed interesting scientific features found at these altitudes. This included the existence of large wind shears in the area under study.

During the fiscal year 1964 approximately thirty-five of these launches are currently planned. The results are expected to lead to the refinement of measurement techniques, and provide additional scientific data. These launches will be distributed among Wallops Island; Ft. Churchill; John F. Kennedy Space Center, NASA; Ascension Island; and, possible, an Alaskan artic location. The launches from these locations, when possible, will be coordinated to provide measurements of geographical variation in addition to seasonal variations. In fiscal year 1965 funds are planned to provide for additional ground equipment and to pay for 45 large sounding rockets, of which 35 will be launched in fiscal year 1965.

Direction of the large meteorological sounding rocket project is by the Office of Space Science and Applications at NASA Headquarters. Implementation of the project is the responsibility of the Goddard Space Flight Center.

In the project to develop a small meteorological sounding rocket system, the objective is to develop a reliable, simplified, self-sufficient sounding system (rocket vehicle, sensors, and data acquisition) which would provide a capability for routine measurements of the basic meteorological parameters for research and an operational system in the 20 to 40 mile region of the atmosphere.

Data which have already been obtained in connection with previous developmental flights indicate that this region serves as an important link between the higher regions dominated by solar effects, and the lower regions where convection and air mass movement and mixing determine the surface weather. Thus, obtaining more data leading toward further understanding of the atmospheric processes is a step toward the solution of significant problems in weather analysis and forecasting.

The fiscal year 1963 funds paid for seventy-five small meteorological sounding rockets and launch costs. The fiscal year 1964 funds provide for an increment toward development of the small sounding rocket system (motor, sensors, data acquisition equipment, etc.), purchase and flight test of 100 small sounding rockets of various types. The fiscal year 1965 funds are planned for the flight testing of 100 rockets, improvement of the rocket systems, and a start on the design and development of an advanced system.

These launches are coordinated with those from the other national ranges as part of the meteorological rocket network.

Direction of the small meteorological sounding rocket project is the responsibility of the Office of Space Science and Applications in NASA Headquarters. Langley Research Center is responsible for the project implementation.

OFFICE OF SPACE SCIENCE AND APPLICATIONS — COMMUNICATIONS SATELLITES PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

Communication satellites make it possible to establish microwave communications over long distances by providing relay stations at altitudes where they are simultaneously in line-of-sight of many points on the Earth's surface. With their use all types of telecommunications can be extended to the entire Earth. This program will support the continuing development, improvement, and expansion of the practical uses of communication satellite systems through research, development, and flight tests.

Launches of communication satellites through the first half of fiscal year 1964 have (1) proved the feasibility of erecting passive satellites in space and of placing active satellites in intermediate and synchronous orbit, and (2) permitted successful conduct of communications experiments with Echo I, Relay I, Telstar I and II, and Syncom II, linking the United States with Europe, United States with Africa, United States with South America, and United States with Japan. As the year 1964 begins, Echo I is still in orbit after 3½ years, Relay I has completed one year of successful operations, and Syncom II has operated successfully for six months since its launch in July 1963. Echo III, Relay II, and Syncom III, to be launched in the last half of fiscal year 1964, will be of greater reliability than their predecessors and will furnish additional lifetime data. In addition, Syncom III will be placed in a synchronous equatorial orbit over the Pacific Ocean whereas Syncom II is in a synchronous orbit included 33^{o} to the equator over the Atlantic.

This program utilizes and advances the practical application of space communication, seeks the full exploitation of the communication satellite potential, and assists in attaining the national goal of the early establishment of an operational global communications satellite system.

SUMMARY OF RESOURCES REQUIREMENTS:

	1963	1964	1965
Supporting research and technology	$3,012,000	$1,700,000	$3,500,000
Echo II	2,299,000	2,600,000	300,000
Relay	13,751,000	2,900,000	1,800,000
Syncom	13,013,000	6,300,000	2,000,000
Early gravity gradient experiment	---	---	5,000,000
Total costs	$32,075,000	$13,500,000	$12,600,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1963	1964	1965
Advanced passive satellite studies......................	$700,000	$500,000	$1,000,000
Research, experimentation, and development..................	2,312,000	1,200,000	2,500,000
Total costs..................	$3,012,000	$1,700,000	$3,500,000

In the Communications Satellites program there is a continuing need for activity in supporting research and technology which will identify and solve critical technical problems, advance the state-of-art, and provide a technical foundation for future improved communications and navigation satellites.

Research on overall communication system problems over the past several years has been concentrated in three areas: integration of communications satellite systems with conventional terrestrial systems; economic factors; and technical aspects of frequency allocation and sharing. The latter effort contributed importantly to the International Telecommunications Union Conference on Space Communications. Additional studies will be conducted in fiscal year 1965 on integration of satellite and terrestrial systems, to determine the influence on design of future communication satellite systems of present and planned routing, signalling, switching, and multiplexing schemes for terrestrial systems. These studies will provide a basis for upcoming international negotiations relating to the integration of satellite and terrestrial systems.

Economic studies in the past have begun to provide valuable information on tradeoffs between various communication satellite systems and between design parameters. These studies will be pursued in fiscal year 1965 as an aid in selecting the best course for research and development.

In fiscal year 1963, three navigation-traffic coordination satellite system feasibility study contracts were initiated and are scheduled for completion in fiscal year 1964. An in-house comparison of the results will then be made with cooperation from potential user agencies. It is anticipated that, through the joint efforts of National Aeronautics and Space Administration and the various government departments or agencies (Federal Aviation Agency, Departments of Commerce, Interior, Treasury, and Defense) having an interest, a recommended national program plan will be developed which will set forth the required future effort.

In fiscal year 1965, investigation effort will continue on satellite systems capable of linking terminals of greatly reduced size and cost making possible communications with aircraft, ships at sea, and small portable emergency land stations. A capability of this sort will be necessary for navigation and air traffic control systems, and will require the use of either a high-powered, fully stabilized satellite or a satellite with moderate power and high-gain, narrow-beam, steerable antennas.

A modest laboratory effort on materials, structures, and erection-system development in advanced passive satellite research has been conducted in the past and will continue during fiscal year 1965. Materials and structures development efforts are directed toward providing for greatly reduced weight and adequate stiffness of space structures to reduce the perturbing and deforming effects of solar pressure and aerodynamic drag. Erection systems will be developed having characteristics required for reliably deploying and erecting these lightweight structures in the space environment.

The fiscal year 1965 program to improve subsystems will provide for continuation of studies on modulation techniques, with emphasis on techniques which improve multiple access capabilities; on raising the conversion efficiency between the satellite's primary power source and transmitter power output; and on improving the characteristics of both satellite and ground receivers.

Echo II

	1963	1964	1965
Spacecraft....................	$1,544,000	$300,000	---
Ground operations and support..	255,000	1,000,000	$300,000
Thor-Agena launch vehicle......	500,000	1,300,000	---
Total costs..................	$2,299,000	$2,600,000	$300,000

The objectives of Project Echo II are to design, develop, launch, and evaluate a 135-foot diameter spherical passive satellite (Echo II), which will be rigid enough to maintain its suitability as a reliable reflector of radio waves throughout its orbital life of several years, even after the pressurizing gas has escaped. The passive communication satellite will be launched into a 800 statute mile near-polar orbit. A test program involving two ballistic launches from the Atlantic Missile Range to test the satellite deployment and inflation sequence has been completed. The first ballistic flight, which was conducted on January 15, 1962, was unsuccessful. A redesigned payload was launched in the second ballistic test on July 18, 1962. Inflation was successful but the sphere was not a good reflector of radio waves because of insufficient pressure. Accordingly, the satellite inflation system has been redesigned to provide sufficient pressure in the sphere. Flight spacecraft are being prepared for the orbital launch scheduled for the first quarter of calendar year 1964, using a Thor-Agena vehicle.

The launch vehicle will carry a television system of the type used on the ballistic launches to permit observation of satellite separation and inflation during injection into orbit.

The Office of Space Science and Applications, National Aeronautics and Space Administration Headquarters, is responsible for the overall management of Project Echo II. Responsibility for project management is assigned to Goddard Space Flight Center. Vehicle systems management for the Thor-Agena vehicle is assigned to Lewis Research Center. Major contractors are G. T. Schjeldahl Company for the inflatable spheres, Grumman Aircraft Corporation for the canisters and launch support, Douglas Aircraft Corporation for the ballistic launch vehicles and the Thor booster for the orbital launch, and Lockheed for the Agena stage and integration of the launch vehicle. Support is also provided by participation of various Department of Defense tracking facilities.

Fiscal year 1963 and prior years funds amounting to $14.7 million have provided for design, development, fabrication, and evaluation of the spherical satellite; its associated tracking beacons and canister; and partial funding of the orbital launch vehicle. They have also supported all costs for the two ballistic flights. Fiscal year 1964 funds cover spacecraft costs, qualification tests, launch operations of Echo III, remaining launch vehicle costs, and initial operation of the radar and optical stations which will be used to obtain data from which the performance of the satellite in orbit will be assessed. Fiscal year 1965 funds are required to continue the radar and optical coverage of the satellite as well as for data analysis, correlation of that data with ballistic launch, and ground test results. It is estimated that an additional $200,000 will be required after fiscal year 1965 for continued data acquisition, reduction, and analysis.

Relay

	1963	1964	1965
Spacecraft......................	$6,616,000	$ 500,000	---
Ground operations and support..	6,135,000	2,100,000	$1,800,000
Delta vehicle..................	1,000,000	300,000	---
Total costs..................	$13,751,000	$2,900,000	$1,800,000

The mission of Project Relay is to perform experimental narrow band (telephone, etc.) and wide band (television) communications tests between widely separated ground stations by means of intermediate altitude active communications satellites; to measure the effects of the space environment on these satellites; and to determine the useful lifetime of the satellites.

Project Relay provides for the design, development, launch, operation, and evaluation of two intermediate altitude wide band active communications satellites. These satellites include circuits and components to monitor the important parameters of the satellite while functioning in the space environment. The satellites contain, in addition to power supplies and command and telemetry equipment, two (duplicate, but not simultaneously operating) communication transponders each providing a single television channel or twelve two-way telephone or data channels; and experiment packages to monitor both the radiation environment encountered and the damaging effects of that environment on components designed for satellites.

Relay I was launched into orbit on December 13, 1962. An early failure occurred which prevented operation of the transponders for the first three weeks after launch. Since that time the satellite has been operating successfully for more than a year performing more than 1,800 technical experiments and 125 demonstrations involving ground stations in the United States, Great Britain, France, Germany, Italy, and Japan. During this period more than 550 hours of radiation data have been recorded. An improved satellite has been prepared for launch into orbit in the first quarter of calendar year 1964 to gather further experimental data, evaluate the spacecraft improvements, continue radiation measurements, and provide a measurement of useful satellite lifetime.

The Office of Space Science and Applications, National Aeronautics and Space Administration Headquarters, is responsible for the overall management of Project Relay. Responsibility for project management is assigned to the Goddard Space Flight Center. Vehicle systems management for the Delta vehicle is also a Goddard responsibility. Major contractors are Radio Corporation of America for the satellites; Space Technology Laboratories for satellite preliminary design, systems coordination and planning, test station operation, and experiment review and analysis; Philco Corporation for the West Coast station antenna; American Telephone and Telegraph and International Telephone and Telegraph for ground station operations; and Douglas Aircraft Corporation for the launch vehicles.

Fiscal year 1963 and prior year funds amounting to $39.8 million have provided for spacecraft design, fabrication, test, a major part of the procurement of launch vehicles, launch operations support, ground station operational services, and performance of experiments for Relay I. Fiscal year 1964 funds provide for the final experiments and data handling costs for Relay I, final assembly, test, launch, ground station operation for the first six months of the Relay II, and final incremental funding of launch vehicles. Fiscal year 1965 funds are required to maintain and operate the communications ground stations, to perform communications experiments, to coordinate the overall experimental program, and to gather, reduce, correlate, and analyze the data obtained through the Relay I and II experimental programs. This analysis will result in improved design criteria and techniques for future satellites, both communication and scientific, and in more reliable data as to satellite lifetimes and operational systems design. It is estimated that an additional $500 thousand will be required after fiscal year 1965 for operation of ground stations, data collection, reduction, and analysis.

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Syncom

	1963	1964	1965
Spacecraft......................	$5,092,000	$2,700,000	$300,000
Ground operations and support...	3,921,000	500,000	1,700,000
Thrust-augmented Delta (TAD)....	4,000,000	3,100,000	---
Total costs..................	$13,013,000	$6,300,000	$2,000,000

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

Project Syncom provides for the design, development, testing, and launching of four active communication satellites into synchronous orbits.

Syncom I was launched on February 14, 1963, but all electronic systems failed during the firing of the apogee kick motor although subsequent optical sightings showed that the spacecraft did achieve a near-synchronous orbit.

Syncom II was launched successfully on July 26, 1963, into a synchronous orbit. As planned, this orbit has a 33 degree inclination to the equatorial plane which results in the satellite describing a slender figure eight path along a preselected longitude on the Earth's surface with excursions of 33 degrees of latitude to the north and south.

The availability of a Thrust-Augmented Delta (TAD) launch vehicle now makes it possible to launch Syncom III and IV into synchronous orbits of low inclination to the equatorial plane. This capability will make it possible for the first time for a satellite to remain virtually stationary with respect to a point on the Earth's equator. The Syncom IV spacecraft would serve as a means of flight testing new design advances in transponders and range and range-rate equipment for orbital determination while making maximum use of other existing hardware.

The Office of Space Science and Applications, National Aeronautics and Space Administration Headquarters, is responsible for the overall management of Project Syncom. Responsibility for project management is assigned to Goddard Space Flight Center. Vehicle systems management for the TAD is also a Goddard responsibility.

The major contractors are the Hughes Aircraft Company for spacecraft, telemetry and command equipment, and the Space Technology Laboratories for range and range-rate equipment. The Department of Defense through the United States Army Satellite Communications Agency has furnished the ground stations with the exception of ground equipment required for telemetry, command, and range and range-rate.

Fiscal year 1963 and prior year funds amounting to $26.1 million provided for spacecraft design and development, a major portion of vehicle costs, communication experiments, and ground and launch support for the first two launches. Fiscal year 1964 funds provided for flight hardware, communication experiments, ground and launch support, operation of Syncom and the balance due for launch vehicles. Fiscal year 1965 funds are required for flight hardware, communication experiments, ground and launch support for Syncom IV and continuation of operation of the others. It is estimated that an additional $2.0 million will be required after fiscal year 1965 to complete the communication experiments, operational support, and data reduction and analysis.

Early Gravity Gradient Experiment

	1963	1964	1965
Spacecraft..................	---	---	$5,000,000

This project includes research, development, and test of gravity gradient stabilized spacecraft, which directly supports the Department of Defense communications satellite program. The spacecraft design will be compatible with the requirements provided to NASA by the Department of Defense; stabilization components will be designed for orbital test into a 6,500 mile circular orbit; and responsibility for flight demonstration of the spacecraft will rest with the Department of Defense.

The fiscal year 1965 funding estimate covers the design and development of spacecraft, but does not include launch vehicle and ground support services as these will be provided by the Department of Defense.

OFFICE OF SPACE SCIENCE AND APPLICATIONS

ADVANCED TECHNOLOGICAL SATELLITES PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objectives of the program are (1) to develop spacecraft technology particularly suited for space applications, (2) to provide capability for experimental testing of the techniques and devices from various engineering and technological disciplines in the space environment, particularly in the higher altitude orbits, and (3) to provide basic technological and scientific data on gravity gradient stabilization in the 6,500 mile orbit which may be extrapolated to the more difficult synchronous orbits. There is an existing and growing need in the Department of Defense and in National Aeronautics and Space Administration for improved spacecraft technology in the areas of stabilization, orientation, and station keeping in the 24 hour orbit. There is a requirement for obtaining engineering data on the 24 hour orbit for use in designing systems for that discrete orbit with its unique features. There is also a requirement of great importance to both the Department of Defense and National Aeronautics and Space Administration for basic information to validate theoretical concepts of gravity gradient stabilization. This information should be amenable to extrapolation to other altitudes and be convertible to engineering handbook type data for use in systems design. It is the purpose of the Advanced Technological Satellites program to meet these requirements.

SUMMARY OF RESOURCES REQUIREMENTS:

	1963	1964	1965
Supporting research and technology....................	$8,668,000	$2,100,000	$1,100,000
Advanced technological satellites....................	---	16,400,000	29,900,000
Total costs..................	$8,668,000	$18,500,000	$31,000,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1963	1964	1965
Advanced synchronous satellites studies............	$8,668,000	---	---
Stabilization techniques........	---	$1,500,000	$500,000
Propagation studies.............	---	300,000	300,000
Components development..........	---	300,000	300,000
Total costs..................	$8,668,000	$2,100,000	$1,100,000

In the Advanced Technological Satellites program there is a continuing need for activity in supporting research and technology to identify critical problems and long lead-time development items; to advance the state-of-the-art; and to provide a technical foundation for advanced technological satellites.

Spacecraft components and materials investigation and development will be continued. It is anticipated that newly initiated work in microwave and millimeter-wave components for spacecraft will advance the state-of-the-art, and that investigations of existing components will improve reliability. The program to develop high-gain, steerable spacecraft antenna initiated in fiscal year 1963 has begun to yield promising results and will be continued in fiscal year 1965.

Design of radio propagation experiments at frequencies above ten giga-cycles was begun in fiscal year 1964, and development of components necessary to perform the experiments will be carried out in fiscal year 1965. This investigation may extend the useful areas of the radio frequency spectrum.

In fiscal year 1963 and prior years, parametric studies were initiated on passively damped gravity gradient attitude control systems. Rigorous mathematical models have been established and computer analyses have been completed on several three-axis orientation systems. These studies have provided the basis from which conceptual designs for use with satellites in intermediate altitude and synchronous orbits have evolved. In fiscal year 1964, a major advanced technical development effort will be initiated for stabilization components, such as magnetic hysteresis and eddy current libration dampers, extendable gravity gradient booms and associated control mechanisms, and sensors. These efforts will be continued in fiscal year 1965. This program effort is in direct support of planned flight test and demonstration.

Advanced Technological Satellites

	1963	1964	1965
Spacecraft....................	---	$12,700,000	$18,400,000
Ground operations and support..	---	3,700,000	5,600,000
Atlas-Agena vehicle............	---	---	5,900,000
Total costs..................	---	$16,400,000	$29,900,000

The objectives of the Advanced Technological Satellites project are: (1) to provide a capability for performing varied scientific and technological experiments in the synchronous orbit with a single spacecraft; (2) to conduct a carefully instrumented gravity gradient experiment in a 6,500 mile orbit; (3) to develop the technology for an Earth-oriented satellite in the synchronous orbit; (4) to investigate in space a directed antenna from a spin-stabilized satellite; and (5) to investigate access to a communication satellite by more than one pair of ground stations at a time. This program represents a reorientation of Advanced Syncom, reflecting results of studies which have indicated that the original spacecraft has the potential of being used for more than just communications experiments. It can, in fact, be used for many scientific and space technology investigations. It is planned that the technology accruing from this program will form an important input to future spacecraft design and development in the fields of stabilization, orientation (both gravity gradient and active systems), station-keeping, communications, meteorology, radiation damage, and possibly navigation.

The advanced technological satellites spacecraft will be large structures of the 650 pound class. It is planned to launch a total of five spacecraft with five Atlas-Agena launch vehicles over a period of three years. One spacecraft will be launched into a 6,500 mile orbit without the use of an apogee-kick motor. This spacecraft will be gravity gradient stabilized and will be highly instrumented as a gravity gradient technology experiment. The next two spacecraft will be spin-stabilized, launched in a synchronous equatorial orbit, and will carry communications, meteorological, radiation damage, and other technological and scientific experiments suited for a spinning spacecraft. The last two launches will be devoted to developing technology for an Earth-oriented satellite in a synchronous equatorial orbit. These satellites will also carry technological and scientific experiments suited to the Earth-oriented spacecraft.

The Office of Space Science and Applications, National Aeronautics and Space Administration Headquarters, is responsible for the overall management of the Advanced Technological Satellites project. Responsibility for project management is assigned to Goddard Space Flight Center. Vehicle systems management for the Atlas-Agena vehicle is assigned to Lewis Research Center. Major contractors for the spacecraft have not as yet been selected.

Funding on this project started in fiscal year 1964 under the Advanced Syncom line item of the fiscal year 1964 budget, and a substantial study effort preceeded that in fiscal years 1962 and 1963 under supporting research and technology. Fiscal year 1964 funds pay for the reorientation of the project, for initial funding of the 6,500 mile orbit gravity gradient spacecraft, the synchronous orbit spinning spacecraft, and for procurement of ground station equipment. Fiscal year 1965 funds will be required for incremental funding of the launch vehicles for the 6,500 mile and the 24 hour spinning spacecraft, to continue funding the 6,500 nautical mile and synchronous spacecraft procurements, and to complete procurement of ground station equipment.

It is estimated that approximately $77,000,000 in additional funding will be required after fiscal year 1965 to complete the entire program described, to provide for spacecraft design, development, test, launch; launch vehicles; operational support, and data acquisition, reduction, and analysis.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1965 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — BASIC RESEARCH PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The purpose of the Basic Research program is to initiate and administer fundamental research to obtain basic knowledge for our rapidly advancing technology. In order to improve our technological knowledge and techniques, NASA will conduct basic research in the physical and mathematical sciences. Work in the mechanisms of energy conversion in atoms will be helpful in fabricating new gaseous and solid state lasers for use in space communication and tracking; mathematical research is leading toward an improved capability of predicting the motion of a space vehicle; explorations in plasma behavior will provide information helpful to the development of space power systems and electrical engines for spacecraft propulsion; and research devoted to materials will provide techniques to develop newer and lighter materials operating at higher temperatures for space vehicles and supersonic aircraft.

SUMMARY OF RESOURCES REQUIREMENTS:

	1963	1964	1965
Supporting research and technology................	$17,696,000	$21,000,000	$21,000,000
Total costs................	$17,696,000	$21,000,000	$21,000,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1963	1964	1965
Fluid physics...............	$6,716,000	$7,820,000	$7,800,000
Electrophysics..............	3,160,000	3,960,000	4,000,000
Materials...................	7,080,000	8,020,000	8,000,000
Applied mathematics.........	740,000	1,200,000	1,200,000
Total costs...............	$17,696,000	$21,000,000	$21,000,000

Fluid Physics

Fluid physics research provides a fundamental understanding of the flow processes of liquid and gas mixtures involved in aircraft, spacecraft, and advanced propulsion systems. This research is concerned with the flow of gases at very high temperatures (up to 40,000° Fahrenheit in the case of spacecraft entry). At these temperatures, gas mixtures are composed not only of electrically-neutral molecules, but also of atoms, ions and electrons with varying characteristics and accelerated chemical reactions. Thus, theoretical work in fluid physics cuts across conventional disciplinary lines of fluid mechanics, chemistry and physics, and experimentally requires the use of advanced laboratory facilities and instrumentation techniques for producing and measuring high speed and high temperature phenomena. As in most basic research efforts, the work is performed on a continuing basis over a time span of many years.

Examples of some of the projects and the particular emphasis to be given to them in fiscal year 1965 include: the measurement of radiation characteristics, and the heat, viscous, and electrical conductivities and chemical reaction rates of planetary gas mixtures at temperatures up to 40,000° Fahrenheit; the experimental measurement of convective and radiant heat transfer on spacecraft nose shapes for Earth, Venus and Mars entry, and the assessment of the effects of ablation products on conventive and radiant heat transfer; application of fluid physics principles to understand the mechanism of combustion instability of liquid fuel rocket engines; the development of the physics of accelerating and decelerating ionized gas flows by means of magnetic and electric fields; and the extension of knowledge of flow reactions at very low gas densities.

Electrophysics

Electrophysics includes experimental and theoretical investigation into the reactions of electronic, atomic and nuclear states of solids, liquids and gases which are influenced by the static or dynamic forces or gravitational, nuclear, magnetic and electric fields. Information from this research is generally applicable to engineering advances in such fields as space power, radiation effects and electronic communications.

Research is underway to determine and explain the mechanisms of energy transfer in the atomic levels of solids and gases. This will lead to new sources for the stimulated emission of coherent electromagnetic waves (lasers) in the region from gamma ray to millimeter wavelengths. Such signal sources may be applicable to electronic communication and navigation for spacecraft.

Theoretical and experimental superconductivity research will find ways to increase the critical temperature and magnetic field strength of superconductors. Superconducting coils offer a superior method for obtaining magnetic fields which may conceivably be used to shield spacecraft from undesired solar particle radiation.

Investigation is underway to reduce the energy losses in superconducting fields which would make them particularily attractive for use with gyroscope rotors. If the losses can be reduced to an acceptable level, then a new engineering technique will be available for further work on an improved gyroscope for spacecraft guidance.

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Also, experimental research is being conducted on the fission-electric cell. This new technique, if successful, will use the neutron flux of a fission reactor to initiate action of the fission-electric cell thereby directly producing electric power. The work includes high voltage breakdown phenomena, current leakage, secondary electron control and design and fabrication of laboratory units.

For fiscal year 1965, basic research will be continued on the mechanisms of energy transfer in atoms of solids and gases, on the reaction between ionized gases and magnetic fields, and on superconductivity theory and practice.

Materials

Space vehicles and high speed aircraft require superior light-weight materials resistant to heat, stresses, corrosion, erosion, radiations, and the vacuum of space. This program supports integrated basic research and technological developments in materials to help meet the demand.

Basic materials research involves the study of the chemistry and physics of solids and the nature and behavior of metals, ceramics, and polymers. Research and development of new production processes and forming and joining techniques are required for the translation of basic and applied research to reproducible and economical engineering materials.

In fiscal year 1965 a vigorous materials program ranging from the studies of fundamental characteristics to advaneed technology will be pursued and should result in alloys, ceramics, and polymers better able to perform required functions in space vehicles. Particular emphasis will be placed: on gaining an understanding of the behavior of materials in the space environment, particularly looking for the synergistic effects produced by the different components of that environment; and on the NASA polymer chemistry research program to yield polymers capable of desirable structural properties at low temperatures, superior polymers capable for use as adhesives in honeycombs and laminates and as binder in paints, elastomers for use as elastic structure at low temperature, and polymers which appear useful for electronic application.

Applied Mathematics

Work in applied mathematics includes research in mathematical techniques necessary or relevant for application to aeronautic and space problems in science or engineering. A mathematical approach is sometimes the only one possible for rapid and economic consideration of conditions not yet achieved.

In fiscal year 1965 the applied mathematics program will sponsor contracts or grants for investigations in aerodynamic mathematics for predicting vehicle motions within planetary atmospheres; for mathematical work seeking theoretical solutions to problems connected with rocket propulsion; and for research on control of motion and attitude of vehicles in orbit. Research is also planned in the areas of new procedures for improvement of orbit prediction, and abstract numerical analyses aimed at more efficient exploitation of expensive computing facilities.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — SPACE VEHICLE SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objectives of the Space Vehicle Systems program are to identify and solve critical technical problems bearing on present generation space vehicles, and to advance the state- of-the-art to enable the development of more advanced space vehicles.

The space vehicle represents a system of enormous complexity in which the major elements must be brought together and integrated in such a way as to insure reliable and efficient performance. The space vehicle research and technology program reflects the broad scope of mission and operational requirements.

Comprehensive knowledge must be obtained on atmospheric winds and turbulence, aerodynamic forces and moments buffeting and flutter, aerodynamic heating of the vehicle during ascent, and heating of the base and afterbody due to the high-temperature exhaust. The refinement of structural design requires knowledge of the dynamic behavior of the large, highly stressed and flexible vehicles and requires further evolution and development of new and advanced structural materials and principles of structural design.

Comprehensive knowledge of the space environment is required. NASA will study: high-energy charged particle radiations and the interactions of the radiation with matter and new means of shielding; the distribution and population of hazardous particles, and the phenomena of hypervelocity impact and penetration, and means for protection of spacecraft from penetration; the high vacuum of space; thermal radiation from the sun; weightlessness which influences the behavior and control of propellants and other fluids; and the control of spacecraft temperatures.

Atmosphere entry and soft landing of unmanned and manned spacecraft pose continuing vehicle design problems. A broad research program in the areas of aerothermodynamics, fluid physics, structures and materials is required to produce basic understanding of high-temperature gas properties, flow fields, distribution of radiative and convective heating, stability and control, ablative materials and thermal protection systems, and high-temperature structural design.

To guide the overall program of theoretical and experimental research, continuing studies are being conducted of advanced space missions and vehicle concepts. These studies have the specific objectives of assessing new missions or flight operations, providing ideas and innovation in space vehicle concepts, and identifying technical problems requiring long-lead-time research.

Research will also be continued on the aerothermochemical properties of air and various predicted atmospheres of Mars and Venus at the very high temperatures associated with entry flight. More refined theoretical and experimental research on reentry heating will be continued in fiscal year 1965, particularly for the very high speeds associated with Earth reentry upon return from interplanetary flight where the radiative heating becomes increasingly important.

Recent research has shown that zero- or low-lift spacecraft configurations can be achieved to reduce the hot gas radiative and total heating at very high entry speeds (25,000 to 45,000 mph). It is difficult to maintain in the hot environment the relatively sharp nose required on these configurations. Some promising techniques will be studied further in fiscal year 1965.

Significant progress was made in the past year to improve the aerodynamic performance, stability, control and general flying characteristics of advanced "lifting body" type spacecraft throughout the speed range from reentry to landing. Such spacecraft offer considerably improved maneuverability during reentry flight and approach to landing compared to spacecraft of the Apollo and Gemini types. These spacecraft also permit horizontal landing much like the X-15. Some weight penalties for these desirable features and a more difficult problem of assuring adequate reentry heat protection are imposed. The heating is aggravated by complex flow phenomena for these configurations with canopies, aerodynamic control surfaces and other protuberances that are only partially understood. Research on the heating and aerodynamics will continue to be an important part of this work. Also, research will be continued on emergency landing and abort flight problems for this class of vehicle.

Last year evidence indicated the heating of a probe in a Venus atmosphere at speeds above 20,000 miles per hour may be less than previously indicated. This will be examined in greater detail in fiscal year 1965. New evidence on the composition of the Mars atmosphere has also changed the views on a probe shape suitable for Mars entry flight. Such a probe shape will have greater aerodynamic heating and stability problems than previously expected and will require considerable research in order to provide adequate data on heat protection and control during entry.

In fiscal year 1965 research on landing and recovery aids for ballistic type spacecraft will concentrate on aerodynamic and deployment problems of steerable parachutes, paragliders, aerodynamic decelerators, rotors, retrorockets and combinations of such devices.

Spacecraft Loads and Structures

The program provides the technology for improved and reliable structural performance of flight vehicles. The trend toward more thorough ground qualification is a direct consequence of more stringent mission requirements involving performance improvement and longer operating times. Applied research to assure the timely acquisition of appropriate analytical methods and experimental facilities will be continued.

Work will continue on obtaining research information for the design of thermal protection systems for spacecraft atmospheric entry. Current effort is directed toward retaining the high thermal efficiency of ablating materials, while improving their structural properties to an acceptable level.

Research will be continued on the structural advantages of composite materials. Filament reinforced composites exhibit superior strength characteristics and appear to be particularly advantageous for the containment of cryogenic fluids such as liquid hydrogen. The major problem limiting their immediate use centers about mechanical compatibility of liner materials. Primary effort is directed toward providing an acceptable solution to the liner problem. Additional research objectives in spacecraft loads and structures are concerned with environmental vibrations, analytical methods and landing impact.

Launch Vehicle Aerothermodynamics

This research effort is aimed at the solution of aerodynamic and thermodynamic problems of currently approved launch vehicles and provides the necessary body of technological knowledge that will be required for the development of the more highly advanced launch vehicles of the future. The research effort in fiscal year 1965 will place emphasis on launch vehicle heating during flight with particular reference to the effect of nozzle clustering on base heating, improved experimental methods for the laboratory investigation of base heating, and measurements of the radiative heating component due to the incandescent rocket exhaust plumes. Research will also continue on trajectories and staging; launch vehicle static and dynamic stability; vehicle aerodynamic forces; loads, and flow phenomena; and hinge moments on gimballed rocket nozzles.

Research will also be continued on large rocket engine noise. This will include analytical and experimental studies on the generation, propagation, and effects of noise under a variety of operating conditions. This research will include studies of aerodynamic noise generation by boundary layers, wakes, and separated flow, and absorption of low frequency acoustic energy in atmospheres. With particular reference to the advanced vehicles of the future, emphasis will be placed on the aerothermodynamic problems of new and different launch vehicle concepts capable of recovery and re-use.

Launch Vehicle Loads and Structures

This NASA effort is directed toward increasing the efficiency and reliability of launch vehicle structures, through a better understanding of the loads imposed on the vehicle by atmospheric winds and buffet loads, and by striving for lighter structures capable of withstanding these loads. One of the significant accomplishments during fiscal year 1964 was the advance made in dynamic modeling technology attested to by the excellent correlation of the 1/5-scale Saturn I vibration data with the full-scale test data. The present level of effort will continue in most areas of structures research in fiscal year 1965 with an accelerated effort in a few areas.

In this regard, studies of large launch vehicle structural configurations will be made where novel design applications, such as the use of semi-toroidal tanks, will permit shorter vehicles with improved strength and rigidity characteristics. In order to provide adequate containment of low fuel temperatures with no leakage and low heat transfer, a detailed investigation of new materials and their application to lightweight tanks, liners, and insulation will be conducted. The prediction of design loads will receive additional impetus. Methods for the prediction of the dynamic response of structures to winds and other loads will continue to be studied. The increased use of models to aid these investigations will also be studied.

Space Vehicle Environmental Factors

This effort concerns environments encountered beyond the atmosphere that are important to space vehicle design, and the effects of these environmental factors on space vehicles. The five principle areas are high-energy space radiation effects and shielding, meteoroid environment and impact hazard, zero gravity fluid behavior, high-vacuum technology, and thermal radiation and temperature control.

In the high-energy radiation and shielding area, one of the major efforts is the transport of charged particle radiation through matter. A program yielding theoretical estimates of electron penetration will be continued with experimental verification being obtained for the theoretical results. A long-range program, now in its second year, for study of the interaction of protons with matter will continue. Studies of electromagnetic shielding concepts will be continued as a potentially lighter weight, more effective means of shielding. In the area of radiation effects on components and systems, two kinds of research effort are being undertaken. One will provide engineering data for immediate design use in radiation effects on specific components. Another effort of a more basic nature will provide a better understanding of the underlying mechanisms of radiation damage.

The problem of defining the meteoroid hazard to spacecraft is one of both immediate and long-range importance. With increased mission duration and hence increased time of exposure to the hazard, the danger from this source increases. Major research progress was made during the past year with the conclusion of the successful Explorer XVI satellite experiment in which the first direct meteoroid penetration measurements were made. The experiment marked the real beginning of a series of satellite experiments, discussed under flight projects, whose objective is to eliminate insofar as possible the large uncertainty that presently exists with regard to the population and penetrating power of hazardous meteoroids. In addition to the flight experiments, the radio meteor project will be continued in which meteors are observed and their properties measured by radio reflection techniques as they enter the Earth's atmosphere to determine their physical characteristics as well as their distribution in space and time. To properly assess the hazard from any given meteoroid distribution, the phenomena associated with high-velocity impact must be understood. Theoretical impact studies and laboratory experiments using the best available particle acceleration techniques will be continued. In addition, several approaches to the problem of obtaining the yet unattained true meteoroid velocities and masses in the laboratory will continue under development.

Some two years of comprehensive experimental research, using a modest sized drop tower facility, has recently been completed. Major current emphasis will be on research on the dynamics of fluid motion under small accelerations (near-weightlessness) in flight experiments and in available drop tower facilities.

The program in the vacuum area will be primarily concerned with the advancement of techniques for producing better vacuums in the laboratory and for measuring these vacuums with precision.

An important problem in the design of spacecraft is maintaining temperatures in the desired range. Research on active temperature control systems (i.e. those in which the thermal characteristics of a vehicle are varied during a mission) will be continued, as well as further development of improved passive systems which will not degrade in effectiveness during extended space flight for long times to the space environment. Solar radiation design studies will be continued to develop improved light sources, better techniques for calibration, improved optics and the possible use of thermal scale modeling.

Advanced Space Vehicle Concepts

This effort involves the study and analysis of advanced missions, spacecraft, and launch vehicles beyond presently approved projects. Principal objectives are to understand problems associated with advanced missions; to assist in guiding the overall research efforts of the Office of Advanced Research and Technology by the identification of critical and long-lead-time problem areas; and to provide for the innovation and invention of new concepts and vehicles.

In fiscal year 1964, research efforts identified research requirements and provided concepts in support of manned orbital laboratory and manned and unmanned planetary missions. Consideration was also given to the potential and problems of advanced nuclear and nuclear-electric vehicle systems.

Space Vehicle Design Criteria

This effort is directed toward the improvement of future NASA space vehicles by providing the designers with a basic and uniform set of conditions for use in designing launch vehicles, spacecraft, and entry and landing vehicles, as well as integrated space vehicles. Fiscal year 1965 funds will continue this effort.

A number of individual criteria monographs dealing with specific design topics are now in preparation at NASA Centers, some of which should be published in calendar year 1964. These will be coordinated with other Federal departments and with industry to obtain wide acceptance of the criteria and to aid the ultimate development of national criteria for designing space vehicles.

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FLIGHT PROJECTS

Flight experiments are used when ground facilities cannot provide adequate simulation of the space environment, when information about the nature of the space environment is important to space design, or when data is needed to correlate or validate important results from ground facilities.

Scout Reentry Heating Experiments

	1963	1964	1965
Spacecraft and support services...	$1,383,000	$500,000	$1,000,000
Launch vehicles..................	---	1,000,000	1,000,000
Total costs.....................	$1,383,000	$1,500,000	$2,000,000

These tests measure the performance of promising heat shield materials. Ground facilities provide only partial simulation of the heating environment for bodies entering the atmosphere at velocities higher than ICBM speeds. The objective of the Scout reentry experiments is to obtain data on heat shield materials under flight conditions at entry speeds of 28,000 feet per second and higher. Early experiments developed and demonstrated the techniques for obtaining heating data at high entry velocities but did not achieve the expected velocity because of difficulties with the launch vehicle.

Beginning with the second flight planned in calendar year 1964, provisions for recovery will be incorporated in the Scout entry experiments. The funds requested for fiscal year 1965 will provide for one experiment in this series.

FIRE

	1963	1964	1965
Spacecraft and support services..	$ 9,912,000	$ 6,470,000	$ 1,890,000
Launch vehicle..................	4,000,000	1,530,000	1,110,000
Total costs.....................	$13,912,000	$ 8,000,000	$ 3,000,000

The objective of this project is to investigate the heating environment and effects around a blunt Apollo-shaped vehicle during an actual reentry at 37,000 feet per second. The flight tests will provide critical anchor points for validating results from laboratory test facilities and will provide guidance for applying experimental and theoretical reentry data generated by laboratory research. The project provides two flight articles and a prototype spacecraft.

Fiscal year 1965 funds provide for changes in the second flight spacecraft arising from results of the first flight and check-out, launch, data reduction, and reporting of results.

Saturn-Launched Meteoroid Experiments

	1963	1964	1965
Spacecraft and support........	$ 3,940,000	$ 8,000,000	$ 2,600,000
Total costs................	$ 3,940,000	$ 8,000,000	$ 2,600,000

The experiments to be launched on development Saturn vehicles will expose an area almost 100 times that of the Scout-launched experiments to meteoroid penetration. This will permit measurements of the frequency of penetration of metal surfaces as thick as 0.015 inches, approaching nominal vehicle wall thicknesses used in propellant tanks for Apollo and other projects.

Small Space Vehicle Flight Experiments

	1963	1964	1965
Behavior and handling of cryogenic propellants at zero G..	$ 719,000	$ 1,050,000	$ 640,000
Wind shear measurements.........	113,000	200,000	200,000
Meteor simulation...............	535,000	750,000	610,000
Reentry detection...............	84,000	200,000	150,000
Meteoroid penetration probe.....	273,000	100,000	---
Secondary environmental experiments.......................	---	500,000	1,400,000
Total costs..................	$ 1,724,000	$ 2,800,000	$ 3,000,000

This project provides a number of 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 objectives include: studies of the behavior and handling of cryogenic propellants (liquid hydrogen) and their associated systems in the zero gravity and near-zero gravity condition; measurements of wind shear profiles in the vicinity of major-rocket launching bases; 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; measurement of radar cross-section of reentering objects as affected by the ionized air surrounding the object; and secondary experiments, flown on launch vehicles funded elsewhere, to establish the effects of the space environment on the physical characteristics of a wide variety of spacecraft materials.

Lifting Body Flight and Landing Tests

	1963	1964	1965
Flight vehicle & support services..	$ ---	$ 900,000	$ 1,900,000

Present manned spacecraft are of the blunt-body, ballistic or semi-ballistic type (Mercury, Gemini and Apollo), capable of coping with entry heating at speeds as high as lunar return velocity but with very limited maneuverability. Entry spacecraft of the lifting body class, intermediate between ballistic configurations and winged configurations, promise good maneuverability in the atmosphere coupled with ability to withstand the entry heating associated with lunar return or return from missions even beyond the Moon. However, before practical application can be made of the lifting body concept, it is essential to determine the flying characteristics and whether pilots can handle such vehicles.

A preliminary investigation of the approach and landing characteristics of one promising type of lifting body configuration has been accomplished by the Flight Research Center using a simple, inexpensive glide vehicle constructed of steel tubing and plywood. This lightweight vehicle was tested extensively by ground and air tow with release into free-flight. It has now been demonstrated that it can be flown and landed successfully.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1965 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — ELECTRONIC SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Electronic Systems program provides, through research and technology, the basis for developing reliable and efficient components, and flexible and proven techniques for ultimate use in guidance, control, communications, tracking, instrumentation and data processing systems. The spectrum of research activity ranges from laboratory and theoretical investigations which make possible new approaches, to flight experiments employed to examine the feasibility, or provide environmental verification of new devices or theories.

SUMMARY OF RESOURCES REQUIREMENTS:

	1963	1964	1965
Supporting research and technology....................	$15,535,000	$24,900,000	$25,400,000
Small flight projects...........	1,536,000	3,800,000	3,000,000
Total costs..................	$17,071,000	$28,700,000	$28,400,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1963	1964	1965
Guidance systems................	$3,565,000	$5,265,000	$5,435,000
Control systems.................	2,858,000	4,850,000	5,460,000
Communications..................	2,802,000	4,315,000	4,455,000
Tracking and data acquisition...	1,329,000	3,220,000	3,060,000
Data handling and processing....	1,897,000	3,530,000	3,380,000
Instrumentation.................	3,084,000	3,720,000	3,560,000
Total costs..................	$15,535,000	$24,900,000	$25,400,000

Guidance Systems. The guidance system research and technology program is directed towards the derivation of information necessary to understand and design simple, reliable and lightweight sensors, reference elements and associated components which make up a guidance system. The program emphasizes technique and component research in inertial, optical, passive and active electromagnetic phenomena for principal use in the sensing and reference functions. Trajectory analysis provides the framework for examining energy requirements, error analyses, and sensor and data processing trade offs for any specified space mission.

The areas of research in which potential improvements appear most likely are in cryogenic (super-conducting magnetic) and electrostatic gyros, and in atomic and micron size particle gyros and accelerometers. The fiscal year 1965 program will continue these tasks where progress warrants and in addition proposals for gyros and accelerometers using atomic and micron size particles have been evaluated for initiation.

Various factors related to future missions such as range, duration, energy available and abort dictate the need for on-board, autonomous, navigation systems. NASA is emphasizing research in such passive devices as on-board optical space navigation instruments (similar to sextants) and on electro-optical sensors for use as star mappers. In addition, television techniques for data collection and closed-loop guidance systems are planned.

The current effort in active guidance phenomena such as radar and laser type devices and systems is research analysis oriented, and is directed towards examining the requirements and performance parameters from which conceptual designs can be formulated. In parallel with this activity a limited effort will be continued in exploring specific sub-systems and techniques to provide improved systems for later versions of existing spacecraft.

Control Systems. Control system research and development seeks to optimize flight control techniques for manned and unmanned vehicles. Analytical and experimental studies of sensors, controllers, and actuation mechanisms are conducted in order to devise combinations which maximize probability of over-all mission success.

Exploitation of phenomena inherent in the space environment is pursued for control purposes. In the on-going program, the utilization of solar radiation pressure in combination with a momentum exchange device will be investigated as a device for controlling the orientation of a vehicle. The Ames Research Center has completed ground-based studies of a gravity-gradient vehicle orientation system which uses a single passive damper. Bearings, rods, and dampers for such vehicles have been developed. A technological flight test will be proposed for fully demonstrating the feasibility of a passive vehicle orientation system.

The work in controls has also emphasized no-wearing part control sensors and actuation devices, in order to obtain the greatest vehicle life reliability. A research program has been undertaken to increase the sensitivity and accuracy of these devices.

A no-moving part gas valve is being developed for micro-thrusters in the 2-6 micropound range, as a result of research completed in the past year related to the diffusion of hydrogen through a palladium alloy. Theoretical control research will be conducted, in addition to application of adaptive and optimal controls to specific classes of vehicles.

A portion of the manned controls research is related to the investigation of the control and display requirements for future space vehicles, where new and unexplored mission tasks are involved, such as rendezvous, lunar landing, and mid-course attitude control.

Much of the control systems effort is related to understanding man's operation as a control element, and development of a rational design procedure for manned systems. In fiscal year 1965, emphasis will be placed on testing of electronic and mathematical models of control tasks. It is also planned in fiscal year 1965 to examine quantitatively the effects of display dynamics upon the analytical manual control system models developed to date.

<u>Communications Systems</u>. Communications systems research provides technology to minimize spacecraft volume, weight and power devoted to the transmission of data. Present communications systems are prime consumers of spacecraft power and account for a significant percentage of the weight of the spacecraft. The communications systems research effort is directed towards solving this problem by exploring new technologies heretofore not employed for space communications.

To achieve this objective, the research emphasis is placed on submillimeter and optical technology, which, due to its shorter wavelength allows considerable reduction in physical size and weight of the associated components. Also, in electronic components, emphasis is placed on thin film and microelectronics which show promise of smaller size, weight, and power, as well as improved reliability and considerable immunity to radiation.

A laser signal transmission measurement program was initiated in fiscal year 1964 and will be continued in fiscal year 1965. This program will identify the atmospheric effects on the coherence character of radiation and will determine which new techniques or procedures can be employed to minimize such effects.

Submillimeter electromagnetic radiation has received little research attention directed towards communications; however, these frequencies offer considerable promise for deep space communications. During fiscal year 1965, the effort to improve the state-of-the-art in sources and detectors will be continued. Also, an effort will be initiated in radiation transmission measurements under realistic aerospace conditions.

NASA has initiated studies in fiscal year 1964 to determine the feasibility of achieving microelectronic micropower devices; that is, extremely small active and passive devices which perform conventional functions such as amplification, switching and digital logic at power level orders of magnitude below those in use today. A program will be initiated in fiscal year 1965 to fabricate prototype devices.

In fiscal year 1965, studies will be conducted into the pertinent applications of microelectronics in the Saturn V vehicle. Three subsystems have been selected which will be converted to microelectronics. These systems will be thoroughly tested, evaluated, and compared with the existing subsystems to determine the advantages that application of microelectronic techniques offer.

Tracking and Data Acquisition Systems. This research covers the development of technology that will enable more accurate ground determination of spacecraft orbital parameters, such as range, range rate and angular position.

Emphasis is placed on two approaches: optical tracking, which, theoretically, will enable orders of magnitude improvement in both range rate and angular data concerning the spacecraft; and large effective aperture antenna technology which will afford an improvement in the range and data acquisition capability of the ground based system.

Development of real time optical tracking technology will provide an accurate means of tracking during reentry and development of techniques, and will enable a greater portion of the data acquisition equipment to be located at the ground terminal.

The size of ground antennas or radiating aperture has a direct relation to data acquisition capability -- the larger the aperture the greater the capability. During fiscal year 1964, experimentation related to "signal combining" confirmed that arraying of individual apertures can be accomplished with the threshold of detection of the array lower than that of the individual antennas. As a result, a study has been initiated to determine the type of experimental facility that will be required in order to fully evaluate the technique and uncover the effects of the atmosphere on the signal combining procedure. This effort will be continued during fiscal year 1965.

The S-66, Polar Ionosphere Beacon Satellite, has optical corner reflectors which will enable considerable experimentation to be conducted in fiscal year 1965 on both non-cooperative tracking and ground based data acquisition.

Also in fiscal year 1965, laboratory experiments will be conducted on the feasibility of acquiring data, via optical techniques, without the use of a transmitter aboard the spacecraft. If this research verifies the theoretical calculations, then it will be possible to consider earth orbital satellites without transmitters with the attendant increase in reliability and performance of the satellite.

Research will continue on two basic problems associated with optical tracking -- precision position sensing techniques and precision control of the direction of a laser beam. In the former, the effort will be concerned primarily with the interferometric angle measurement techniques, which show promise of at least an order of magnitude improvement in accuracy. Precision closed-loop control research will utilize electro-optical techniques, which will allow complete electronic control of the laser beam.

Data Handling and Processing. In fiscal year 1965 work will be initiated on additional kinds of computer memory systems, notably those using continuous sheets of "ferrite" (magnetic ceramic) plates. Such investigations will produce memory systems having the capacity to retain large amounts of information, and capable of rapid data recall. On-board data processing capabilities, particularly where the handling of television images is concerned, will accordingly be greatly improved.

Research concerning systems and computer programs for the handling of television images is continuing. Work was begun on a new type of TV image-forming device employing thousands of light sensitive elements called "phototransistors". The response of each phototransistor can be determined by electronic means much simpler than the complex switching and synchronizing systems required for conventional TV electron beam scanning.

Television systems will be analyzed, the intent being the reduction of the burden on the communications channel, with some improvement in the image itself. Expected TV system improvements should soon make practicable direct, immediate viewing of the lunar surface or of other nearby objects - for example, artificial satellites.

New, advanced devices which facilitate direct, rapid communication between men and data processing complexes will be developed and tested. These include special keyboard devices, special displays, and appropriate computer programming and other required system developments. In addition to man-machine links, devices which improve communication among computers will be studied and improved.

Instrumentation. Anticipated requirements involve the development of instruments utilizing minimum power and yielding information in a form suitable for immediate use or digital computer processing. These devices must be reliable and precise, have adequate response speed, and be able to operate despite extremes of temperature and radiation levels.

Instruments will be needed to determine the characteristics of the atmosphere, electromagnetic environment, and gravitational and particle fields which surround the major bodies in the solar system.

One of the most difficult measurements is the determination of atmospheric pressure as we move away from Earth. Available devices are accurate in the lower part of the Earth's atmosphere, but are of questionable accuracy in the hard vacuum of deep space.

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Present electromagnetic radiation sensors cover only narrow frequency bands. A series of units must be used to cover the optical-to-infrared-range. Broad-band radiation sensors will be developed to cover the complete range.

The physical condition of personnel in spacecraft and the essential life support systems will be monitored by biomedical instruments of optimum design, and must be integrated into the over-all space vehicle instrumentation.

Recently striking results have been achieved in the area of design and fabrication of miniaturized, completely self-contained, medical sensors. These can be applicable to biomedical instrumentation since they are easily attached to astronauts or animals, are self-powered, and transmit their information - concerning heart-beat and respiration, for example - to radio receivers which may be yards away. Such units, occupying a volume of only a small fraction of a cubic inch, were successfully tested.

A laboratory micro-balance was developed at Ames of such sensitivity that it has detected the pulsations of the heart of a developing embryo within a quail egg.

In fiscal year 1965, in addition to improvements in the miniaturized wireless sensors, studies will be initiated in the general area of sensing of the presence of non-terrestrial living organisms.

Engineering instruments are those sensors needed to acquire information concerning the behavior of the space systems themselves - the ground test facilities, the prototype or final versions of spacecraft during checkout, the launch systems, and the spacecraft in flight. Such information must be made immediately available to ground operations personnel and spacecraft crews - where such exist - during pre-launch, launch, and all post-launch phases.

In fiscal year 1965, NASA will place special emphasis on measurements at high vacuum. Application of the mass spectrometer to the problem of determining the composition of gas mixtures at extremely low pressures will be studied. The lowest pressures at which a gas molecule damped diaphragm pressure-measuring device may be used will be greatly reduced.

In addition, reductions in size and weight and increases in speed of response of devices making use of the "gas chromatography" principle will be accomplished. This technique should be of great value in the analysis of manned spacecraft artificial atmospheres.

In light of its general applicability to all instrumentation programs, attention will be given to new concepts in the digital transducer area. Solid state transducers present encouraging possibilities and will be emphasized in fiscal year 1965.

While the foregoing developments represent specific steps to be taken in fiscal year 1965, research will also be continued on instrumentation for high and low temperature measurement, force and torque measurement, and on particle detection devices of enhanced performance.

Small Flight Projects

	1963	1964	1965
Radio attenuation measurements (RAM)..................	$1,305,000	$2,000,000	$2,000,000
Scanner.........................	110,000	1,800,000	1,000,000
Spacecraft orientation control system (SOCS).........	121,000	---	---
Total costs..................	$1,536,000	$3,800,000	$3,000,000

Radio Attenuation Measurements (RAM). This flight project is designed to provide the flight experimentation and verification of the interaction of electromagnetic radiation with the ionized plasma generated by reentering spacecraft, and the evaluation of means whereby the effects of the plasma on radio waves may be minimized or eliminated. Flight experiments are essential to our understanding of the interaction of radio waves with plasma, as it is not possible to simulate the varying conditions encountered during reentry. Data obtained from flights conducted will supply the technological base upon which solutions to the communication black-out problem will be made for both manned and unmanned reentry at speeds of 25,000 feet per second and above.

Scanner. The Scanner project has the objective of making detailed measurements, from high altitudes, of the natural radiation gradients which define the earth's horizon. A secondary objective is to develop a flight-proven technique for gathering statistical data, possibly in earth satellite spacecraft. The project is an extension of the current research on horizon characteristics. Two flight experiments are planned with an additional set of payload backup equipment and instrumentation provided. Technical advances in Scanner over previous experiments will be the use of star-mapping techniques to correlate sensor pointing directions with observed data, and the acquisition of extremely high resolution gradient data. Recent measurements at 14-16 microns indicate an independence from clouds and seasonal effects for this frequency band. Further study is necessary to verify the optimum frequency for horizon sensor development and application and to assess the spacecraft orientation accuracy attainable with horizon scanner techniques.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY HUMAN FACTOR SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

Future aerospace project successes depend upon the effective utilization of man, both space and ground based. The Human Factor Systems program is providing research supporting the successful consummation of these projects. Specific program objectives are (1) to obtain a better understanding of man's capabilities and limitation and to determine his utilization is advanced aerospace systems, (2) to obtain information which will be the basis for designs of systems for maintaining the high operating efficiency of crews during programmed and emergency phases of advanced aerospace missions, and (3) to determine overall human factor requirements and integrate them into the design of advanced aeronautical, astronautical and ground support systems.

The major program effort is located at Ames Research Center with participation by other NASA centers, other government agencies, universities and industry. The intra-NASA and Department of Defense-NASA review procedures for life sciences tasks avoid duplication of effort and provides a better balanced national life sciences program. Intra-agency coordination of supporting research and technology tasks is conducted through the Life Sciences Subpanel of the Supporting Research and Technology Panel, Aeronautics and Astronautics Coordinating Board. This across-the-board cooperative effort makes certain of a maximum utilization of current data and capabilities in the life sciences.

Future manned space missions depend on the effective, safe utilization of man for extended periods of time. Maximum reliability and safety, and minimum payload weight can be realized by utilizing man as a primary or backup component. Determination of the assignment of such tasks is dependent upon the physical condition of the crew, their performance and their ability to communicate. Throughout these missions, man will be subjected to a variety of natural and mission dependent environments such as vacuum, temperature, acceleration, weightlessness, radiation, and magnetic fields. We must know the physiological and psychological effects of each unique environmental factor, as well as the interaction of these factors to insure the effective integration of man as a part of the total system.

SUMMARY OF RESOURCES REQUIREMENTS:

Supporting Research and Technology

	1963	1964	1965
Supporting research and technology..................	$9,678,000	$13,200,000	$13,200,000
Flight program:			
Small biotechnology flight projects..................	112,000	---	3,000,000
Total costs..................	$9,790,000	$13,200,000	$16,200,000

BASIS OF FUND REQUIREMENTS:

	1963	1964	1965
Advanced concepts..............	$ 311,000	$1,053,000	$ 900,000
Human research and performance.	4,275,000	3,488,000	4,057,000
Life support and protective systems......................	3,407,000	5,216,000	5,000,000
Man-systems integration	1,685,000	3,443,000	3,243,000
Total costs..................	$9,678,000	$13,200,000	$13,200,000

Advanced Concepts

Studies in advanced concepts analyze problems and their solutions in terms of concepts beyond the present state of scientific and technical art. Continuing fiscal year 1965 research in this area includes investigations in systems analysis, human analogs, and bionics. Bionics concerns the analysis of operating principles and of the construction of natural biological systems to determine what they may contribute to the science and technology of systems which include man. Other research includes investigations of cybernetic organisms (cyborgs) which involve the development of mechanisms which work like or may be combined with man. On the most elementary level, this science offers such devices as mechanical limbs which may be controlled as one controls his own limbs. Advanced concepts will offer auxiliary devices which will extend man's ability to perceive and act. For example, the electrical transmission of information to the auditory centers of the brain would bypass the ear entirely. Space suited astronauts would not need earphones; aircraft pilots could have unimpeded communications and yet be able to monitor the airborne sounds of their vehicle.

Human Research and Performance

Space requires man to adapt to new environmental conditions such as zero gravity, zero or intense magnetic fields, variable degrees of ionizing radiation, various pressures and types of artificial atmospheres, relative social deprivation, and toxic effects resulting from contaminants. These environmental differences and their combinations are analyzed in terms of their effects on man's principal body systems; e.g., cardio-vascular, respiratory, central, nervous, gastro-intestinal, and endocrine. They are also analyzed in terms of effects on the whole man when living and working in the space environment. Research results will be used to establish design requirements for life support and protective systems and in determining the most effective utilization of man in future space missions.

In the hermetic space vehicle, many items not normally considered toxic or hazardous can create problems. For example, most plastic is characterized by a slow loss or evaporation of plasticizers or solvents. The closed air cycle of the space vehicle allows such air additives to concentrate, and reduced pressure in the vehicle accelerates such evaporations.

Toxic substances previously unknown are a potential hazard to ground personnel. New fuels are primarily the source of such exposures. An extensive toxicological program has been initiated.

Shielding systems using cryogenic super-conducting magnets offer protection from ionizing radiation with small weight penalty. Such systems, however, produce intense magnetic fields. Research is in progress to determine the effects of such fields on body chemistry and nerve conduction. Such fields have definite biological effects, but more intensive research is required.

Breathing systems using the conventional 5psi and 100% oxygen are unsatisfactory for long term exposure. Pure oxygen causes a number of toxic reactions to body tissue, and the combination of 100 % oxygen and low pressure causes lung deterioration. Further investigations are being conducted to determine the optimum gas pressure and mixture for long term use. Such data is a prerequisite for extended space flights.

Calcium loss from bones and reduction in vascular tone have been observed following brief periods of zero gravity exposure. An investigation is in progress to determine the extent of this problem and corrective measures to prevent or counteract its effects.

Life Support and Protective Systems

Life support and protective systems research has two major goals: (1) development of design concepts for life support equipment which can meet human requirements during long-term space flights, and (2) accumulation and validation of biotechnology data which can be used in the design of manned spacecraft and extra-vehicular systems. In equipment design, emphasis is on systems which require a minimum of auxiliary power, on regenerative systems which require a minimum of supplies, and on bio-instrumentation and associated data processing equipment for adaptive control systems. In design data studies, emphasis is on man's performance in a realistic space environment.

In fiscal year 1965 research in biotechnology will cover (1) work on advancing the state-of-the-art displays, specifically in analog types, which present man with unambiguous visual cues, (2) further surveys of existing psychological and environmental data to determine the validity of these data in the space environment, and, (3) bioinstrumentation and biodata processing equipment, including data display, to optimize man-machine integration and to minimize the work of the man in controlling his environment.

Some advanced display systems, to improve navigation and attitude control, will be flight tested. Ground based simulators using these advanced systems will be operated in conjunction with computers for solution of in flight visibility problems for all environments.

Work on protective systems will cover (1) preliminary designs of manned extravehicular locomotion and protective systems for both "zero-G" and lunar environments, (2) continuing studies on advanced space suits, and (3) preliminary studies on restraint equipment, radiation protection, support equipment, and escape systems applicable to earth orbital, lunar, and interplanetary missions.

Fiscal year 1965 effort will provide expanded laboratory testing of preliminary systems resulting from the advanced studies and feasibility experiments. Research center activity will be divided between Langley, Lewis and Ames.

Man-Systems Integration

Key activities in manned-system integration involve: (1) determining human engineering performance and engineering design criteria for use in design of future aerospace systems; (2) analyzing and simulating future possible aerospace missions to determine additional research requirements, design requirements, or possible experiments; and (3) implementing research experiments, through ground demonstrations and check out, which are intended to be flown in other flight programs.

Continuing efforts are aimed at improved safety in aircraft. Included are studies of pilots' ability and passenger comfort in flight through turbulent air, the abilities of pilots to react to sudden changes in control systems, or to abrupt changes in information input, such as transition between instrument and visual flight or from normal to emergency displays.

A contract effort, begun in fiscal year 1963, continues to investigate the ability of man to maintain space systems when wearing a space suit. The intent is to derive design criteria for space systems. Future investigations are planned to incorporate the zero-G environment. A specific investigation is being made as to the role man can play in maintaining or repairing nuclear power and propulsion systems. The role of man in reusable booster systems was investigated from a flight systems standpoint in fiscal year 1964; and continuation of this effort will be extended into the area of ground support, maintenance and turn-around.

Further investigation will determine design requirements for manned interplanetary and lunar base missions. These investigations will provide improved guidelines for research on subsystems. Mockups of potential payloads for advanced missions are being used in simulation studies of tasks and procedures.

Small Biotechnology Flight Projects

	1963	1964	1965
Small biotechnology flight projects........................	$112,000	---	$3,000,000

There is inadequate information concerning human reactions during, and supporting equipment needs for long duration manned flights. 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 is necessary to provide the answers.

Small flight projects and experiments obtain data not possible through ground experimentation. Experiments will be included in ongoing flight projects as "piggy-back" payloads, where the flight characteristics and engineering design features are compatible.

Advances in sensing and data analysis techniques will be integrated in F104 and X-15 flights conducted at Flight Research Center to obtain improved psychological and physiological data. Biotechnology experiments, such as, heat transfer and fluid flow experiments will be integrated in biosatellite project flights to obtain data required for design of advanced space suits and life support systems. Experiments utilizing small mammals are being planned for integration with Saturn flights. These experiments demonstrate the effects of prolonged zero gravity (6 months or more) on the physiology and performance capacility of test subjects. The combined data from these small biotechnology flights will provide information on the effects of the space environment on humans, and will provide criteria for maximum utilization of man in future space systems.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — NUCLEAR ELECTRIC PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

Nuclear electric power generating systems offer the most practical sources of electric power in the kilowatt and megawatt levels for future spacecraft power. Nuclear electric propulsion systems have the highest performance potential of any system capable of development within the predictable future.

The nuclear electric program is intended to explore and evaluate the advantages and disadvantages, the limitations and problems of the various power and propulsion concepts and their subsystems, and develop the most promising concepts for mission use. The program covers: (1) technology development which includes gathering basic data for component design and component fabrication for evaluation in ground and flight facilities; and; (2) the development of selected systems.

SUMMARY OF RESOURCES REQUIREMENTS:

	1963	1964	1965
Supporting research and technology....................	$19,463,000	$24,600,000	$25,000,000
SNAP-8 development...............	15,994,000	15,500,000	18,000,000
Space electric rocket test (SERT)	3,188,000	4,000,000	5,100,000
Small nuclear electric propulsion and power flight projects.	1,248,000	600,000	---
Total costs....................	$39,893,000	$44,700,000	$48,100,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1963	1964	1965
Nuclear electric power	($9,084,000)	($12,600,000)	($13,000,000)
Space environment effects......	450,000	931,000	840,000
Liquid metal and metal vapor properties and technology....	2,640,000	3,517,000	3,900,000
Gaseous systems and components.	30,000	1,512,000	1,180,000

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	1963	1964	1965
Dynamic systems and components.	$3,195,000	$3,336,000	$3,880,000
Direct conversion..............	1,700,000	1,694,000	1,700,000
Advanced concepts and mission analysis.....................	1,069,000	1,610,000	1,500,000
Electric propulsion	($10,379,000)	($12,000,000)	($12,000,000)
Electrostatic propulsion.......	6,997,000	5,662,000	5,700,000
Electrothermal propulsion......	1,298,000	1,623,000	1,700,000
Electromagnetic propulsion.....	1,092,000	2,330,000	2,500,000
Component technology...........	992,000	2,385,000	2,100,000
Total costs..................	$19,463,000	$24,600,000	$25,000,000

Nuclear Electric Power. The Nuclear Electric Power subprogram provides the technology needed for the design basis of the energy conversion equipment of advanced nuclear electric power generating systems. By "advanced" is meant systems which will be higher in power, lighter in weight, with longer operating lives than systems now being developed, such as SNAP-8. Advanced systems are required for both electric rocket propulsion and future auxiliary power applications.

Specific performance requirements will depend upon the specific applications; overall technology program goals are electrical power levels from hundreds of kilowatts to tens of megawatts, weights of less than twenty pounds per electrical kilowatt, and operating lives of years.

The Rankine cycle liquid metal turbogenerator systems, the Brayton cycle gas turbine type system, and the thermionic direct conversion type system are the principal approaches under investigation for conversion of thermal energy of electrical energy. Other concepts are being explored to a lesser extent for special applications, such as the Stirling piston engine concept for very low power use.

The technology program is being conducted for the most part under the technical direction of the Lewis Research Center, with a small supporting effort at the Jet Propulsion Laboratory.

Space Environment Effects. This technology area is concerned mainly with the space meteoroid problem as it effects radiator design. In the megawatt power range, armor needed for meteoroid protection has been estimated to be as much as 50 percent of the total radiator weight. Determinations of the mechanics of meteoroid penetration and the best approaches for protection are of first priority importance in providing long life, light weight electric power systems. The overall problem of space meteoroids, including all flight testing, is described in the Space Vehicle Systems program.

The environmental effects program consists of:

(1) Simulation of meteoroid impacts using hypervelocity particle accelerators. Simulated meteoroid impacts into targets of simple geometry have been conducted during fiscal year 1964. The results have established the damage mechanisms likely to occur in a real impact; such as dimpling, spalling, cratering, etc. Target configurations closely simulating space radiators are presently being studied. These include liquid-filled tubes, with varying thicknesses of armor and bumper configurations. In fiscal year 1965, additional radiator sections will be fabricated and extensive testing will be performed.

(2) Analytical studies to support the experimental meteoroid simulation program. Studies employing "blast wave" theory have demonstrated a capability of predicting the actual extent of damage using existing facilities as well as a method for predicting damage at actual meteoroid velocities which cannot be simulated in the laboratory. The work will continue in fiscal year 1965.

(3) Continuing examination of photographic and radar records of near-Earth meteoroids to improve the reliability of the meteoroid physical property and flux distribution data now available.

Radiators require ceramic coatings to improve the efficiency of the heat rejection (by radiation) process. Present programs have indicated a dozen promising coatings, some of which will be suitable for SNAP-8 and Surveyor flight radiator applications. Long term tests (up to 15,000 hours) have been conducted on four of these coatings. In fiscal year 1965, the performance of coatings at higher temperature levels will be established. Studies of techniques for applying beryllium armor to refractory metal alloy tubing and the development of diffusion barriers to prevent beryllium from altering the emissivity properties of the ceramic coatings discussed above will be started.

<u>Liquid Metal and Metal Vapor Properties and Technology</u>. This work deals with the materials problems associated with high temperature liquid metal systems and the accumulation of the thermophysical and transport properties of the alkali metal working fluids at the high temperature levels required for light weight systems.

The materials program includes:

(1) Accumulation of data on the physical properties of promising alloys.

(2) The development of suitable alloys of the refractory elements such as columbium and tantalum, for use as tubing and turbine materials as well as materials suitable for use in high temperature electrical generators.

(3) Welding and experimental fabrication studies of refractory alloys.

(4) Methods of improving chemical analysis techniques for determining the amounts of such impurities as oxygen in liquid metals, since corrosion rates and embrittlement are extremely sensitive to impurity levels.

(5) Corrosion testing with boiling alkali metal pumped loops and refluxing capsules.

Programs were started in all of the above areas in fiscal year 1963. Tests indicate that columbium base alloys are satisfactory for boiling potassium at 2,000 degrees Fahrenheit. By the end of fiscal year 1964 two columbium alloy pumped corrosion loops with liquid sodium will have been operated up to 2,000 degrees Fahrenheit for evaluating and endurance testing components such as valves, flow meters, pumps and heaters. A prototype corrosion test loop with boiling potassium is under construction and will be completed in fiscal year 1965. Alkali metal journal bearing materials are presently being evaluated and equipment is being constructed for measuring the friction and wear characteristics of candidate journal bearing materials in potassium at temperatures on the order of 1,600 degrees Fahrenheit. Similar friction and wear tests are planned for materials in high vacuum of 10^{-9} Torr over the same range of temperatures.

The dispersion hardened, tantalum-base alloy development program has resulted in initial alloy compositions which should exhibit high creep strengths up to 3,000 degrees Fahrenheit. All of these programs will continue in fiscal year 1965.

Prior to fiscal year 1963, little data was available concerning the thermodynamic, physical and transport properties of liquid metals at temperatures in the 1,500-2,000 degrees Fahrenheit range. A number of these properties for potassium are currently being obtained under contract. These are: liquid viscosity, liquid specific heat, vapor pressure, heat of vaporization and fusion, liquid thermal conductivity and pressure-volume-temperature relationships. An enthalpyentropy diagram and the vapor specific heat have been calculated from these data.

In fiscal year 1965 work will be completed on the vapor thermal conductivity and surface tension of potassium, plus most of the above properties for cesium.

Gaseous Systems and Components. The Brayton cycle gas turbine power system may be used with a space oriented fission reactor or isotope heat source. The inert gases, Neon, Argon and Krypton, are being studied for use as working fluids. The program consists of contracting for system components and subsystems with performance and endurance testing in-house. Three radial flow compressor-turbine packages were delivered in fiscal year 1964 and will be tested in fiscal year 1965. Additional axial flow equipment and electrical generator packages development has been started in mid-fiscal year 1964. The funds in fiscal year 1965 for the most part cover special test equipment plus construction of some higher temperature components.

Dynamic Systems and Components. Effort is concerned with the technology associated with the key components of turbogenerator systems of both the intermediate temperature (1,500 degrees Fahrenheit), superalloy and the high temperature (2,000 degrees Fahrenheit) refractory alloy types. These key components include alkali metal vapor turbines, pumps, liquid metal lubricated journal bearings, boilers, electrical generators, condensers and seals.

The first two full-scale potassium vapor turbine test facilities in this country were put in operation in fiscal year 1964 at General Electric, Cincinnati, and at Lewis. The contractor facility will provide performance tests with potassium and will be completed in fiscal year 1964 at the contractor facility. A one thousand hour endurance test to simulate erosive conditions will be started. The Lewis facility will be used to investigate design details of turbines.

Present programs have been concerned with obtaining the first data on the boiling and condensing of potassium in single tubes at temperatures up to 2,200 and 1,500 degrees Fahrenheit, respectively. Over 8,000 hours of boiling operations at temperatures above 1,500 degrees Fahrenheit have been accumulated. A multi-tube potassium boiler will be tested in fiscal year 1965.

Two facilities at Lewis are used to investigate liquid metal pump problems. Testing will continue in fiscal year 1965. The analytical phase of contract work on electromagnetic pumps was completed in fiscal year 1964, and construction of promising components and subsystems will begin in fiscal year 1965.

The first fully instrumented test rig for journal bearings utilizing water as the lubricant and operating in the flow region anticipated for space power conversion systems was completed in early fiscal year 1964. Adequate data to permit the evaluation of promising designs can be obtained in this rig. Six advanced journal bearing configurations have been evaluated experimentally. A liquid metal bearing test rig will be built in fiscal year 1965 for proof testing the bearings showing promise from the water test rig.

Work began in fiscal year 1964 to prove the endurance capabilities of a low power Stirling piston engine for use with either a radioisotope or solar energy source. This engine is theoretically more efficient than other energy conversion systems in the low power sizes. In fiscal year 1965, it is planned to initiate the design and construction of a radioisotope package for this engine and to design a power system with all its components, including pumps, radiator, and control elements.

Direct Conversion. The absence of rotating components, bearings, seals, etc., makes the direct conversion of heat to electricity potentially an attractive concept from the reliability standpoint. The major concept under investigation by NASA is the use of thermionic emitter systems. The

major technological obstacle is the development of a satisfactory fuel element which can operate for a long time at a temperature level of 3,500 degrees Fahrenheit, a level far beyond the present state of the art. The work to date under contract has been concentrating on metallurgical studies of the compatibility of fuel and emitter materials. Compatibility, in terms of temperature limits for the refractory cladding materials, has been established for carbide and oxide fuels. In-pile tests have been conducted in the Vallecitos Test Reactor on a number of fuels. In fiscal year 1965, fueled diode testing will begin in the Plumbrook test reactor. In-pile tests of 5,000 hours equivalent operating life will be completed on the promising clad fuels. Work will continue on insulator and seals technology.

Advanced Concepts and Mission Analysis. Major effort deals with magnetohydrodynamic (MHD) approaches to electric power generation. Component investigations on a lithium-cesium liquid magnetohydrodynamic device are being done. Lewis is working in-house and under contract on single fluid Rankine magnetohydrodynamic systems. A program investigating an electrical generator concept using the direct conversion to electricity of the high energy particles emitted by radioisotopes is being supported.

To define the performance potential, technological problem areas, weights, and endurance, a number of power plant system studies have been performed which emphasize engineering detail rather than the parametric approach. Studies include work on systems for auxiliary power (100 kilowatt electric maximum) and propulsive power (1 to 5 megawatt electric). Analytical studies of this type will continue in fiscal year 1965.

Electrostatic Propulsion. This thrustor effort provides fundamental process and applied component research information necessary for the development of electrostatic thrustors in the range of a few tenth's of a pound to hundreds of pounds at specific impulses of 3,500 to 10,000 seconds or greater. Data is obtained on means of generating ions, on means of accelerating ions, on electrical theory relating to effects of building up a space charge, and on the composition and behavior of ion beams. Applied technology includes: the factors influencing fabrication of porous metal ion emitters; design considerations of electrical circuitry and components; design of propellant feed and storage components; selection of various materials for the construction of the different components; effects of scaling engine performance; size; clustering of low power engine modules into high power level engines; and instrumentation.

Investigations into the generation of ions by bringing cesium or mercury atoms in contact with a warm surface (surface contact ionization) will provide data and evaluation of the most suitable porous tungsten ion emitters. The condition of the ion emitters can limit the life of the ion engine. Two principal phenomena which influence the selection of the ion emitter material and design or fabrication techniques are: grain growth of the porous tungsten ionizer which can cause shrinkage and breakage of the ionizer or closure of the pores; and impurities, initially the cesium introduced by corrosion of that metal, in contact with hot cesium, which could affect the ionizer by means of a reduction in work function, oxidation or clogging of the feed system.

Preliminary results of recent studies indicate that tungsten made by sintering spherical particles may be an excellent ionizer. The program in fiscal year 1965 will provide more information to judge the qualities of spherical powder ionizers.

Work will continue to apply brazing and electron beam wielding techniques to the problem of attaining leak-free seals between the porous ion emitter and its support structure, particularly in larger ion engines.

A new type of surface contact ion source, one which operates at high current densities with simultaneous emission of ions and electrons, has demonstrated roughly an order magnitude increase in efficiency over other current sources. The present fiscal year 1964 and 1965 study is designed to improve the degree of ionization without undue power input increases, and to expand the resulting plasma to a density distribution from which the ions can be conveniently extracted and accelerated.

Several studies of means of generating ions through electron bombardment of targets are being continued to provide design information for the development of electron producing cathodes which will demonstrate high efficiency along with long life, and to examine the problem of extracting high intensity beams from the source. Other electron bombardment ion sources which produce high beam current densities with the promised long life are being investigated along with their associated accelerators.

Acceleration of ions without causing ion impact erosion of the accelerating electrodes is a problem area which is closely related to engine life. The research program in this area will be directed toward attaining long life by: studying means of improving the beam current density profile by developing improved electrode configurations, by analyzing and improving the ion optics, and finally by diverting ions toward noncritical areas. In addition a fundamental study on the sputtering erosion of accelerators is being conducted using electrode materials, propellants and voltage differences typical of ion engines.

One of the major questions regarding feasibility of ion engine operation in space is whether ion beams can be neutralized before leaving the engine thrust chamber exit. It is expected that final proof of this feasibility will be determined in the Space Electric Rocket Test I flight project. Studies are being continued in fiscal year 1965 of the fundamental phenomena involved and of the optimization of engine neutralizer systems.

Several colloid particle sources are being studied to obtain higher thrust per unit area than with conventional ion engines. The objective of these studies is to provide means of charging and accelerating previously prepared milli-micron size particles. Development of diagnostic instrumentation is being continued.

The objective of large ion engine experiments is to provide the information needed to develop engine systems (multi-kilowatt to 15 megawatts) capable of missions in cis-lunar and planetary space, and to explore and provide experimental confirmation of the problems involved in developing such large ion engines.

This effort includes development of contact ionization engines, and an electron bombardment ionization engine. The surface contact ion engine shows promise of yielding highest overall engine efficiency for values of specific impulse above about 7,000 seconds. Because of its high impulse capability, this type of engine is the most likely choice for ultimate use with lightweight electric power generating systems on interplanetary missions. The electron bombardment ion engine on the other hand offers the highest efficiency in the intermediate range of specific impulse from about 4,000 seconds up to 7,000 seconds, and is the most likely choice for use on early interplanetary missions.

To achieve reliable high power ion engines the building block technique is utilized, developing low power engine modules and scaling or clustering these modules into the high power (megawatt) level regime. This involves a four phase program: (1) the fabrication of small engine modules (approximately 1 kilowatt) for laboratory and flight evaluation (Space Electric Rocket Test I) of such basic problems as beam neutralization; (2) development of 3 kilowatt flight prototype modules for scaling or clustering to the 30 kilowatt size; (3) development and qualification of 30 kilowatt systems for determining scaling and system performance problems for reaching the next higher power level plateau (100 kilowatts to 1 megawatt); and (4) projecting the design criteria of the 30 kilowatt engine into the many megawatt power engine regime.

During Phase 1 and Phase 2, a circular strip surface contact ion engine was designed, fabricated and tested which provided 40 percent efficiency at a specific impulse of 4,500 seconds, impulse and 85% at 8,700 seconds impulse, and tested for more than 200 hours. This module was then scaled into a higher kilowatt power size. Studies have been conducted on other types of surface contact ion engines, such as the linear strip ion engine discussed last year, which present fewer engineering problems for scaling than the previously tested contact ion engines.

Also during Phase 2, a cesium electron bombardment engine was designed and developed which showed good performance between 4,500 and 7,000 seconds specific impulse. The most serious development problems of this engine type are: (1) ionization of a high percentage of propellant atoms with a minimum power utilization; (2) ion acceleration through the engine with a minimum of electrode erosion; (3) the requirement for 100 percent neutralization of the ion beam by injecting electrons from a cathode source into the beam at the accelerator exit so that the beam will leave the thrustor with a neutral charge; and (4) evelopment of materials for the ion emitter (ionizer) which will permit maximum propellant utilization efficiencies with minimum heat radiation losses.

The objective of small ion engine experiments is to develop thrustors with long life, with high reliability, and with the capability for a large number of restarts over a period of several months or years. Engine systems will be capable of being integrated in a three axis attitude control and station keeping system for various orbit missions. Thrustors will also be suitable for lifting or transfering small satellites from one orbit to another. The small ion engine will be initially designed for cyclic operation over a one year life span and ultimately for three to five years. Once these thrustors become available they will be placed on a flight simulator at the Goddard Space Flight Center to obtain system performance data over a range of station keeping attitude control missions requirements. These data will then be compared with other methods for station keeping attitude control to determine the most promising approach.

One small ion engine is scheduled for laboratory demonstration in September 1964. In fiscal year 1965, performance tests will be continued of the laboratory prototype system developed during fiscal year 1964. The development and engine test control and power elements will be performed and simulator facility tests will be conducted.

Electrothermal Propulsion. The objectives of this program are to advance the technology of electrothermal engines, so that efficient and reliable electric engine systems can be built in the specific impulse range of 700 to 2,500 seconds for a thrust range of tenths of a pound to possibly several hundreds of pounds, at power level range of a few kilowatts to possibly several megawatts. To achieve these objectives analytical and experimental studies are being conducted on components and basic processes, including electrode geometry required to generate the electric arc that heats the propellant; the process of converting electrical energy to thrust energy; the physical mechanisms which transfer heat from the propellant gases to the surrounding walls of the accelerator of electrodes; selection of propellants and methods for storing these propellants; and electrical circuitry (lightweight, efficient electronic components).

Electrothermal engines (including the arc jet and the resistojet) develop thrust by electrically heating a gaseous propellant, such as hydrogen, and expanding it through a nozzle. The difference between the arc jet and the resistojet concepts is the manner of propellant heating. In the arc jet the propellant is heated by passing it through an electric discharge, while in the resistojet the propellant is heated by passing it between electric resistance heated elements.

The objective of the small resistojet and arc jet engine experiments is to develop thrustors with long life and high reliability, and a capability for a large number of restarts over a period of several months or years. The engine systems will be capable of being integrated in a three axis attitude control and station keeping system for various orbit missions. The thrustors will also be able to lift or transfer small satellites from one orbit to another. Initial resistojet and arc jets will be capable of operating continuously for at least 90 days. Later resistojets and are jets will be

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designed for cyclic operation over one year and, ultimately, three to five year life spans.

The objective of large arc jet engine experiments is to develop experimental arc jet thrustors in the 30 kilowatt to 4 megawatts power range to provide the technology for scaling from small engines to sizes for future mission applications. The building block technique is being utilized, starting with the development of a 30 kilowatt engine capable of operating continuously for 90 days to several months. A 30 kilowatt DC engine has been designed and fabricated. This engine has been successfully demonstrated for 700 hours continuous running in a vacuum tank without any apparent electrode erosion, component deterioration or significant malfunctions. Engine efficiency was 45 percent at a specific impulse between 1,000 and 1,350 seconds. During fiscal year 1965 emphasis will be placed on performance improvement in an effort to attain high efficiency in the high specific impulse range (2,200 seconds) for the 250 kilowatt direct current arc jet engine.

Electromagnetic Propulsion Research. The program objective is to conduct feasibility studies of promising types of electromagnetic (MHD) engine system concepts for propulsion application, placing considerable effort on such areas as the physics of plasma production and acceleration processes. Included are analytical and experimental studies to determine the mechanisms which influence the conversion of electrical to dynamic energy, the transfer of heat to surrounding media, the coupling of ionized gases with its associated electric and magnetic fields to produce thrust, the selection of propellants, and the devising of methods for producing plasmas.

This engine concept develops thrust by accelerating a gaseous propellant plasma such as argon or hydrogen by coupled electric and magnetic field forces. The two general types of magnetohydrodynamic accelerators are pulsed and steady flow plasma accelerators which differ by the manner in which the electromagnetic forces that accelerate the plasma are created, and the manner in which the plasma is generated. These concepts show promise for covering the range of specific impulses from 700 to greater than 10,000 seconds.

Feasibility studies are being conducted on five different magnetohydrodynamic plasma accelerator concepts as follows: two different coaxial pulse type accelerators, a steady state Hall current accelerator, a microwave cyclotron resonance accelerator, and a traveling wave accelerator. Study of the fundamentals of electrical discharge in plasmas and the generation and acceleration of a plasma in a converging thrustor chamber is continuing; specifically, this study will cover the mechanisms of the initial breakdown of the propellant gas, electrical current intensification and localization within the gas, stability of the electrical discharge and current carry media through the plasma, and the coupling of the plasma with the electric and magnetic fields to produce magnetogasdynamic acceleration of the plasma. The intrinsic accelerator efficiency will then be determined.

The pulsed device now in operation shows potentialities of conversion to a high repetition rate continuous wave acceleration which should function like a steady flow machine. This would have considerable significance to space engine design, since the thrust levels attendant on steady flow acceleration would be considerably higher than for ion engines.

Laboratory data on the small (10 kilowatt) General Electric repetitively pulsed coaxial accelerator indicate power efficiencies of 40 to 45 percent at 6,000 seconds specific impulse. This concept shows promise for early electric propulsion application. The traveling wave magnetohydrodynamic accelerators also show potential for propulsion application.

Component Technology. Studies in this area provide parametric data which are required to make design trade-offs between the electric thrustors the power conditioning, switching equipment and the power supply system, to obtain optimum electric propulsion system capability. Analysis will define design requirements for components as influenced by potential mission requirements. Tests will be performed on electric propulsion system components, such as electronic components in their operating modes, and propellant storage and feed system components for long time periods in a zero G environment.

Investigations will be continued on mission applications for electric propulsion, in order to orient propulsion and vehicle requirements to research work and objectives. These studies must be continued and updated since experimental design and performance data continually change, thereby affecting the nature and results of the analysis.

SNAP-8 Development

	1963	1964	1965
Development and flight proj.	$15,994,000	$15,500,000	$18,000,000

SNAP-8

The objective of this project is to develop a 35 electrical kilowatt nuclear electric generating system suitable for space applications in the 1970's. The system must be capable of starting and operating continuously and without maintenance for 10,000 hours in the space environment. Future missions requiring electrical powers within single or multiple SNAP-8 design capability range from large orbiting space stations and lunar bases to manned and unmanned planetary probes and satellites. SNAP-8 is the only space power system under development in this power range.

SNAP-8 development is a joint National Aeronautics and Space Administration-Atomic Energy Commission program. 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, which includes the reactor, its control system and shielding, is the responsibility of the Atomic Energy Commission.

SNAP-8 utilizes a boiling mercury, turbogenerator cycle to convert thermal power developed by a compact space nuclear reactor into electrical power. The design approach places a major priority on reliability and ease of development rather than on light weight, and also considers flexibility to adapt with a minimum of change to a range of potential space missions. The program is presently planned through the ground development phase and includes in excess of 60,000 hours of non-nuclear and nuclear testing to develop the required reliability. Development of the space radiator required to reject waste heat from the power conversion process is deferred, pending assignment of a specific space mission.

During fiscal year 1964 the redesign of all major power conversion components to reflect the more conservative system concept has been completed. The fabrication of most components is well advanced, and the preliminary testing of some major components is underway. Supporting laboratory programs in materials and corrosion have been expanded to include long-term tests simulating both the reactor and power conversion loops. The SNAP-8 experimental reactor, the first major step in the Atomic Energy Commission reactor development program, after undergoing extensive nuclear physics tests at very low power, was brought to design power and temperature to obtain data necessary for the design of a flight-worthy reactor.

Accomplishments in the remainder of fiscal year 1964 will include the first testing of a fully-assembled turbine with hot mercury vapor, followed by initial testing of a complete SNAP-8 prototype power conversion subsystem at rated power conditions. The Atomic Energy Commission will complete power operation of the SNAP-8 experimental reactor. Design of the first prototype reactor will be nearing completion.

During fiscal year 1965 the project will concentrate on obtaining system performance of both the nuclear and non-nuclear subsystems in preparation for combined overall system operations. Test operations will commence on two complete SNAP-8 prototype power conversion subsystems for design verification, calibration, and evaluation work. Power conversion subsystem performance and start-up will be demonstrated and the first of four 10,000 hour endurance tests will be initiated. The Atomic Energy Commission will initiate power testing of the first prototype SNAP-8 space reactor. Preparations for the first nuclear testing of a complete prototype system in the Atomic Energy Commission Ground Prototype Facility at Santa Susana will be nearing completion.

Subsequent major project milestones as planned in joint National Aeronautics and Space Administration-Atomic Energy Commission coordination meetings are as follows:

(1) Complete 90 days of power conversion subsystem endurance testing utilizing prototype components in early calendar year 1965.

(2) The first integration of a complete electrical generation system and the first generation of nuclear electric power by a ground prototype SNAP-8 system at Atomic Energy Commission's Ground Prototype Test Facility in calendar year 1966.

(3) Complete first 10,000 hour endurance test of prototype SNAP-8 power conversion subsystem in calendar year 1967.

(4) Delivery of a flight prototype SNAP-8 system to NASA Plumbrook Space Propulsion Facility in calendar year 1967 for space simulation test.

Space Electric Rocket Test (SERT)

	1963	1964	1965
Spacecraft design, development and support............	$2,588,000	$4,000,000	$5,100,000
Launch vehicles...............	600,000	---	---
Total costs.................	$3,188,000	$4,000,000	$5,100,000

The purpose of the space electric rocket test flights is to provide required basic information on electric engines and electric engine systems not obtainable from experiments conducted in ground facilities.

All electric propulsion experimental investigations to date have taken place in ground vacuum chambers. During the initial experiments on ion engines, the problem of neutralizing the ion beam by the injection of electrons could not be fully investigated since electrons omitted from the vacuum chamber walls tended to automatically neutralize the beam. In later tests, the tank effects were eliminated and successful neutralization was limited to microseconds. Therefore, study of the neutralization problem over a longer period of time and demonstration that neutralization will occur in space is still required. In addition, 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.

Solving the neutralization question and correlation of tank data with flight data are the primary objectives of the Space Electric Rocket Test I ballistic flights now under active development. Space Electric Rocket Test I will be launched by the Scout vehicle for a ballistic flight time of approximately 50 minutes at altitudes above 250 miles. The capsule will 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 cesium contact-ionization engine and a mercury electron bombardment engine of different basic designs and utilizing different methods of beam neutralization.

The first complete capsule vibration survey was completed in April 1962. In fiscal year 1963 flight simulation tests of an integrated test capsule, with ion engines operating, were conducted utilizing the identical mobile launch instrumentation and equipment which is to be used during the flight. During these tests both engine power converters failed. Solution of this problem required a lengthy research and development ground test program, including repeated testing of the engines and redesigned converters in vacuum tanks. During fiscal year 1964 successful tests were conducted on the test capsule using the redesigned power converters through the complete flight sequence, including engines operating during capsule spin.

The results of the above tests will be factored into the final capsule and subsystem designs. The prototype and flight capsules will be assembled and ground tested under simulated flight conditions prior to launch.

Because Space Electric Rocket Test I indicated a greater need for data in the area of power converters, a research program was started in fiscal year 1964 to provide the technology for the design of reliable long-life converters. In addition, a ground test program will evaluate the performance capability of electric engine systems for use in station-keeping and attitude control systems before flight of the system.

In fiscal year 1965, Space Electric Rocket Test I launches will be completed. The ground test programs on power converters and evaluation of electric engines for station-keeping and attitude control systems will be well underway. The results from this work and from the electric propulsion effort will determine the necessity for further space electric rocket test flights.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — NUCLEAR ROCKETS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

This program provides the research, design and engineering data, test hardware, and general technology required to assure that nuclear rocket systems can be developed at the power levels, operating times, restart conditions, and specific impulse values needed in advanced space exploration missions.

It is generally accepted that nuclear rocket propulsion will be required in advanced missions beyond Apollo, such as a lunar logistics ferry, very heavy deep space instrumented probes, and manned exploration of the planets. This area of manned planetary expeditions is considered among the major applications for nuclear rockets; a nuclear rocket propelled Mars spacecraft can be 1/3 to 1/10 the weight of a chemically propelled spacecraft.

The emphasis in the nuclear rockets program is on laying a foundation for rapid development of nuclear rocket systems that will be required to accomplish heavy payload, high energy missions in space.

Nuclear reactor research and engineering work is of major importance, since this area constitutes the major new technology part of the program. In addition, emphasis is placed on non-reactor components whose operating requirements tax the available technology and on the study of the fundamental heat transfer, fluid flow, stress, and nuclear phenomena involved. An essential part of this program is work on experimental ground test engine systems to develop a full understanding of the interaction of components in nuclear rocket engines and of the system performance characteristics. These data form a basis for flight system development and provide information required by mission planners to incorporate nuclear capabilities in advanced missions. The effort is, therefore, directed to ultimate use in flight systems.

This is a joint Atomic Energy Commission-National Aeronautics and Space Administration program wherein the Atomic Energy Commission has primary responsibility for the nuclear reactor research and engineering work, and the National Aeronautics and Space Administration is responsible for the non-reactor components of the system, for combining the reactor and other components into engine systems, for vehicle development, and for providing propellants that are used throughout the program. The Space Nuclear Propulsion Office has been established by the Atomic Energy Commission and National Aeronautics and Space Administration agreement to manage all aspects of the nuclear rocket propulsion effort. The RIFT (Reactor-In-Flight-Test) vehicle system has been directed by National Aeronautics and Space Administration's Marshall Space Flight Center. Research and technology work in the nuclear rocket program is conducted both in Atomic Energy Commission and National Aeronautics and Space Administration laboratories, such as the Los Alamos Scientific Laboratory, Argonne National Laboratory, the Lewis Research Center, the Marshall Space Flight Center and also is conducted in industry and universities under contract.

SUMMARY OF RESOURCES REQUIREMENTS:

	1963	1964	1965
Supporting research and technology....................	$12,878,000	$21,200,000	$23,000,000
Kiwi...........................	3,856,000	1,500,000	---
NERVA..........................	41,884,000	52,000,000	34,500,000
RIFT...........................	10,847,000	7,500,000	---
NRDS...........................	---	500,000	500,000
Total costs....................	$69,465,000	$82,700,000	$58,000,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1963	1964	1965
Rocket reactor research.........	$7,607,000	$12,265,000	$13,100,000
Nuclear rocket engine component research............	4,826,000	7,635,000	8,300,000
Safety.........................	200,000	500,000	500,000
Vehicle technology..............	245,000	800,000	1,100,000
Total costs....................	$12,878,000	$21,200,000	$23,000,000

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

The Kiwi and NERVA technology projects represent work starting at a nominal 1,000 megawatt thermal power to serve as stepping stones to higher power, as well as to provide design information, hardware, and systems that could ultimately be developed as flight systems for use in space. To provide basic support to 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 the major technical areas involved with nuclear rocket engines and vehicles. The emphasis is on component research under the proper environmental conditions for the purpose of supplying design data and for extending available technology.

Rocket Reactor Research. The reactor is the key, new component of a nuclear rocket propulsion system. Because its principal function is to heat hydrogen to an extremely high temperature, the uranium fuel-bearing materials (fuel elements) in the reactor must operate close to their melting points. The materials for this purpose are selected from the most available refractory materials, and are materials whose properties and fabrication processes are not well known. The reactor is also required to operate reliably and stably through start-up, steady-state, shut-down, and restart. A total operating time of an hour or more is desired in some space applications. Reactor research is the primary responsibility of the Atomic Energy Commission and consists principally of the advanced graphite reactor work at Los Alamos. It also includes fast-tungsten reactor work at Argonne, some support of the water-moderated tungsten reactor concept, and supporting research and advanced concept projects such as cavity reactors at various laboratories.

NASA funds three activities under the heading of reactor research: (1) applied research on a tungsten reactor concept, the major part of which is done in-house; (2) a research program in specific problem areas in support of the graphite reactor development project and various advanced concepts; and, (3) the development and purchase of nozzles and liquid hydrogen feed systems (turbopumps) to support reactor tests at the Nuclear Rocket Development Station. The program is principally devoted to the investigation of the feasibility of a thermal, water-moderated, tungsten fuel element reactor concept proposed by the Lewis Research Center. Important continuing tasks include fabrication research to produce tungsten-uranium dioxide fuel elements of satisfactory strength and uniformity, prevention of fuel loss at the required operating conditions, development of a fuel element assembly with acceptable thermal and neutronic behavior, and verification of properties through high-temperature testing in flowing hydrogen and nuclear radiation environments.

Some of the goals for fiscal year 1965 are: (1) complete definition of a reactor control system for the water-moderated tungsten reactor concept; (2) completion of the inital basic critical experiments; (3) in-reactor tests and electrically heated tests of promising fuel element configurations; and, (4) preparation for water and hydrogen flow systems tests in a cold flow engine simulator. The Lewis Research Center in-house effort is augmented by outside contracts, principally in the areas of fuel element fabrication, control analysis, and physics experiments.

The graphite reactor program is supported by National Aeronautics and Space Administration grants to Rensselaer Polytechnic Institute and the University of Arizona for studies in reactor control theory.

Advanced concept work is concentrated on various types of cavity reactors, in which the fissionable materials are in gaseous, liquid or dust form. NASA has a grant with Princeton University to investigate the fundamental problems of a liquid core rocket reactor. Gas core research is being conducted at Lewis Research Center and by industry contract. Smaller efforts in this area are

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also underway at Jet Propulsion Laboratory, Catholic University, and Case Institute of Technology. The emphasis is on laboratory research because propulsion systems and large scale experiments cannot yet be defined due to a lack of basic information on feasibility and, in some cases, a lack of basic research data.

It is also NASA's responsibility to provide turbopumps and nozzles for reactor tests. NASA has been funding the development of a liquid hydrogen turbopump feed system to be used in the testing of high-power reactors at the Nuclear Rocket Development Station. This system is based on the liquid hydrogen pumps and turbines developed for Kiwi tests. System development tests on the operation of two feed systems in parallel are underway. Funds will be expanded in fiscal year 1965 to increase the flow capacity of this feed system to satisfy the pumping requirements for the high-power Phoebus reactor tests to be conducted at the Nuclear Rocket Development Station by Los Alamos.

Lewis Research Center has initiated a study of nozzles to support the Los Alamos Phoebus reactor program and to develop the technology of this essential area. One of the objectives of this study is to advise on the selection of a proper nozzle, in terms of performance, cost, reliability, and delivery date, that will meet the proposed schedule for Phoebus reactor tests at the Nuclear Rocket Development Station. Following the definition of the proper nozzle for the Phoebus reactor experiments, in fiscal year 1964, a contract will be let for the design and development of nozzles to support the high-power Phoebus reactor experiments.

Nuclear Rocket Engine Component Research. This research provides the necessary advanced component 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 establish a general base of information on the design and operation of components and engines. Engine component technology is the responsibility of NASA; the in-house effort is conducted by the Lewis Research Center with other work being accomplished under industrial and university contracts principally under Lewis' direction.

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 establishing and improving technology prior to incorporation into any engine project.

Turbomachinery research is directed at the unique problems posed by application to a nuclear rocket engine, and is coordinated with turbomachinery research conducted for advancement of chemical rocket technology. The means for pumping boiling cryogenic fluids is the goal of much general research on turbomachinery for both nuclear and chemical rockets. Nuclear radiation heats the hydrogen flow passages at the inlet to the hydrogen pump and causes increased boiling. During fiscal year 1964 a pump test rig at Lewis is being modified to simulate various inlet duct geometries with the capability for adding heat to the walls of these pipes. Tests commenced in fiscal year 1964 will continue during fiscal year 1965, with research and development costs incurred through the purchase of additional test hardware to cover a range of desirable operating conditions extending beyond NERVA requirements to higher pressure and flow conditions. In addition to in-house design studies of turbomachinery, some contract studies will be let in fiscal year 1965 to define further research and development problems and their solutions for advanced nuclear rockets.

Advances in nuclear rocket controls and instrumentation technology are required to provide reliable techniques for sensing operating conditions in order to permit reliable control of nuclear rocket engines. 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 serious two-phase flow problems 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 providing control components such as sensors, actuators, and measurement signal conditioning devices. Promising approaches will be continued and expanded during fiscal year 1965 in this area of research, since it governs the progress that can be made in developing improved and reliable control systems. The experimental program on control systems is augmented by extensive analytical study of the startup sequence utilizing analog and digital computer systems acquired during prior fiscal years.

Engine design studies will be performed to establish power levels, engine cycles, chamber pressures, and other engine parameters required for high-power systems. Studies of mission and vehicle aspects will be supported to assist in establishing important features that should be incorporated into engine designs. In fiscal year 1965 design study of clustered engines will be conducted to define problem areas, development approaches, and facility requirements. This information is vital to proper planning of future nuclear rocket developments and mission capabilities.

The radiation effects effort conducted as part of the engine component research work is directed toward defining the behavior of materials in combined radiation, cryogenic, and vacuum environments. Such information supports all phases of the nuclear rocket program and is essential for design work. Work in this area was started in calendar year 1959 and is continuing in the Plum Brook reactor.

The combined environments of radiation, vacuum, extreme temperatures and very high bearing speeds create difficult development problems in regard to bearings, seals and lubrication. By the beginning of calendar year 1965 an in-pile bearing test loop will be in operation for research on bearing configurations in a combined radiation and cryogenic environment. Fiscal year 1965 funding will support completion of the in-pile bearing tester, the operation of the tests, and the acquisition of test hardware.

Research on nozzles for nuclear rocket engines is essential because current technology is extended close to the limit to provide a nozzle for the NERVA engine conditions. The next step is to explore novel designs and materials for fabrication of higher performance nozzles. Analysis and research have been undertaken in areas of refractory metals and coatings, fluid mechanics and heat transfer, stress analysis and thermal fatigue. These technology efforts will continue in fiscal year 1965. By the middle of fiscal year 1965 a hydrogen heat transfer facility will be in operation which will permit testing nozzle concepts in a hot hydrogen stream. Appropriate nozzle hardware must be procured for these tests to provide pertinent data for design of advanced engines.

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, the J-2 engine, etc.) by supplying basic property data and cryogenic engineering support. This program will be continued in fiscal year 1965.

Safety. Safety work is an integral part of the overall Nuclear Rocket Program. It includes effort on hydrogen safety by the Bureau of Mines. This work is aimed at unique safety problems associated with handling large quantitites of liquid hydrogen in the nuclear radiation environment. Also included is work on evaluation of destruct systems in a radiation field to assure safe disposal of nuclear engines.

Vehicle Technology. Studies completed during fiscal year 1964 indicate that a nuclear rocket powered stage on a Saturn V vehicle could perform logistics support missions in the post-Apollo time period with significantly increased payload capabilities. Thus, the nuclear stage provides logical advances to extend the capabilities and usefulness of chemical systems. Additional mission studies are planned to provide definition of concepts for nuclear powered vehicles suitable for planetary scientific probes and manned vehicles for advanced mission applications. These studies would include stage requirements based on clustered nuclear rocket engines, as well as other concepts.

Investigation of stage problems peculiar to nuclear propulsion require continuing effort to provide design criteria and information not available from chemical systems technology programs. Specifically, this involves experimental investigations of heating of the hydrogen propellant by nuclear radiation. This type of work should lead to analytical approaches for solution of problems of reactor radiation heating on propellants, vehicle components, and tankage.

An additional stage problem peculiar to nuclear rockets is the effect of nuclear radiation on critical stage materials. Specifically, it is planned to conduct environmental testing (combined nuclear radiation and cryogenic temperatures) on stage insulation, vapor barrier, and bonding materials. Radiolytic off-gassing in particular will be checked because of its deleterious effect on insulation properties, adhesive properties, and strength.

Since nuclear rocket stages use considerable amounts of hydrogen propellants both during ground tests and flights, propellant loss due to "boil-off" from solar or nuclear heating, pressure build-up from liquid hydrogen evaporation, and tankage weight to withstand such pressure build-up can be significant. Preliminary analyses have shown that boil-off losses and tankage weights could be reduced markedly by use of "slush hydrogen". It is planned to investigate possible benefits and trade-offs resulting from use of "slush hydrogen" systems.

<u>Kiwi</u>

	1963	1964	1965
Reactor test support components..................	$2,556,000	---	$ ---
Propellants..................	1,300,000	$1,500,000	---
Total costs..................	$3,856,000	$1,500,000	$ ---

This project provided reactor test support components, such as nozzles and turbomachinery--and propellant support for the Kiwi test series of reactors designed by the Atomic Energy Commission's Los Alamos Scientific Laboratory. With the completion of Kiwi testing in fiscal year 1964, support of this project is terminated.

<u>NERVA</u>

	1963	1964	1965
Engine systems development.....	$5,829,000	$7,900,000	$3,500,000
Component and subsystems development..................	18,718,000	20,300,000	18,500,000
Propellants..................	1,984,000	3,000,000	3,000,000
Ground test and operations support..................	15,353,000	20,800,000	9,500,000
Total costs..................	$41,884,000	$52,000,000	$34,500,000

The project objectives have been revised to constitute a NERVA technology development project as part of the Nuclear Rocket Program. This revised project maintains a continuing effort including emphasis on reactor engineering and sufficient engine testing to permit the United States at some future time to undertake with assurance, the development of nuclear rocket propulsion systems that will be needed for heavy payload, deep space missions.

This work is conducted as a joint Atomic Energy Commission-National Aeronautics and Space Administration effort by the Aerojet-General Corporation and the Westinghouse Electric Corporation under the direction and management of the AEC-NASA Space Nuclear Propulsion Office.

The program contains a reactor research and engineering program to provide reactor technology for the power levels, temperatures, operating times and operating cycles required for various nuclear rocket missions. It will allow assembly and testing of reactors with turbopumps, nozzles and suitable control systems into experimental ground test engine configurations to establish a base of information on the system design and operating characteristics. The experimental data from the reactor and engine system testing will permit advanced mission planning to consider the use of nuclear rockets, and the initiation of development, with assurance, of a nuclear rocket propulsion system at any required power level. It will lay the foundation from which the United States can proceed rapidly to develop the capabilities required for advanced missions.

Specific technical objectives for the NERVA technology project will be in the areas of reactor, engine systems, facilities and component technologies.

Reactor technology development will be based initially on full-scale reactor testing at the nominal 1,000 megawatt power level to determine the suitability of the reactor design both for continuing technology advancement, for use in obtaining engine system data, and for ultimate application to a flight system. Other objectives will include investigation of the overall performance capability of fuel elements and core structure, to include investigation of the trade-offs of such parameters as operating temperature, lifetime, and restart characteristics.

Engine system technology work will include transient investigations of engine system start-up characteristics, demonstration of typical operating cycles, the system dynamics of engine throttling, and an investigation of engine restart characteristics.

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

Selected engine components technology will be developed to support the engine systems technology efforts of system integration and evaluation. However, component development will be limited. Valves and lines will be facility "boiler plate" types wherever possible. Components will not have to be qualified to the high degree of reliability necessary for flight operation. Components such as turbopumps, nozzles with hot bleed ports, and actuators for engine reactor control will be developed to allow satisfactory operation when exposed to such extreme environments as nuclear rocket reactor radiation levels, liquid hydrogen cryogenic temperature, and high temperature hydrogen exhaust gas. The radiation environment will require a radiation effects program to prove component and instrumentation performance at high radiation levels before use in the more complex reactor and engine systems experiments.

Progress made to date has resulted in demonstration of the ability of a reactor to start up rapidly and operate stably using liquid hydrogen as the coolant; in redesign of the reactor support to avoid the flow induced vibrations that were previously encountered; in cold flow tests demonstrating that the general design approach does avoid such vibrations; in demonstration of the suitability of the reactor control approach used; in fabrication of good quality fuel elements which in laboratory testing meet required operating conditions; in development toward the achievement of a radiation resistant actuator for operation during reactor and engine tests; in advances in high speed bearing technology for application in hydrogen turbopumps; and in many other areas related to reactor, engine, and vehicle technology.

Engine System Development. The objective of this part of the NERVA effort is to perform the necessary system engineering, fabrication and testing leading to experimental engine configuration testing. This effort provides the data necessary for engine system integration and evaluation. In addition, this task includes the efforts necessary to coordinate and integrate the component and sub-system development as well as ground test and operations support efforts.

Cold flow tests with a non-nuclear engine simulator will be conducted prior to and concurrent with full-scale experimental nuclear engine system testing. This simulator will utilize the NERVA components planned for the experimental power engine system tests. Some of the major problems which will be investigated include the initial portion of engine start-up with liquid hydrogen, flow stability, flow leakage, system pressure losses, and control response times. In fiscal year 1965, the fabrication assembly, and thorough system checkout of the cold flow development test system will be completed and the test program initiated. Test data from the reactor test will be correlated with results from the engine simulator testing.

Component and Subsystem Development. This effort, supports the experimental reactor and ground test engine system testing. The task includes efforts on propellant feed system, thrust chamber assembly and controls. Feed system efforts will be directed towards obtaining a suitable centrifugal turbopump capable of providing propellant at required flow rate and pressure to the nozzle inlet. This turbopump will be designed to withstand the radiation levels caused by the reactor. Efforts will be minimal on other components in the feed system such as a tank shutoff valve, reactor cooldown valve and lines and disconnect assemblies. A radiation-resistant turbine power control valve will be developed. Efforts during fiscal year 1965 will include test programs to obtain performance characteristics of the turbopumps throughout its operating range. Additional radiation testing of turbopump bearings operated at design conditions will be undertaken and closely coordinated with work to be done at Lewis.

Efforts during fiscal year 1965 will include provision for pressure vessels, propellant inlet lines and nozzles necessary to support reactor experiments. Dynamic testing and structural testing of the thrust chamber assembly will be conducted. The nozzle will be subjected to long-duration chemical firings to evaluate performance and mechanical integrity.

The controls components being developed are the turbine power control valve, its actuator, and an engine system controller which controls turbo-pump and reactor operation. Development work during fiscal year 1965 will include irradiation testing of the actuator at its expected design conditions, analytical evaluation of the control system, and testing of control system hardware, both in the non-nuclear engine simulators and in the reactor experiments at the Nuclear Rocket Development Station.

A radiation effects effort will be conducted as part of the component development effort. The objective of this effort will be to evaluate the effect of the combined nuclear and cryogenic environment on the performance characteristics of engine components and systems. Irradiation tests of mechanical and electrical components will be conducted during fiscal year 1965.

Ground Test and Operations Support. This effort provides remote handling equipment, checkout and test equipment and handling and maintenance equipment for reactor and engine system test operations. Other subtasks of this effort include development, proof testing and provision of instrumentation for diagnostic and control purposes, reliability and quality assurance, and operational safety efforts. During fiscal year 1965, equipment necessary for engine support will be delivered to the Nuclear Rocket Development Station and proof testing and procurement of diagnostic instrumentation for engine system testing will be undertaken. Technical guidance on ground test safety will be continued and safeguard reports and procedures will be issued. Activation and checkout of Engine Test Stand No. 1 (ETS-1) and Engine Maintenance, Assembly and Disassembly Building (E-MAD) will be undertaken in fiscal year 1965. Reactor assembly and disassembly operations in E-MAD are planned for fiscal year 1965.

Propellants. This task area covers propellant procurement based on test schedules for the NERVA technology project required for reactor tests, non-nuclear component tests, engine simulator tests, etc. Over 90 per cent of the propellants procured will be liquid hydrogen.

RIFT

	1963	1964	1965
Stage development...........	$6,557,000	$3,700,000	$ ---
Development support.........	1,890,000	1,800,000	---
Program support.............	2,400,000	2,000,000	---
Total costs...............	$10,847,000	$7,500,000	$ ---

The RIFT Project was initiated to provide a vehicle for evaluating the operating characteristics of the NERVA engine and associated stage and engine sub-systems in the space flight environment. The vehicle was to be designed as a third stage for the Saturn V permitting the evaluation of stage operating characteristics in the physical, dynamic, radiation, and space environment required for deep space missions. This contract was terminated in December 1963. Vehicle technology work in fiscal year 1965 will be conducted only under Supporting Research and Technology programs.

The RIFT Project was paced by the reactor development work with no major full-scale hardware commitments permitted. The fiscal year 1963 effort was aimed at the definition of technical problem areas and the fiscal year 1964 effort is concentrated on establishing an integrated test program leading to solutions of the major identifiable technological problems. Initial testing has been conducted in the fields of structures, insulation, radiation effects, welding, and fabrication techniques. In addition to the preliminary design and testing work accomplished during fiscal year 1963 and in process during fiscal year 1964, design refinement was continued with an extensive effort in handling and transportation techniques. Almost all of the work performed in this project provides useful information for the chemical rockets now under development and will be available for use in eventual nuclear rocket flight applications.

Nuclear Rocket Development Station Operations

	1963	1964	1965
General site support...........	$ ---	$100,000	$100,000
Facility checkout and maintenance......................	---	350,000	350,000
Capital equipment..............	---	50,000	50,000
Total costs..................	$ ---	$500,000	$500,000

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

Technical support, maintenance, housekeeping, services, and management functions must be provided at this site. These funds provide for NASA's share of the general site operations; the major part is now an Atomic Energy Commission obligation.

General Site Support. These costs represent the NASA share of the 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

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cafeteria services. In includes NASA's share of 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. There are routine or recurring services. Cost specifically for test operation services requested by individual test contractors on a work order basis are not included. These test operation costs are budgeted through the respective NASA project manager's office.

Facility Checkout and Maintenance. All major facilities making up the reactor test facility complex are under construction. Modifications and additions to some facilities are under design or construction. Engine test facilities consisting of the Engine Test Stand #1 and the Engine-Maintenance and Disassembly Building will be activated during fiscal years 1965 and fiscal year 1966. Other facilities will be added as the program requires.

Capital 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, such as shop equipment and warehousing equipment.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — CHEMICAL PROPULSION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objectives of the chemical propulsion research and technology programs are to conduct research to increase knowledge of chemical propulsion processes, to investigate new concepts and techniques to advance the technology of chemical propulsion to meet the requirements for space exploration, and to support the mission office role in applying these technologies to the achievement of NASA's mission objectives.

The supporting research and technology objectives in chemical propulsion are to provide and to extend the knowledge that will increase the national capability to explore space. Although a principal part of this effort is directed toward future advances, an equally important part is to develop the engineering data that will apply to and aid in solving problems arising from projects under development.

Chemical propulsion is the prime mover in transporting payloads from Earth into space and in the space environment. It appears certain that chemical propulsion methods will continue to be used as prime movers for at least the next decade and as auxiliary propulsion devices when nuclear propulsion systems become operational.

The full potential of chemical rockets has not yet been exploited. Continued research and development will make possible the accomplishment of difficult missions not now programmed, as well as increasing the effectiveness of accomplishing missions such as flights to the Moon and operations in Earth orbit. Increases in performance by use of better propellants, more efficient engine cycles, and better integration of the engine with the total vehicle system have the potential not only of increasing the payload-carrying capability of our space vehicle systems but also of lowering the overall operational cost of fabricating and operating these systems.

In current NASA development programs, problems of inadequate engineering data or experience on which to judge the most appropriate solution have often been encountered. An example of this is the combustion instability problem in F-1 engine development, a matter which is now substantially in hand. Part of the research and technology program is to provide a sound engineering basis for the solution of such problems so that costly delays to development programs can be avoided.

The chemical propulsion supporting research and technology program is presented in five categories. These are: chemical propulsion research, high impulse propellant investigations, liquid rocket engine technologies, solid and hybrid rocket motor technologies, and experimental feasibility demonstrations of advanced systems. Chemical propulsion research includes analytical studies of propulsion systems, conceptual designs and cycle analysis, combustion phenomena including ignition and combustion oscillations, fluid mechanics, gas dynamics, heat transfer phenomena, and applicability of materials. High impulse propellant investigations cover examination of new propellants, determination of properties, theoretical calculation and experimental verification of performance, as well as actual engineering experience in dealing with such new materials. From this work will come the sound design criteria and engineering data for use in major engine development programs. This technology effort can be further subdivided in terms of its application, such as booster propulsion, upper stage propulsion, spacecraft propulsion, attitude control systems, retrothrust engines and the like. Experimental engine work is to demonstrate advanced concepts in a complete engine system prior to their application to specific mission objectives. This early development work will prevent the delays in mission accomplishment which result when the propulsion system development, a long-lead item, must wait for mission selection and approval. Included herein are the continuation of the M-1 engine project and the demonstration of large solid propellants motor feasibility.

SUMMARY OF RESOURCES REQUIREMENTS:

	1963	1964	1965
Supporting research and technology....................	$14,392,000	$21,800,000	$21,800,000
Experimental engines............	35,000,000	24,000,000	38,000,000
Small chemical propulsion flight projects..............	330,000	---	---
Total costs..................	$49,722,000	$45,800,000	$59,800,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1963	1964	1965
Analysis, aerothermochemistry...) Heat transfer and materials.....)	$3,095,000	$5,892,000	$5,983,000
High energy propellants.........	3,710,000	7,225,000	7,413,000
Liquid rocket engines...........	6,790,000	6,640,000	6,000,000
Solid rocket motors.............	797,000	2,043,000	2,404,000
Total costs..................	$14,392,000	$21,800,000	$21,800,000

Analysis, Aerothermochemistry, Heat Transfer and Materials

Analysis and conceptual design studies are conducted to identify problem areas, to compare competitive systems, and to guide future work.

For example, recent interest in an old idea - air thrust augmentation - has led to an analytical study of its advantages and some experimental work. A cooperative investigation between NASA and the Air Force has been established to examine the advantages of the air augmentation schemes as applied to the booster propulsion system in a practical flight.

In aerothermochemistry, a number of research projects are now underway in converting chemical energy to kinetic energy. In combustion, studies of combustion oscillations will be continued to provide design criteria for future engine development. Other work of a fundamental nature is the study of the kinetics of detonation waves and their relationship to combustion oscillations, and the examination of non-equilibrium flow processes in nozzles.

In solid rockets, research on burning rate and combustion processes includes ignition characteristics, the effect of rate of change of pressure on extinguishing combustion on surface burning rates, and other combustion phenomena.

More information will be sought on film cooling techniques used in conjunction with high temperature and ablative materials, with partial cooling by radiation in some cases.

High Energy Propellants

The program in high energy propellants was broadened last year to investigate three combinations: (1) addition of fluorine in oxygen to boost the performance of launch vehicles using oxygen-kerosene, (2) hydrogen-fluorine, and (3) oxygen difluoride and diborane. Investigations on fluorine additions to oxygen-kerosene show that performance gains up to 30 percent could be realized in vehicles such as Atlas. Investigations of compatibility of materials and the feasibility of using this additive in existing oxygen-kerosene engines is underway.

Hydrogen-fluorine work is underway on an experimental engine to be described on subsequent pages.

Performance of an oxygen difluoride-diborane engine of 2,000 pounds thrust is being investigated. Plans for additional work are underway to assess more completely the performance of this promising combination.

Work on other combinations is planned. These include propellant property studies, oxygen-fluorine or oxygen difluoride with light hydrocarbons, and metal additions.

During the past year work was started on experiments with a turbo-pumped hydrogen-fluorine engine. The RL-10 engine already developed for use with hydrogen and oxygen was selected for the experiments. Some problems with material compatibility in rotating seals in the turbo pump have been encountered and work is underway to obtain improved seal materials. High energy fuel performance in the present engine will be limited by the oxidizer to fuel ratio that can be run. After pushing the limit operation of the present engine, additional work will be undertaken on new thrust chamber materials and pump modifications to reach higher mixture ratios which favor the high performance characteristics of the fluroine propellant.

A program to develop a gas generator for a hydrogen-fluorine engine has been started to provide a second possible approach to an advanced hydrogen-fluorine engine. This work will be continued and preliminary design studies of an advanced hydrogen-fluorine engine will be made based on the knowledge gained from this experimental engine work.

Liquid Rocket Engines

Work in this area is concerned with engineering studies of components, subsystems and systems for launch vehicles and spacecraft.

In launch vehicle propulsion, work has continued on high pressure engine technology as a promising approach to very large engines for first-stage propulsion. The increase of pressure to the order of 2,500 psi and higher introduces new engineering problems in, for example, bearings, and thrust chamber cooling. New combustion chamber concepts, such as the toroidal chamber - expansion nozzle skirt are being investigated. It is planned to scale model a toroidal chamber and gas-confined nozzle to test the performance of this combination. Another concept is a self-contained, high-pressure engine module designed to be used in multiple with a single nozzle. Work is planned on components of this type engine.

Spacecraft propulsion work is continuing on positive expulsion techniques for providing propellant to the engine during zero-g conditions. Combinations of positive expulsion of a portion of the propellant and simple pressurization of the tank under positive acceleration will be investigated. Gas pressurization generated by in-tank reaction processes will be studied. Effort will continue on the application of high temperature and ablative materials for chambers and nozzles and on techniques for varying thrust.

Solid Rocket Motors

Solid rocket motor technology is concerned with components, subsystems, and complete systems for both launch vehicles and spacecraft. Effort in this category is primarily directed towards research in propellant characteristics. Other work includes a continuation of studies of an internal support for very large grains. Also being continued are studies of improved methods of thrust vector control by use of hot gases which are supplied either by a gas generator or by a tap directly from the combustion chamber. A key component in this technique is a gas valve capable of operating at high temperature.

In the coming year more emphasis will be placed on research and technology applicable to very large boosters and problems associated with their use. This would include, for example, improving techniques of inspection and qualification of loaded motors, better understanding of instability and ignition problems, improved physical properties, clustering studies, and handling and transportation problems.

Spacecraft engine technology effort is concentrated in four areas. These are: (1) high propellant mass loading, (2) stop-restart capability, (3) hybrid system, and (4) packaged propulsion units for attitude control.

The goal of the program is the design of motors with a high percentage of propellant. Another part of this work is obtaining longer nozzle life through partially submerging or recessing, or through establishment of a cool boundary layer.

A significant achievement during the past year has been the demonstration of accurate thrust termination control by two techniques: rapid venting, and control of chamber volume. These and other techniques are being investigated to achieve stop/start control and recycling capabilities.

Hybrid motor systems offer promise in both launch vehicle and spacecraft applications. These are systems where the fuel is a solid and the oxidizer is introduced as a liquid. Conceptual design studies for space applications are completed and experimental work to demonstrate the feasibility of hybrid propulsion for a spacecraft engine will be initiated.

Ideas for using solids for small propulsion units for attitude control have been examined. One is the use of a series of miniature and expendable solid rocket units to generate small increments of impulse as needed. This work will be extended to flight experiments aboard a TIROS satellite. The second idea is the use of a subliming solid wherein the solid is transformed into gas for propulsion thru the application of heat. These units hold the promise of high reliability as well as long storage time and life.

Experimental Engines

	1963	1964	1965
Large solid motor demonstration.	---*	---*	$13,000,000
M-1 engine......................	$35,000,000	$24,000,000	25,000,000
Total costs...................	$35,000,000	$24,000,000	$38,000,000

* Previously an Air Force program.

Large Solid Motor Demonstration

The large solid propellant rocket motor feasibility demonstration was initiated by NASA and the Air Force in June 1963; it includes both 260" diameter and 156" diameter solid propellant motors.

In November 1963, the Department of Defense requested that NASA fund the 260" class motor program in fiscal year 1965 and thereafter, with the Department of Defense continuing to fund the 156" portion.

In fiscal year 1963 and 1964, the Department of Defense obligated almost $30,000,000 to the 260" motor program. The fiscal year 1965 NASA request is based on a Department of Defense estimate of the amount required to complete the current phase of the 260" motor program. Transfer of the direct management and funding responsibilities for this program to the NASA will allow closer coordination between the demonstration firing program and the solid motor launch vehicle studies currently in progress, to evaluate such vehicles as:

1. Solid stage plus an S-IVB stage.
2. Solid boost assist for the Saturn IB vehicle.
3. Solid boost assist for a Saturn V vehicle.
4. First stage for post Saturn vehicle.

Efforts on this project through fiscal year 1964 will include completing engineering, propellant tailoring, 44" and 65" motor tests, and fabrication and checkout of full scale hardware.

In fiscal year 1965 a two-part effort to complete the current phase of the 260" motor program will be accomplished. The first part is for two parallel projects to design, fabricate, and static test two 260" diameter motors each weighing about 1,800,000 pounds and generating 3,000,000 pounds of thrust for about 110 seconds. The second part covers design, fabrication, and static test of a 900,000 pound 156" diameter motor, to prove a 3,000,000 pound thrust nozzle (same as used on the 260" diameter motor) for a 50-second burning time, plus proof of the fabrication procedure applicable to the 260" diameter motor utilizing a grain configuration and igniter similar to the 260" size. In addition, a 120" motor for component evaluation of the Aerojet program will be completed in fiscal year 1965.

M-I Engine

The M-1 turbopump fed rocket engine is being developed for single or multiple use in upper stages of large launch vehicles. This engine will develop 1,500,000 pounds of thrust, using liquid hydrogen-liquid oxygen propellants.

Development of the prototype engine began in 1962, and is under the technical direction of the Lewis Research Center. The components of the M-1 engine are of a new magnitude in size for hydrogen engines, and will be tested as a system to verify their design and to develop criteria for the design, test and retest cycle.

During fiscal year 1965, the program will emphasize component testing, with a limited effort in engine systems. Most design effort will be completed, and the testing of many major components begun. The majority of sub-scale tests will be near completion. Versions of the liquid oxygen pump and fuel pump, both at 3/8 scale, will be tested.

At Lewis, cold-air tests of fuel and liquid oxygen (LOX) turbines will be performed to determine the aerodynamic performance, range of operation, and flow distortions. Full-scale testing of the fuel and LOX pumps as separate components, and as a system connected in series will be started.

Other test programs to be initiated involve vibration tests of thrust chamber components, and general testing of the thrust chamber and gas generator igniters.

Several testing programs will be continued in fiscal year 1965. These include tests of full-scale injectors, gas generators, and interconnect lines.

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OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — SPACE POWER PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Space Power program provides research and technology to advance our knowledge, by providing new and improved methods of chemical and solar power generation for space exploration. The program includes all elements of complete systems such as: (1) the energy collection equipment (solar collector) or reactant supply; (2) the prime converter (i.e., solar cells, thermionic generators, thermoelectric converter, fuel cell, etc.); (3) the energy storage system (battery or thermal energy storage material); and (4) power conditioning equipment devices and switch-gear. In addition to the more basic work, part of the effort is directed at development of improved devices and demonstration of the feasibility of advanced systems, including, when necessary, flight demonstration.

All space vehicles use electrical energy for the operation of their equipment, such as communications, telemetry, life support, and instrumentation. Thus, this multi-disciplined program makes a direct contribution to a broad cross-section of the national space program. The energy source for space power systems may be chemical, solar, or nuclear; this program deals with methods of obtaining energy from the first two sources. Work on power generation using nuclear energy sources is covered under Nuclear Electric Systems.

The electrical power for space vehicles and the total time this power is needed varies widely. The power levels vary from a few watts to many kilowatts and durations from a few minutes for a launch vehicle to goals of several years for space vehicles. This wide range of applications requires a number of power generation techniques, each with its own capabilities and limitations.

As launch vehicle capabilities increase, making possible more complex spacecraft, it is essential that the technology in the power generation field not become a limiting factor. All systems experience to date has been at rather low power levels.

Many problems also remain to be solved in the types of systems presently being used to improve reliability and life as well as to reduce weight and volume requirements. This work is needed to develop equipment and the knowledge needed to avoid failures such as those in the past associated with the adverse effects of the space environment (i.e., the Van Allen belt, solar flare radiation, ultraviolet degration, and high and low temperature effects).

SUMMARY OF RESOURCES REQUIREMENTS:

	1963	1964	1965
Supporting research and technology....................	$8,335,000	$13,000,000	$13,000,000
Total costs....................	$8,335,000	$13,000,000	$13,000,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1963	1964	1965
Photovoltaics..................	$2,141,000	$2,750,000	$2,750,000
Thermionics and thermoelectric..	1,872,000	1,750,000	1,750,000
Solar dynamic systems...........	1,660,000	4,850,000	4,850,000
Batteries, fuel cells and engines......................	2,662,000	3,650,000	3,650,000
Total costs....................	$8,335,000	$13,000,000	$13,000,000

Photovoltaics. Solar cells are the most common energy-conversion devices used in space. Significant progress has been made on cells which resist radiation damage and in obtaining a fundamental understanding of the mechanism of damage. Cells currently in production have benefited from the research program and have three times the useful life in the radiation belts compared to cells in use a year ago. During this year, experiments were conducted on special silicone cells which are 12 times more resistant to such damage as the reference cells. This work will continue so that the advantages can be fully exploited in flight programs.

Progress has also been made on thin film solar cells which are very light and flexible. A contractor production facility has been established to produce experimental quantities of 6" by 6" cadmium sulfide thin-film cells. A program has been initiated to evaluate the simulated environmental effects of space on these advanced devices, a necessary first step before practical application. Studies are also being conducted on techniques of deploying large arrays of these cells for multi-kilowatt systems. The anticipated results are considerably lower costs, improved mechanical characteristics, and better stability in the space environment.

Work will be continued to develop solar cells for high and low-temperature applications. More payload and greater reliability are anticipated.

Thermionics and Thermoelectrics. The direct conversion of heat energy to electricity by the thermionic process continues to show great promise. The development of a prototype, solar-heated, thermionic system with all of its elements shows significant progress. Efforts extend from basic research on materials and metallurgy, through physics and thermionic generation, to engineering development of thermionic devices.

Improvements in thermionic converter design have extended converter life from 1,000 hours or less to more than 3,000 hours in tests presently underway. Alternate designs have been explored, and multi-converter generators have been fabricated and tested with both electrical and solar heating. This effort will be continued in fiscal year 1965.

It is desirable to keep a thermionic system operating during dark periods in orbit, by supplying heat energy stored during sunlight to avoid thermal cycling. Fundamental information has been obtained on thermal storage materials, such as thermal conductivity and heat of fusion. The whole thermal storage area will receive increased attention in the coming year, because of its great promise for solar-thermionic and dynamic systems with long life and low weight.

Important progress has been made on the development of fabrication technique for solar collectors. Work on a 9.5 foot diameter high precision mirror master by spin casting offers a solution to extending this technology to mirrors larger than 5 feet. A successful plastic submaster was produced and reproduced in nickel. A test mirror made from the nickel master is undergoing tests.

The feasibility of power systems based on thermoelectric conversion of heat is also under investigation. An example of work in this area is a flat sandwich panel with thermoelectric couples between the skins. One skin is treated with a coating to produce a high equilibrium temperature when exposed to sunlight, while the other surface runs at a much lower temperature as it faces black space. Progress has been made in this technique, and the work has been supported by research on improved thermoelectric materials. Effort in this area will continue.

Solar Dynamic Systems. A significant milestone was reached in the solar mercury Rankine cycle system (Sunflower) this year with the successful completion of a life test with an accumulated time of 4,300 hours. The test was terminated by test-rig problems rather than any basic fault in the machine. While many problems remain to be solved, the feasibility of this system concept has been demonstrated.

Work was also started on an alternate approach to dynamic power conversion, based on a gas (Brayton) cycle, which is expected to have higher efficiency and hence produce more power from a given size solar collector, if the expected component performance can be achieved. It is planned to continue development of this system to a point where a selection can be made between the alternate approaches. Solar dynamic systems are expected to be most useful in the range of power of a few kilowatts to tens of kilowatts. Applications may come late in this decade, and hence an aggressive program is required at this time.

Batteries, Fuel Cells, and Engines. Much progress has been made in this area. For example, a new type of sealed, rechargeable battery has been developed. This device includes a fuel-cell oxygen electrode which reduces pressure build-up to a safe level, and provides an external signal at the completion of charge, facilitating charge control. This advance is expected to improve the life and reliability of space batteries and significantly reduce their weight for many applications. Testing required to provide the engineering data needed by applications engineers is planned for next year.

To determine the basic limitations in fuel cell life and reliability and find ways of extending them are the goals of much of the work. Important development work has been accomplished this year on an improved H2/02 fuel cell of moderate temperature. The system is simplified and uses materials which should have longer life. Work needs to be done to verify these improvements. Effort to date has been on an open-cycle system (product water vented to space); work will be done on the application of the basic equipment in a closed cycle and tests of the endurance of the components.

Progress has been made on other fuel cell tasks, including the development of inorganic ion-exchange membranes (electrolyte and separator) which should have longer life than the organic type now being used. Studies of fuel cells as biochemical reactors for processing human wastes are also underway. Much work remains to be done in these areas, now at the basic research stage.

An experimental hydrogen-oxygen internal combustion engine designed for operation in space has been operating successfully. Potential applications include mechanical, hydraulic and emergency electric power generation. In fiscal year 1965, effort will be concentrated on improved engine efficiency.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — AERONAUTICS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objective of the Aeronautics program is to conduct the research necessary to generate information for the design, construction, and operation of advanced aeronautical vehicles. This research program supports current and projected civil and military requirements and helps to maintain United States leadership in these fields.

Research is carried on in the technical disciplines of aerodynamics, loads and structures, propulsion, and operating problems. This research has provided the information and technology for such advanced vehicles as the F-111 (TFX), the tri-service XL-142, and the supersonic transport.

The detailed research program will continue at the Langley, Ames, Lewis and Flight Research Centers, in support of the supersonic transport program. It is the National Aeronautics and Space Administration's responsibility to provide the required research information and technical support to enable industry to build a reliable, economical, safe, and publicly acceptable commercial supersonic transport.

In advanced aeronautical research, manned hypersonic air-breathing vehicles are being investigated. Such vehicles have the potential of providing hypersonic reconnaissance capabilities, hypersonic transport, and recoverable hypersonic air-breathing space boosters.

Studies of vertical and short take-off and landing aircraft (V/STOL) will continue in fiscal year 1965, with particular emphasis on high-speed jet-powered types and those types nearing military operational status.

Research in basic areas includes studies of new materials for airframes requiring long duration, high temperature operations; studies of high temperature air-breathing engine components which will increase engine efficiency and economy; studies of noise to gain a better understanding of its origin and means of alleviating it; studies of the boundary layer and boundary-layer control to reduce drag; studies of structural concepts to provide reliable light-weight structures; and 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 continues to be conducted. This work is performed in cooperation with government-sponsored contractors at the request of cognizant government agencies.

Experimental research and development aircraft and engineering test pilot proficiency aircraft considered necessary to carry out and support the aeronautics effort are included under this program.

SUMMARY OF RESOURCES REQUIREMENTS:

	1963	1964	1965
Supporting research and technology....................	$6,580,000	$8,900,000	$9,400,000
X-15A..........................	5,580,000	900,000	900,000
Supersonic transport............	2,513,000	10,200,000	24,700,000
V/STOL..........................	925,000	2,100,000	2,000,000
Total costs...................	$15,598,000	$22,100,000	$37,000,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1963	1964	1965
Aircraft aerodynamics...........	$879,000	$1,500,000	$1,900,000
Aircraft loads and structures...	1,510,000	1,600,000	1,700,000
Air-breathing propulsion........	1,519,000	2,520,000	3,290,000
Aircraft operating problems.....	2,672,000	3,280,000	2,510,000
Total costs..................	$6,580,000	$8,900,000	$9,400,000

Aircraft Aerodynamics

Aircraft aerodynamics relates to the performance, stability, and control of manned vehicles during sustained atmospheric flight. This program is a continuing one directed toward improvements in subsonic, supersonic and hypersonic airplanes.

In fiscal year 1965 there will be an increased effort in hypersonic aerodynamics and aerodynamic configurations for hypersonic air-breathing vehicles now that their aerodynamic feasibility has been established.

Further increases in overall aerodynamic efficiency are needed to produce an economic, profitable United States supersonic transport. Research in this area will be increased by exploring all possible means of increasing lift and decreasing drag at supersonic-cruise speeds, and by investigating advanced configuration concepts to improve range and payload.

Recent wind tunnel and flight research on V/STOL aircraft has placed greater emphasis on the stability and control during hovering and transition of higher-performance jet-powered types. General as well as detailed configuration studies with models and man-carrying test-bed aircraft will be carried on in order to provide a better understanding of jet-interference flows and how to avoid undersirable effects on control during the V/STOL mode of operation.

In the helicopter area, the aerodynamics of high speed rotors is being studied by industry contract. Increased attention will be devoted to the compound helicopter which utilizes auxiliary wings, in addition to rotors, in order to increase limited range and endurance.

Included in these estimates, as in the past, are funds for wind tunnel and related studies in direct support of the development of military aircraft and missile systems.

Loads and Structures

The design of efficient and reliable aircraft structures is dependent upon the loads and heating which the structure must withstand, the physical properties of the material used, structural techniques, and improved methods of design analysis, including dynamic effects.

An important problem in aircraft design is fatigue, which has the characteristic of fracturing or weakening of structural materials under a relatively small load, if this load is applied a large number of times. For aircraft which will operate at supersonic speeds, aerodynamic heating introduces complicating factors into the fatigue problem. This heating degrades the properties of the commonly used aluminum alloys and places emphasis on heat-resistant materials such as stainless steels or titanium alloys. During fiscal year 1965 extensive research will evaluate the fatigue properties of structural specimens utilizing heat resistant alloys.

It is expected that by fiscal year 1965 the structural configuration and characteristics of the supersonic transport will be broadly established. Analytical and wind tunnel investigations will be conducted to evaluate structural designs. Additional studies will be required to establish flutter characteristics.

Those aircraft designs proposed for hypersonic aircraft which employ hydrogen as a fuel present formidable structural problems. A particularly severe problem is the design of that hydrogen tankage which is exposed to high temperatures on the outside and cryogenic temperatures on the inside. During fiscal years 1963 and 1964 studies of refractory metals and design concepts culminated in the construction of a sizeable specimen of tankage structure for testing under realistic temperature conditions. This structure will be studied experimentally during fiscal year 1965, with realistic heating and loading, in a high temperature hypersonic wind tunnel at the Langley Research Center.

Air-breathing Propulsion

The air-breathing propulsion program supplies the basic and applied research information required in the development and planning of both military and commercial aircraft. New and existing propulsion systems will be analyzed to determine potential improvements which can be realized, and engine component modifications will be studied to determine inter-related effects throughout the system. Air inlets and exhaust nozzles will be investigated experimentally to provide future design criteria for supersonic aircraft.

Research in the hypersonic propulsion regime will include basic boundary layer and shock-wave-interaction studies to define the pressure and temperature fields existing in a hypersonic inlet. Studies will provide information on the operation of hypersonic inlets at off-design conditions. Necessary data on supersonic mixing and combustion will be obtained.

Aircraft Operating Problems

Research in this area is directed toward improving flight safety. Objectives of the research program are to obtain improvements in aircraft flying and handling qualities, in operational techniques during landing and take-off under all-weather conditions, and in instrumentation directly related to the safety of flight. National Aeronautics and Space Administration research in the field of sonic boom and aircraft noise is also included in this area.

Spin entry mechanics will be studied to improve prediction of an airplane's tendency to enter spins. Dynamic model tests will be run on specific airplane models, such as the TFX and several executive types. These aircraft will be flight tested to evaluate their stability characteristics in the spiral mode.

A Lockheed Jetstar aircraft, purchased in fiscal year 1963, is being equipped to simulate in flight the stability, control, and performance characteristics of a variety of advanced airplanes. The flight test phase of this program will be initiated in fiscal year 1965.

Jet engine noise research continues to obtain information on the contribution of the exhaust jets and other components to the total noise level. On-going flight and wind tunnel tests and analytical work are directed toward minimizing sonic booms for projected supersonic transport configurations, and determining atmospheric effects on boom intensity and propagation.

A variety of aircraft are being tested to develop steep approach techniques to alleviate the airport noise problem. Helicopters, V/STOL, and conventional aircraft are being used under simulated IFR (Instrument Flight Rules) conditions to determine information requirements for landing under all weather conditions.

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To improve ground directional stability during take offs and landings, experimental investigations will be made to determine tire corner force during high speed braked and unbraked rolling on wet and dry runway surfaces. Several runway additives will be investigated to ascertain their effectiveness.

X-15 Research Aircraft

	1963	1964	1965
Aerodynamics....................	$35,000	$32,000	$30,000
Loads and structures............	60,000	1,000	95,000
Propulsion......................	10,000	10,000	25,000
Operating Problems..............	5,475,000	857,000	750,000
Total costs..................	$5,580,000	$900,000	$900,000

As the X-15 program has progressed, new problems have been defined in the areas of structures, stability, control, heating, and operation. The X-15 aircraft will continue to be used to obtain additional vitally needed research data in the areas of air-breathing propulsion, aerodynamics, and structures. The X-15 is the only vehicle available to obtain this information. The X-15A-2 airplane, which was damaged during an emergency landing, is being repaired and modified to increase its performance capability. This modification will provide a design mission of Mach eight, at an altitude of 100,000 feet. This will permit extension of basic investigations, especially aerodynamic heating. The first flight of the modified X-15 should be made near the end of fiscal year 1964.

Supersonic Transport

	1963	1964	1965
Aerodynamics....................	$392,000	$967,000	$1,810,000
Loads and structures............	612,000	930,000	790,000
Propulsion......................	342,000	1,389,000	19,500,000
Operating problems..............	1,167,000	6,914,000	2,600,000
Total costs..................	$2,513,000	$10,200,000	$24,700,000

The National Aeronautics and Space Administration's role is to provide the research information necessary to meet the goals of the project. Work in various areas will be intensified in fiscal year 1965. Work in fiscal year 1965 will be concentrated mainly on improvements in the areas of propulsion, aerodynamic efficiency, dynamic stability, noise, sonic boom, and structural materials.

The increase in funds requested for fiscal year 1965 for supersonic transport research reflects the need for continued research on propulsion systems to provide the advanced power plants that will be needed for future operational supersonic transports and for follow-on vehicles. In prior years, fiscal years 1962 and 1963, funds were procured by the Federal Aviation Agency for a joint Federal Aviation Agency-National Aeronautics and Space Administration-Department of Defense research program for a supersonic transport. It is the responsibility of the National Aeronautics and Space Administration to provide the research information and technology in support of the program while the Federal Aviation Agency proceeds with the prototype development.

A major increase is required in fiscal year 1965 for work in the supersonic transport propulsion field. At present, the most advanced high-Mach number engine available in the United States is not suitable for the supersonic transport aircraft because its thrust level is too low for the supersonic transport mission and it has a high specific fuel consumption. A new, advanced engine will be required for an economically feasible supersonic transport airplane. The increased funds will be used to continue work at the level required to produce the supersonic transport engine that is required. Work will be done in-house and on contract in the areas of inlets, compressors, gas generators, turbines, and exits during fiscal year 1965 to support this development program.

V/STOL Aircraft

	1963	1964	1965
Aerodynamics................	$520,000	$570,000	$740,000
Loads and structures........	9,000	535,000	180,000
Propulsion..................	106,000	195,000	450,000
Operating problems..........	290,000	800,000	630,000
Total costs...............	$925,000	$2,100,000	$2,000,000

Increased emphasis will be given in fiscal year 1965 to National Aeronautics and Space Administration wind tunnel studies of configurations representative of high speed jet V/STOL types. Particular attention will be given to studies of the interference effects of direct-lift and vectored-thrust jet fighter types. This research will require relatively large, highly-instrumented models to obtain reliable simulation and measurement. Work will continue on propulsion system improvement.

Flight studies are planned utilizing the XH-15A helicopter in order to determine structural loads and dynamics of a nonarticulated (rigid) rotor system, and to study the apparent potential of this new concept for improving helicopter flying, handling and performance characterisitics.

Investigations with the variable stability X-14 deflected jet airplane and the YHC-1A helicopter will increase general information on handling requirements for V/STOL aircraft, particularly for steep approach and blind landing conditions. Other related work will be carried out, both with ground simulators and in flight, to determine optimum guidance and control systems and pilot instrument displays for all weather landing of V/STOL aircraft.

Flight studies of short-take-off-and-land type aircraft which have particular application as civil medium and short-range transport will continue. The recently modified C-130B boundary layer control airplane will be used.

OFFICE OF TRACKING AND DATA ACQUISITION

TRACKING AND DATA ACQUISITION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objective of the NASA tracking and data acquisition program is to provide operational ground instrumentation support required by all NASA flight projects.

Every space flight mission undertaken, whether launch vehicle development, scientific satellite, space probe, or manned spacecraft, is undertaken to further our knowledge of the space environment by means of the acquisition and analysis of scientific information recorded during these missions. The critical element in getting such information back to the managers of the mission is the world-wide network of tracking and data acquisition stations. These stations, linked together and to the NASA mission control and data centers by a communications net, receive and record telemetered scientific data, including voice and video data; track the spacecraft in order to determine its position; and transmit signals to the spacecraft 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 other than NASA stations, are a flexible and responsive tool used to fulfill the requirements of the flight missions.

SUMMARY OF RESOURCES REQUIREMENTS:

	1963	1964	1965
Supporting research and technology	$13,277,000	$12,000,000	$15,500,000
Network operations	55,943,000	81,500,000	99,800,000
Equipment and components	52,922,000	116,500,000	152,600,000
Total costs	$122,142,000	$210,000,000	$267,900,000

BASIS OF FUND REQUIREMENTS:

To be responsive and flexible in giving tracking and data acquisition support to varied flight projects, the NASA networks require a continuing program of component and system improvement and development, station network operations, and equipment additions and modifications.

The program for supporting research and technology will be directed primarily toward the improvement of existing equipment systems and subsystems and, in addition, toward development of new equipment for ground instrumentation support. Greater capability than that which presently exists in ground instrumentation is necessary to support planned manned and unmanned flight projects.

The program for network operations reflects the increasingly complex support capability required by the NASA flight programs. To perform these functions, additional personnel, logistics and maintenance are required for operating the networks as new stations and equipment become operational.

To meet specific ground support requirements for the various types of flight projects, new equipment capability in the networks is necessary. Major equipment requirements for fiscal year 1965 are related to the observatory class satellite projects, the Apollo manned space flight missions, and the deep space flight projects. There are also increasing equipment requirements for the communications and data processing functions which are vital for an integrated tracking and data acquisition capability.

Supporting Research and Technology

	1963	1964	1965
New systems development.........	$3,088,000	$2,995,000	$3,100,000
Integrated systems analysis, development and test..........	826,000	1,361,000	2,090,000
Improvement to existing systems.	9,363,000	7,644,000	10,310,000
Total costs..................	$13,277,000	$12,000,000	$15,500,000

The purpose of the supporting research and development program is to provide for the developments necessary to assure the orderly augmentation of tracking and data acquisition support systems. From this program evolve the techniques and prototype hardware elements for improving existing systems and demonstrating the feasibility of new systems to meet the support requirements of future space flight missions.

New Systems Development

A major effort in fiscal year 1965 is the development of the Airborne Range and Orbit Determination (AROD) system which was initiated in fiscal year 1963. This project was initiated to provide a flexible tracking system to meet the upcoming requirements of the Saturn V project. The objective of the AROD development is to provide the necessary on-board and mating ground equipment so that the range and orbit of space vehicles can be accurately determined. A prototype of an AROD station will be built and the test phase started. The test phase will include aircraft flight tests to provide a preliminary performance evaluation of the integrated system.

Integrated Systems Analysis, Development and Test

This category provides for: (1) analysis, test and evaluation of prototype components and subsystems prior to integration into the networks; (2) development of more efficient mathematical techniques for determinging trajectories and orbits; and (3) development of mathematical techniques and equipment modifications to provide improved in-orbit checkout support for Saturn V class vehicles and spacecraft.

An example of the second area of effort is the development of better mathematical techniques to determine rapidly, more accurately, and efficiently the orbits and trajectories of spacecraft. With the increased number and complexity of space flight missions such as Apollo, Interplanetary Monitor Probe (IMP), Pioneer and Lunar Orbiter, improved computational techniques are required to rapidly and efficiently compute and predict spacecraft trajectories. Diverse missions such as these require optimized computer programs essentially unique to each project. As new missions are evolved, additional unique modifications to the computer routines or programs are required to meet the spacecraft and experimenter requirements for orbit determination.

For the Saturn V vehicle and Apollo spacecraft, the tracking and data acquisition network must provide means for checking out the entire system while in orbit. This checkout is quite similar to the prelaunch one but is somewhat more difficult since it must be accomplished remotely. Large amounts of data will be transmitted to the ground network, collected, edited, sorted and processed to arrive at command decisions in near real time. These decisions are then transmitted from the ground to the vehicle. In fiscal year 1965 further analytical effort and equipment modifications will be undertaken to meet the Saturn and Apollo requirements. The techniques and equipment resulting from this continued effort will be integrated into the In-orbit Checkout Equipment.

Improvement to Existing Systems

This category provides for the development of component and subsystem improvements for existing tracking and data acquisition systems. These improvements will be accomplished by analyzing, developing, and testing the latest techniques that show promise of providing the operational capabilities required by future flight projects. Affected subsystems are:

	1963	1964	1965
Spacecraft subsystems...........	$364,000	$590,000	$1,715,000
Antenna subsystems..............	2,248,000	1,771,000	1,797,000
Receiver and transmitter subsystems....................	4,360,000	4,326,000	4,650,000
Data handling and control subsystems....................	1,350,000	686,000	1,308,000
Central processing and reduction subsystems..........	1,041,000	271,000	840,000
Total costs...................	$9,363,000	$7,644,000	$10,310,000

Spacecraft Subsystems

In fiscal year 1964 an effort was initiated to develop a light weight, highly reliable and efficient on-board data processing and memory subsystem for future spacecraft requirements of the Advanced Orbiting Solar Observatory (AOSO) class. In addition to this developmental subsystem, an initial study effort of feasible telemetry system components (i.e., transmitters, modulators and signal conditioners) was started. The original effort had, as its primary aim, the development of flight proven subsystems which would be compatible with existing ground systems, and would be capable of meeting foreseen space flight projects. The original effort will be continued in fiscal year 1965 and will have as its primary objective the development of a family of standardized on-board transmitters, receivers, data handling modules, and memory units. By such standardization, economies and improved reliability can be realized in such future projects as AOSO and the advanced IMP.

Antenna Subsystems

In fiscal year 1965, the improvements underway on antenna feeds will be continued with the objective of being able to support several spacecraft, operating over a wide frequency range, with a single feed antenna. Prototype cassegrain feeds, currently in use in the Deep Space Network, will be adapted for use on the large data acquisition antennas for support of projects such as Relay B and Syncom III. Improvements in the servo system of these antennas will be required to support the more stringent tracking and accuracy requirements of these projects. The development of antenna surface accuracy measuring techniques originated in fiscal year 1963 will be completed in fiscal year 1965.

Receiver and Transmitter Subsystem

This subcategory of effort includes development and test of prototype hardware, and will provide each network with the receiving and transmitting subsystems that have the capability of meeting the constantly increasing spacecraft requirements for more accurate and reliable tracking and data acquisition support.

To increase the quantity of data that could be acquired by the network without spacecraft weight or other system parameter increases, a considerable effort has been underway for several years to improve the ground receiving subsystems. The results of these past developments are now being incorporated in the networks with such equipments as low noise parametric amplifiers and maser systems. These improvements will yield increases in receiver sensitivity by a factor of between six to ten over that previously available. In fiscal year 1965, effort will be directed toward development and evaluation of improved techniques, such as coherent phase modulation detectors and low threshold frequency modulated detectors, to further increase the sensitivity of the receivers.

During fiscal year 1965, efforts to improve transmitter subsystems for the Deep Space Network and the Satellite Network will be continued. There will also be an initial development of a 1,500 megacycle high power ground transmitter system capable of sending a more varied and greater volume of data to a spacecraft as required by future flight projects.

Data Handling and Control Subsystems

For the Eccentric Orbiting Geophysical Observatory (EGO), Polar Orbiting Geophysical Observatory (POGO), and Orbiting Astronomical Observatory (OAO), special purpose real-time satellite control and tracking systems were developed for each spacecraft. These control and tracking systems were intended to, among other functions, process spacecraft engineering telemetry data, formulate instructions based on such data, transmit these instructions to the spacecraft, supervise the execution of scientific experiments by the spacecraft and provide instructions to the spacecraft regarding future inquiries from other ground control stations. In fiscal year 1965, the development effort will be continued. This system is being developed to meet the requirements of the AOSO and the second generation of the EGO, POGO, and OAO spacecraft.

Central Processing and Reduction Substystems

Effort in this subcategory is directed towards improving the capability of existing telemetry data reduction and central processing systems. During the past several years, specialized telemetry reduction and processing systems have been used to convert the satellite data into the format desired by the experimenters. As the data rates increased with such projects as EGO, POGO, OAO, Surveyor, and Mariner, and in order to reduce the tremendous quantity of data so acquired, it has become necessary to build general purpose processing and reduction systems capable of handling a variety of spacecraft projects. Such general purpose systems will be more reliable and less expensive than present special purpose systems. In fiscal year 1965, the evaluation of several promising subsystems in this area will be made and the development of prototype hardware undertaken.

Network Operations

	1963	1964	1965
Satellite network...............	$12,252,000	$22,000,000	$25,600,000
Manned flight network...........	16,495,000	20,200,000	25,400,000
Deep space network..............	8,117,000	12,000,000	14,600,000
Wallops/Fort Churchill instrumentation...............	3,568,000	5,000,000	5,300,000
Aerodynamics test range.........	450,000	800,000	800,000
Network communications..........	10,821,000	15,000,000	18,700,000
Data processing and handling....	4,240,000	6,500,000	9,400,000
Total costs..................	$55,943,000	$81,500,000	$99,800,000

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There are three basic networks used in NASA programs: the satellite, manned, and deep space networks. In addition, there are the aerodynamic test range at Flight Research Center, the Wallops/Fort Churchill instrumentation, network communications, and data processing systems.

Network Operations - Satellite Network

This network consists of 13 electronic stations operated by the Goddard Space Flight Center and 12 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 toward precision orbital tracking and determination. The stations in the network are operated under various arrangements. Those in the United States and in certain foreign countries are operated under commerical contracts. Other stations are operated by foreign government agencies in close liaison with NASA.

To prepare the network for support of the advanced satellite projects such as OAO and OGO, new facilities projects and equipment augmentation projects are underway. A new facility at Rosman, North Carolina is now operational and another at Fairbanks, Alaska will be operational by mid calendar year 1964. By mid calendar year 1965, a facility near Canberra, Australia and a second antenna system at Rosman, North Carolina will be operational. These facilities, using 85-foot diameter parabolic antennas, are being established to handle the increased bandwidth requirements of the satellite flight projects scheduled during calendar years 1964 and 1965.

In addition to these new facilities, 40-foot antennas are being installed at three existing stations and will be fully operational in fiscal year 1965. Equipment additions during fiscal years 1964 and 1965 include range and range rate tracking systems; automatic tracking, telemetry and command systems; installation of pulse code modulation equipment and a specially equipped mobile facility to support the more sophisticated flight projects.

The optical stations use Baker-Nunn satellite tracking cameras which provide certain optical tracking measurements of greater accuracy than those normally attainable by electronic means. Data obtained by these stations provide information concerning behavior of the Earth's atmosphere and factors affecting the shape of the Earth.

Network Operations - Manned Space Flight Network

The present network consists of 15 stations which collect and communicate real-time information concerning the location of the manned spacecraft, status of the equipment on board, and most important, the condition of the astronaut. All stations have radio voice communications with the astronaut, and can receive telemetry data relating the condition of the astronaut and the functioning of the systems in the capsule; selected stations also have command capability.

In order to support the Gemini and Apollo flight programs considerable augmentation to the network is required. Elements of the Gemini program such as long flight duration, rendezvous and maneuvering in space, demand an increased level of operations. To provide this capability, new equipment consisting of telemetry systems utilizing Pulse Code Modulation, digital command systems, radio frequency command systems, acquisition aids, consoles, displays and on-site data processing systems are being installed at ten primary stations. Additional personnel will be required to operate and maintain this more complex equipment and to man the stations during long duration flights scheduled in fiscal year 1965.

During fiscal year 1965, the Apollo program which is to follow Gemini will place a requirement for a cadre of personnel to train for the operation and maintenance of Apollo support stations.

NASA has overall responsibility for operation, standardization, calibration and operating procedures, and implementation. Of the 15 manned space flight stations, five are operated by a commercial contractor, seven stations and two ships by the Department of Defense, and one station under inter-governmental agreement by the Weapons Research Establishment of the Australian Department of Supply.

Network Operations - Deep Space Network

The Deep Space Network is comprised of stations that are used primarily to acquire, track, obtain telemetry data from, and send commands to space-craft and probes in support of the NASA lunar and planetary programs. Because of the long distances over which communications must be maintained, these stations must have extremely high sensitivity. This high sensitivity is derived from large high-gain parabolic antennas, along with highly advanced transmitting, receiving and signal detection equipment.

During fiscal year 1965, two new stations with 85-foot parabolic antennas at Madrid, Spain and Canberra, Australia are scheduled for completion. These will handle the increased workload starting in calendar year 1965. By the end of fiscal year 1965, the total network will consist: of six operational stations with 85-foot antennas and one station with an 85-foot research and development antenna; of two mobile tracking stations; of a checkout station at the launch site; and of the network control center at the Jet Propulsion Laboratory.

The Deep Space Network supports the Ranger, Mariner, Surveyor, and Pioneer spacecraft missions. Examples of the workload demands of these missions are the flight times to the moon (66 days) and to Mars (270 days).

With the increased number of scheduled flights, stations and types of equipment, additional personnel are required to operate and maintain the network facilities.

Network Operations - Wallops/Fort Churchill Instrumentation

This instrumentation supports sounding rocket flights launched by Wallops Station and the Churchill Research Range at Fort Churchill, Canada. A wide variety of scientific research, vehicle testing, and flight hardware component testing programs are supported.

Most of the instrumentation is located at Wallops Island and consists of tracking, telemetry, data acquisition and data reduction equipment. In addition, an assortment of mobile equipment, including optical tracking and sound-ranging, is available for specific missions. Additional support is furnished by a range ship operating in the general area between Wallops Island and Bermuda.

Operations are accomplished under contract with industrial organizations or by reimbursable orders to other government agencies. The Churchill Research Range in Canada is on a cost sharing basis with the Department of Defense. The importance of this station is due to its geographic position in the high latitudes where probes can be launched into the aurora and other phenomena associated with the polar regions.

Network Operations - Aerodynamic Test Range

The Aerodynamic Test Range was established to provide support to aeronautical development and experimentation requiring coverage of extremely high velocity and high altitude aircraft flights. The range is located in the Nevada-Eastern California area, and is composed of three operating sites. The prime site is located at the Flight Research Center at Edwards Air Force Base in California, and serves as the southern terminus or recovery area for the range. The two up-range stations are located near Beatty and Ely, Nevada.

The principal activity of the range to date has been to support the X-15 research project. In this role, it has furnished the coverage for monitoring and controlling the X-15 research aircraft, the B-52 launch platform, and the "chase" aircraft during all mission phases. Thus, full coverage of the climb-to-launch, space-trajectory, and recovery portions of the test flights is provided.

In addition, the range stations serve as ground sites for mission communications and real time data telemetry. Communications, telemetry, data monitoring, recording, plotting, timing, and computing systems are provided at each station for full mission capability and coverage. The range facility located at the Flight Research Center is operated principally by NASA personnel, while those at Ely and Beatty are manned by contract personnel under the direction of a NASA station manager.

Network Operations - Network Communications

One of the most vital characteristics of an integrated network is a communications system which ties the various stations into the control center. Summarized data concerning the status of manned and unmanned space vehicles are sent from the stations to the control centers so that decisions can be made relative to future operations of the vehicles. 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.

Presently, there are about 500,000 miles of leased voice and teletype circuits; it is estimated that about 1,000,000 miles of lines will be required during fiscal year 1965, due primarily to the Gemini and Apollo programs. Bandwidth requirements for transmission of data by land lines and microwave systems continue to increase in order to handle the large volumes of data for processing, reduction and analysis. In addition, wide-band data lines for scientific information will be required as new stations become operational in support of the larger satellite and deep space projects.

As examples, for the Gemini program an additional voice quality circuit to each station is required; for both Gemini and Apollo, control circuits between the Goddard Space Flight Center and the Integrated Mission Control Center at Houston will be installed; and, for the deep space flight operations, additional overseas communications are required to handle higher data rates and to interconnect the stations at Canberra, Australia and Madrid, Spain, with the Jet Proplulsion Laboratory.

Commercial common carriers, domestic and foreign, provide the majority of communications services; however, wherever these are unavailable, other government agency lines are utilized.

Network Operations - Data Processing and Handling

The utility of a space flight is realized only when data in a form usable by the experimenter is in hand. Although the tracking stations receive the radiated signals that carry the information transmitted by the spacecraft, this information is not in a readily usable form. It is only after the data is processed that usable data outputs from a space program are obtained. Such a capability has been established, and the service provided. In general, two tasks must be performed by the data processing facilities. These are the determination of the spacecraft's position in space as a function of time, and the conversion of the coded telemetered data into the experimenter's form. The determination of the position in space is accomplished by orbits and trajectory computing complexes.

The conversion of the coded telemetry data is performed by an assemblage of electronic equipment identified as a data processing line. Due to the unique nature of many space experiments, most data processing lines are designed to process characteristic data from a given satellite. Thus, a number of lines are necessary.

During fiscal year 1965, as the sophistication of new space missions increases, the quantity and complexity of the data to be processed require a further increase in the size and complexity of the data processing facilities. In addition, the more advanced satellites have a greater number of experiments and thus demand more total line operating time.

Equipment and Components

	1963	1964	1965
Satellite network...............	$9,390,000	$16,800,000	$15,900,000
Manned space flight network.....	28,100,000	69,630,000	106,900,000
Deep space network..............	7,636,000	11,570,000	12,000,000
Wallops and other instrumentation..........................	1,545,000	2,700,000	3,900,000
Aerodynamic test range..........	1,010,000	1,000,000	1,500,000
Communications..................	1,925,000	3,600,000	3,300,000
Data processing and handling....	3,316,000	11,200,000	9,100,000
Total costs..................	$52,922,000	$116,500,000	$152,600,000

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. Estimates for the various equipment items include funds, where necessary, for minor alterations and additions to existing structures or new minor supplementary structures required to house, support and integrate the equipment with the existing network stations.

Equipment and Components - Satellite Network

	1963	1964	1965
Tracking systems................	$2,768,000	$1,696,000	$2,161,000
Telemetry systems...............	3,199,000	4,409,000	3,465,000
Command and control systems.....	509,000	1,242,000	1,912,000
Recording and display systems...	150,000	2,386,000	2,040,000
Test, calibration, and monitoring equipment..........	68,000	871,000	806,000

	1963	1964	1965
Spacecraft checkout equipment...	---	$1,269,000	$104,000
Timing systems.................	---	740,000	690,000
Real-time data handling systems.	$1,187,000	500,000	975,000
Special purpose equipment.......	151,000	510,000	1,175,000
Power systems..................	265,000	495,000	160,000
Maintenance, spares and replacement........................	1,093,000	2,682,000	2,412,000
Total costs..................	$9,390,000	$16,800,000	$15,900,000

In response to the advanced requirements of the complex satellite programs, necessary additions and augmentation of the equipment and components of the network stations must continue. Implementation of these major new requirements began in fiscal year 1963 and is being continued in the remainder of fiscal year 1964 and in fiscal year 1965. The new equipment which will enlarge and update the network is required to provide for more precise tracking at greater distances, for an increased capacity for acquiring and handling high data output rates, and for the more complex command and control functions that must be performed by the stations.

Major items in the tracking category are the range and range rate system and the automatic tracking antenna and receiving system. To meet the requirements for more precise tracking coverage of polar orbits, and of satellites with high apogees (up to 250,000 miles), range and range rate systems are planned for selected stations in the network. These are high precision tracking systems needed to determine spacecraft velocity and location in space with extreme accuracy. Each system basically includes a transponder, antenna, transmitter, receiver, range measuring equipment and data recording equipment. The fiscal year 1965 program provides for one complete additional system plus component additions to the four which have been acquired, or are under contract. Additional automatic tracking and receiving system equipment will be installed at selected locations in the satellite network. The receiving system includes an antenna (136 Megacycles Yagi Array), with necessary hydraulic equipment to move and control the antenna, plus receiver equipment.

Additional telemetry systems and components are required in fiscal year 1965 to expand improved capabilities throughout the network, in order to meet high data output and complex experiment requirements. Improved detection efficiency, increased immunity to noise, automatic selection of bit-rates to accommodate preprogrammed or commanded data rates, qualitative and quantitative performance analysis and evaluation of ground receiving subsystems are included among those tasks necessary to reach this required level of capability. Additional telemetry receivers will be necessary to meet the increased capacity of the stations' telemetry links. Each telemetry antenna requires two dual channel telemetry receivers for reception from satellites with two frequencies. Thirteen receivers are scheduled to be provided in fiscal year 1964 and five more are to be obtained in fiscal year 1965 to meet the network requirements. The requirement to support the Polar Orbiting Geophysical Observatory class of satellites immediately after injection into orbit will be met by the use of equipment installed in trailers for ease in transportation from place to place. Present portable stations are not instrumented to receive the POGO telemetry frequencies and are not equipped with the necessary decommutation, or the command systems. Consequently, additional components are required at these stations.

To adequately perform the command and control functions for the distant satellites as well as for the near Earth spacecraft, additional variable and high-power transmitters are required at selected network sites. Dual systems are required at each site for redundancy and to enable rapid change of transmitting frequency and coding. These transmitters will be fed into suitable command antennas and will require related display, control and switching consoles.

Replacement of present equipment used for calibration and quality checks of the network stations is vital in assuring an adequate level of performance by the stations during spacecraft operations. Development of new calibration prototype equipment is nearly complete, and it is planned to replace the airborne units as well as the ground equipment.

Equipment for spacecraft checkout is required to determine compatibility between the spacecraft and ground systems. While the major portion of this work is performed at NASA centers, similar components are required also at the launch sites in order to enable experimenters to perform a final checkout prior to flight.

It is necessary to continue providing timing equipment for the Goddard Space Flight Center Time Standards Laboratory, and calibrated equipment for new and existing stations. All stations operate by synchronized time signals, and in order to perfect data acquisition in the required mode, improvement in equipment and engineering is necessary to meet the problems inherent in world-wide time synchronization of the network.

The major item in data handling is for real-time activities, a problem which still assumes significant proportions in all future planning for the network. Data control equipment is required to format operational control data for display at the station and for transmission to and from remote sites.

Equipment and components for special purposes, such as the simulation of unique spacecraft transmissions, non-standard data handling and on site processing, and components required to integrate new subsystems into the station complex, are included. Modifications and additions to station power plants are necessary to improve reliability and to increase capacity as dictated by additional equipment.

Included in the maintenance, spares, and replacement category for fiscal year 1965 are spare parts, emergency replacement equipment, and special maintenance items for the 40-foot antenna systems. Present station test equipment is becoming increasingly difficult to maintain because of its age, and much of it is technically inadequate to meet present requirements. A program to replace the existing equipment began in fiscal year 1964 and continues through fiscal year 1965. The equipment involved includes oscilloscopes, frequency counters, signal generators, simulators, audio oscillators, oscilloscope cameras, and assorted testers and checkers.

Equipment and Components - Manned Space Flight Network

	1963	1964	1965
Apollo			
Receiving systems...............	---	$12,379,000	$15,472,000
Transmitting systems............	---	3,223,000	6,986,000
Ranging systems.................	---	980,000	2,156,000
Antenna systems.................	---	15,103,000	5,106,000
Command systems.................	---	1,600,000	3,000,000
Demodulation systems............	---	6,000,000	19,700,000
Data handling systems...........	---	8,406,000	12,284,000
Reentry ship modifications......	---	---	17,400,000
Aircraft modification and design	---	150,000	18,420,000
Maintenance, spares, and replacement.....................	---	1,252,000	3,905,000
Subtotal.....................	---	$49,093,000	$104,429,000
Gemini			
Data processing systems.........	$7,283,000	5,050,000	---
Data handling systems...........	4,428,000	6,040,000	---
Command systems.................	5,439,000	2,195,000	---
PCM telemetry systems...........	8,329,000	4,535,000	---
Maintenance, spares, and replacement.....................	---	2,717,000	2,471,000
Subtotal....................	$25,479,000	$20,537,000	$2,471,000
Mercury			
Maintenance, spares, and replacement.....................	$2,489,000	---	---
Total costs..................	$28,100,000	$69,630,000	$106,900,000

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The manned space flight network will provide the instrumentation support required by the Gemini and Apollo launch vehicles and spacecraft in the areas of tracking, telemetry, command and communications.

The Apollo Saturn IB and Saturn V programs impose more severe instrumentation requirements in these areas than encountered in the Gemini program. Continuous coverage is required for time periods and ranges not encountered with Gemini. The amount of information transmitted to or received from the Apollo spacecraft to enable the successful performance of its mission is greater than that for Gemini. To perform the tracking, telemetry, command and communications functions in support of Apollo in a manner encompassing these more severe requirements, the existing Gemini network will be expanded and augmented with unified S-Band systems and equipment.

Overall, the augmentation for Apollo will result in a network of nine stations with 30-foot antennas, three 85-foot antenna sites, one insertion ship, two ships for coverage of the early translunar coast period, two reentry ships, and aircraft for injection coverage. This implementation will allow the minimum level of ground instrumentation support of the Apollo program requirements.

The final configuration of all network stations to be used in support of the Apollo program, whether they are land stations, ships, or aircraft, will incorporate in the unified S-Band configuration the necessary receiving, transmitting, ranging, antenna, command, demodulation and data handling systems. A modular building-block approach will be used. This approach, which will make use of the same subsystems in all stations even though this number varies at some stations, will reduce maintenance, replacement and training costs.

Receiving systems, which are identical except for small changes in frequency and bandwidth to those of the deep space network, will provide the initial demodulation of voice and telemetry, provide doppler tracking, and emit signals for antenna directing. Transmitting systems will provide the transmitters and other ancillary equipment necessary for transmission of voice, command and ranging signals from the station to the spacecraft. Ranging systems provide the means for measuring the distance to the spacecraft and the spacecraft velocity.

Antenna systems range in diameter from 10 to 12 feet in the case of those used on the reentry ships to 30-foot diameter antennas for the land and ship stations used for orbital and post-injection tracking. These systems include servo mechanisms for precise pointing of the antennas.

The command systems and data handling systems are of the same design for Apollo as for Gemini and will be procured only for those stations not now augmented for Gemini. The command system provides digital data in suitable format for transmission to the spacecraft. Demodulation equipment prepares the data for storage and communication to the mission control centers and provides the input for the data handling equipment. Included in the data handling systems are teletype format equipment, recorders, displays, and operating consoles required for the routing and storing of data at the station.

Requirements for communications and tracking ships for Apollo program support are being coordinated with the Department of Defense, wherein the Department of Defense will be responsible for the implementation or modification of tracking ships required for Apollo. Three communications and tracking ships must be provided for insertion and post-injection coverage. Two existing ships must be augmented to provide reentry coverage. The necessary modifications of two reentry ships will be initiated in fiscal year 1965. The required operational date for these ships, in accordance with current flight schedules, is early 1967.

Studies have been made concerning the means for providing voice communications and telemetry reception and recording coverage of the S-IVB powered flight during the injection of the spacecraft into the translunar coast trajectory. If communications ships were used to meet the requirement for continuous coverage during this period, between six and twelve such ships would be required on station at the time of the injection burn. The specific number of ships between six and twelve is determined by a combination of factors including the date of launch, the desired launch window and the status of the S-IVB propulsion energy budget. It was concluded that the provision for this number of ships is prohibitively expensive and other methods of providing communications coverage were investigated. The most promising method was to provide the necessary coverage by means of instrumented aircraft.

Presently available aircraft are being assessed to determine their suitability for this use and preliminary design for the necessary modifications is planned during fiscal year 1964. The actual modifications will be initiated in fiscal year 1965 and will carry over into fiscal year 1966. Close coordination with the Department of Defense (DOD) will be maintained throughout the program since the DOD will be requested to supply and operate the aircraft.

Equipment and Components - Deep Space Network

	1963	1964	1965
S-band receiver, transmitter, and components................	$1,096,000	$2,936,000	$2,897,000
Atomichron and synchronization equipment................	300,000	115,000	115,000
Klystron and maser amplifiers...	358,000	1,045,000	815,000
Antenna and servo modifications.	1,126,000	1,264,000	1,985,000
S-band ranging and acquisition systems......................	1,079,000	1,155,000	1,297,000

	1963	1964	1965
Digital data and instrumentation systems..................	$460,000	$985,000	$1,175,000
Data transmission and processing equipment.................	1,026,000	570,000	495,000
Test transponders and calibration systems...........	1,001,000	745,000	1,225,000
Recording systems...............	130,000	980,000	---
Maintenance, spares, replacement, and documentation.......	1,060,000	1,775,000	1,995,000
Total costs..................	$7,636,000	$11,570,000	$12,000,000

In response to the increasing requirements for radio tracking, command, telemetry and data acquisition of unmanned lunar and planetary spacecraft and deep space probes, the existing network requires improvements and expansion to handle the specific upcoming spacecraft requirements. To reduce cost and maximize operational efficiency, all deep space network stations are standardized with compatible data acquisition, tracking, command recording and processing equipment. Any new equipment required is initially installed and tested at the Goldstone Station before it is integrated into the system. Once the new equipment has been accepted for general use within the deep space network, it is classed as Goldstone duplicate standard equipment, which standardizes the design and formalizes the documentation of like items throughout the network.

During fiscal year 1964 the L to S-band conversion of the network will continue. In the interim period, the stations will operate on both L-band and S-band frequencies, due to the prior commitments to the L-band spacecraft support. Some of the items that are being purchased and installed are recording equipment, feed systems for the antennas, higher power klystron transmitting tubes, improved operational maser amplifiers and modifications in the servo system and transmitter. One of the large antennas has been cleaned and thermocoated; the result of this has been a reduction in the thermal effects of the reflector.

During fiscal year 1965, the deep space network will consist of six 85-foot antenna stations, two mobile tracking stations and the network control center. The flight schedule for fiscal year 1965 shows an increase in the number of launches with onboard equipment operating in both L and S-band frequency spectrums. (The requirement for L-band coverage is anticipated to end in fiscal year 1965, and equipment directly related to this frequency spectrum is scheduled to be phased out by approximately the end of that fiscal year.) The primary effort in the fiscal year 1965 program continues to expand the S-band capability in the overall network and provides for additional major equipments and associated subsystems necessary for this task. This expansion will enable the network to support simultaneously more than one space probe operating in the S-band area, while retaining required capability for the L-band program. Both Mariner and Surveyor missions will overlap in time, and consequently, the ground antennas will require multiple S-band equipments to allow noninterfering command to and transmission from the spacecraft.

The stations which were not modified in fiscal year 1964 by the addition of the S-band traveling wave maser amplifier will be integrated into the network with these modifications. These changes provide the station with the capability to acquire data from and to track extremely weak radio frequency signals. This capability effectively extends the tracking and data acquisition function to cover greater distances of transmission with increased reliability in the quality of data recorded. To derive optimum performance from the S-band maser subsystem, it is planned to improve the closed cycle refrigerator system and the maser amplifier to be compatible for increased operating efficiency. In addition, servicing equipment of a special nature is required.

Modifications to the antennas will provide an auxiliary electric drive as a backup to the existing drive system. The drive system, including the servo subsystem, will be modified to permit operation by computer programming. To improve the thermal effects, the antennas will be cleaned and thermocoated.

S-band ranging systems and acquisition aid equipment will be added to those stations in the network that have not previously been modified. The ranging systems provide capability of measuring the range accurately to a spacecraft; and the acquisition aid equipment, with the wide beamwidth angle, permits the large antenna to acquire the spacecraft radio signals earlier. Additional work on a prototype planetary ranging system, including the interface between the transmitter and receiver, will be performed.

Digital data and instrumentation equipment will be added as standard equipment, and will be compatible with existing equipment at other stations in the network. This provides the capability to handle data in a timely and efficient manner by automatically putting the raw data in a format that is required for processing, prior to transmission to the network control center.

The data processing and transmission equipment improves the data handling and data processing capabilities that are required at the stations. On-site equipment is required to monitor, edit and transmit data over communication lines to the central computing center. This also includes intrasite communication equipment.

Accurate antenna alignment and calibration of the station's equipment is accomplished by test transponders installed at remote collimation sites. This equipment provides the station the capability to calibrate before, during (usually) and after a flight mission in order to determine the station's operating characteristics for each mission. This includes the microwave standards and special purpose equipment to operate the collimation sites.

Maintenance, repair, test equipment, spares and replacement parts for equipment, including ground support items consisting of generators, cranes, pumps, etc, will be established at each station. These parts, supplies and equipment will reduce the operational down time at each station to a minimum. Normal real property maintenance, upkeep and minor alteration and site improvement is included.

Equipment and Components - Wallops and Other Instrumentation

	1963	1964	1965
Photographic processing equipment.....................	$150,000	$220,000	$200,000
Range camera equipment..........	200,000	250,000	550,000
Aircraft calibration and test instrumentation..........	120,000	160,000	350,000
Antenna systems modifications...	120,000	240,000	180,000
Timing equipment................	---	75,000	---
Range ship instrumentation......	---	80,000	---
Data systems....................	---	---	420,000
Telemetry system components.....	---	---	1,100,000
Radar system components.........	---	---	450,000
Maintenance, spares and replacement....................	955,000	1,675,000	650,000
Total costs..................	$1,545,000	$2,700,000	$3,900,000

This category provides for the procurement of equipments and components in two general areas: (a) expendable (non-recoverable) flight hardware and spare parts; and (b) state-of-the-art improvements to existing range instrumentation systems.

Non-recoverable flight hardware includes radar beacons, DOVAP transponders, antennas, and command-destruct receivers that are installed in the launch vehicles. Small meteorological rockets, to obtain last minute wind profiles so that elevation angles and launch azimuths can be corrected, are included in this category. These rockets constitute a safety measure to assure impact in pre-determined areas; they are ballistic and carry no guidance systems other than spin-stabilization.

The state-of-the-art improvements consist of various electronic components which are installed on existing antennas, or introduced into the circuitry of the range instrumentation systems (tracking, telemetry, data reduction, range safety, optics, etc.) that improve the range, accuracy, speed, and flexibility of these systems. The requirements for these improvements are generated by the number and types of rockets in the flight schedule, larger and improved rockets, and more complex payloads.

Equipment and Components - Aerodynamic Test Range

	1963	1964	1965
Tracking systems................	---	$750,000	$100,000
Telemetry systems...............	$800,000	---	600,000
Real time data handling systems.	---	---	250,000
Maintenance, spares, and replacement.....................	210,000	250,000	550,000
Total costs....................	$1,010,000	$1,000,000	$1,500,000

The aerodynamic test range operated by the Flight Research Center will require equipment modifications and additions to effectively support planned test programs. Such test programs include the hyper-velocity X-15 and the airborne simulator utilized for supersonic transport research.

The fiscal year 1965 program for the range will include radar ranging modification for longer range capability, a PCM ground telemetry system for installation at one of the uprange stations, equipment for the ground telemetry station and additions for real time data handling and display. With the initiation of the new flight research programs an increasing proportion of the estimated funds will be required for maintenance, spares, and replacements. Included in this category in fiscal year 1965 is replacement of the airborne tracking beacons required for use with the ground tracking radars.

Equipment and Components - Communication

	1963	1964	1965
Data terminal equipment.........	$80,000	$195,000	$555,000
Solid state switching units.....	---	2,735,000	1,652,000
Switching center equipment......	100,000	150,000	200,000
Teletype and voice equipment....	173,000	220,000	528,000
South American systems modification.......................	240,000	---	55,000
Test and evaluation equipment...	100,000	150,000	200,000
40 KW radio transmitters........	538,000	---	---
Mobile communication van........	250,000	---	---
Maintenance, spares, and replacement.....................	444,000	150,000	100,000
Total costs..................	$1,925,000	$3,600,000	$3,300,000

In order to support the more complex unmanned and manned space vehicles, it will be necessary to provide communication channels of higher data rates with minimum transmission errors. For example, the communication requirements from the deep space stations to support Surveyor will require over ten times the band width presently provided by the 60 word per minute teletype channel. Additional voice communication capabilities as well as additional automatic switching and monitoring facilities are required to ensure reliable communications.

Further, there will be a continuing emphasis toward better utilization of circuits and standardization of communications into a single system for common use by all programs, in order to keep the total circuit requirements to a minimum.

The requirement for higher data rates with very small error limits makes it necessary that additional error correction and detection equipment be used at the data terminals.

Solid state switching units must be installed in London, Hawaii, and Australia to work with the units being installed at Goddard Space Flight Center. These units will be used to meet the higher circuit speed requirement and to provide automatic checking and monitoring of the circuits.

Facility control and display equipments are required to bring mission network circuits to a central point where the capability exists to transfer these circuits back and forth between communications users, based on the type and priority of mission. This sharing process reduces the total number of circuits required.

A further step to reduce the total circuit requirements will be the use of compaction equipment to utilize the unused time on voice circuits. About 70 percent of the capacity of a four-wire voice circuit is unused due to normal speech pause between sentences, words and even syllables. This compaction equipment allows data to be passed during the unused time. It is estimated that by use of this equipment approximately twelve two-way teletype circuits can be carried simultaneously with a normal conversation over a voice circuit.

As the number and complexity of spacecraft in orbit increase, multiple station voice conferencing becomes necessary in order to provide smooth operational coordination between stations and to provide emergency instructions from the control center. When several voice circuits are conferenced together, they must all be working at the same levels if understandable conversations are to be realized. Because conditions can vary at the various stations, voice operated gain adjusting devices are required to maintain the proper levels.

Within the last two years in South America, such major changes as the provision of a mobile station van at Santiago, Chile as a communications backup for the satellite network, and the installation of three 40 kilowatt transmitters, with associated multiplexing equipment to replace obsolescent 10 kilowatt units, were made. During the coming year, data validity checking units will be installed to complete our planned program to bring these stations up to acceptable standards to handle the communication requirements.

Equipment and Components - Data Processing and Handling

	1963	1964	1965
Digital computing subsystems....	---	$4,950,000	$2,500,000
Off-line data processing systems	---	1,800,000	2,300,000
Peripheral equipment............	---	720,000	1,250,000
Data processing subsystems......	$1,900,000	1,925,000	830,000
Signal conditioners.............	460,000	---	550,000
Special purpose data processing and display..................	540,000	715,000	450,000
Automatic analog data tape evaluation equipment..........	---	590,000	325,000
High density storage and record units.................	---	---	270,000
Test and evaluation equipment...	---	75,000	100,000
Maintenance, spares, and replacement....................	416,000	425,000	475,000
Total costs..................	$3,316,000	$11,200,000	$9,100,000

With the increasing use of onboard spacecraft digital systems, continuing expansion of the data handling facilities to manage the high output data rates is necessary. The equipment program to convert from analog to digital systems and to modify existing equipment, so as to be compatible with the digital systems onboard the spacecraft, will continue into fiscal year 1965.

Digital computing subsystems consist of computer mainframes and peripheral components which were previously leased.

In fiscal year 1965, a high speed central processor, with peripheral equipment to insure compatability with the digital systems in the spacecraft, will be procured.

Decisions on spacecraft performance and evaluation cannot be made by controllers and experimenters within the main computer complex itself. In order to provide the required information, peripheral equipment such as plotters, consoles, displays and computer links, must be located outside the immediate confines of the computer complex. This is a continuing program in fiscal year 1965.

Data processing subsystems consist of modifications to existing data processing lines in fiscal year 1965. Equipment items include a facility monitoring system, evaluators and analyzers to decrease the down time of present equipment and subsystem display devices for existing data processing lines.

Other hardware for data processing and handling include signal conditioning equipment to eliminate expensive multiple data reprocessing. The most significant experimental results are contained in the 20 percent of data lost

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during apogee due to limited capability of existing signal recovery equipment, resulting in expensive reprocessing and refining of data in order to retrieve the necessary information.

Special purpose data processing and display units are required for the particular satellite flight projects. Since data requirements vary considerably for each type of satellite, different types of data handling equipment will be required for the ground systems.

Automatic analog data tape evaluation units will provide for the automatic analog evaluations of tapes which are now made manually. The evaluation of analog telemetry tapes is required to sort out improperly recorded tapes and to monitor ground station recording capability.

High density storage and record units are included in the fiscal year 1965 program, and will provide the required recording and storage for the anticipated volumes of data that will have to be processed. These units will also provide greater accessibility to data.

Test and evaluation equipment includes data simulators necessary for checkout and maintenance of data processing lines and systems.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1965 ESTIMATES

OFFICE OF TECHNOLOGY UTILIZATION AND POLICY PLANNING

TECHNOLOGY UTILIZATION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The primary objective of the technology utilization program is accelerated transfer of new technology generated by NASA research and development into the civilian sector of our economy. Also included within this program are efforts to develop better methods for management of large-scale research and development programs, and to improve our understanding of the implications of the space program.

SUMMARY OF RESOURCES REQUIREMENTS:

	1963	1964	1965
Research and development.......	$2,164,000	$3,500,000	$5,000,000
Total cost...................	$2,164,000	$3,500,000	$5,000,000

BASIS OF FUND REQUIREMENTS:

Begun in 1962, the Technology Utilization program, formerly known as the Industrial Applications program, has been enlarged in both the scope and extent of its activities. The main purpose of the program remains, as before, the identification, collection and dissemination of technical information which has application within non-aerospace industry. Procedurally, innovations originating with either NASA in-house or contractor sources are initially evaluated for industrial potential at the originating NASA field center. Special reports are then prepared and transmitted to NASA Headquarters for further evaluation and eventual publication and dissemination to the industrial community.

Each evaluation action includes relating the innovation to current industrial needs, conducting general or detailed studies, as the case may warrant, of performance characteristics, and the preparation of industry-oriented reports which encompass important technical details. As in the past, NASA will use the services of industry-knowledgeable research institutes in the evaluation of appropriate innovations. These organizations have proved to be valuable adjuncts to the program.

The present level of 600 innovation submissions per year is expected to increase to as much as 1,500 in fiscal year 1965. The major reason for this increase is the implementation of a new technology contract clause which requires more stringent reporting of innovations directly arising from work under NASA contracts.

Another integral part of the technical information aspect of the program is the preparation of extensive state-of-the-art surveys. Teams competent in a particular technical area, search available NASA data on a specific subject, relate technical advance to current knowledge and usage, and, finally, prepare industry-oriented reports of information so gleaned. Approximately 20 such surveys are planned during fiscal year 1965.

Several pilot projects now underway in techniques of information dissemination will be expanded in fiscal year 1965. The outgrowth of these projects will be a strengthening of our national scientific resources through the more localized application of the benefits of NASA research and technology efforts. The most successful project to date has been the university approach, whereby university-run computers located in various geographical regions throughout the country serve as storehouses of NASA technical information. Industries situated within the general area of a participating university may readily request and obtain available data. Industry reaction to this system has been impressive. One electronics firm has, for example, called this approach a prototype for data systems of the future.

Also in fiscal year 1965, a number of universities will conduct research into the management of large-scale research and developments programs. The results of this research, as well as other inputs, will serve as the basis for policy planning studies on the implications of the space program. For the conduct of these planning studies, NASA in-house efforts will be augmented, as required, by contractor assistance.

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