National Aeronautics and Space Administration

BUDGET ESTIMATES

FISCAL YEAR 1968

Volume II

RESEARCH AND DEVELOPMENT

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1968 ESTIMATES

RESEARCH AND DEVELOPMENT

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT

GENERAL STATEMENT

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

MANNED SPACE FLIGHT: A program for the development of a capability for peaceful manned space operations and the utilization of that capability for earth orbit and lunar missions.

SPACE SCIENCE AND APPLICATIONS: An unmanned space flight program directed toward scientific investigations of the earth, moon, sun, planets, stars and interplanetary space; and the development of technology and spacecraft systems which can be utilized for meteorology, communications and geodetic observations.

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

TRACKING AND DATA ACQUISITION: The world wide activity required to support the NASA manned and unmanned flight programs.

MANNED SPACE FLIGHT

The largest portion of the FY 1968 budget request is for support of the Manned Space Flight program. The basic objectives of this program remain unchanged. They include the development of a capability for manned space operations and exploration and the supporting engineering, science, production, and launch and flight operations capability. In this decade a specific objective is landing men on the lunar surface for limited lunar exploration and returning them safely to earth. Project Gemini was completed successfully in 1966. Project Apollo continues to be the hard core of the present flight and ground test, and development effort. The Apollo Applications program, directed at fuller development of manned flight capability in terms of long duration flights and extended operations in space for technological, scientific and applied studies, is being amplified in FY 1968. It will take full advantage of capabilities developed in the Apollo program.

In addition to continuation of the ground test activities, FY 1968 Apollo efforts will continue the manned spacecraft development flight tests with the uprated Saturn I launch vehicle, and the development flights of the Saturn V launch vehicle and lunar mission configuration of the spacecraft. The Apollo Applications program effort will concentrate on the definition and development of experiments and extended spacecraft capability, and support the

procurement of flight hardware and the preparation for flights. Flights being supported include alternate flights on Apollo uprated Saturn I launch vehicles and spacecraft in the event Apollo development proceeds smoothly and successfully in FY 1967 and 1968.

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

SPACE SCIENCE AND APPLICATIONS

In the FY 1968 budget request the second largest program is that of Space Science and Applications. A major part of the scientific program involves unmanned space flights for the study of the earth, moon, and planets, as well as their space environment. The flight projects concerned with these objectives include sounding rockets, Explorer, Pioneer, Mariner, Surveyor and Voyager. Full scale design and development of the Voyager will begin in FY 1968, aimed at a possible 1973 flight to Mars. The specific spacecraft involved with the study of the sun is the Orbiting Solar Observatory. The Orbiting Astronomical Observatory is used in the study of the stars. The Biosatellite program will continue its flights in 1967 and 1968. In the area of applications project Nimbus will continue to support present and future sensor development requirements for operational weather satellite systems for the Weather Bureau. Effort will continue on the Geophysical family of spacecraft. Effort will also continue in the area of Applications Technology Satellites for the development of information for future applied and scientific spacecraft, and sensor systems.

ADVANCED RESEARCH AND TECHNOLOGY

The Advanced Research and Technology effort is a continuing program aimed at providing the technological base for significant future aero-space missions. This effort covers the spectrum of activity from basic research to improve our fundamental scientific knowledge, through applied technology to improve our practical capability for developing advanced systems applicable to space and aeronautical activity. The specific areas of effort in the program are Basic Research, Biotechnology and Human Research, Electronics and Control, Nuclear Systems and Space Power, Chemical Propulsion, Space Vehicle Research and Technology, and Aeronautics.

TRACKING AND DATA ACQUISITION

The tracking and data acquisition effort is directed toward providing the support required by the NASA space flight programs. During FY 1968 the number of launches scheduled for both the manned and unmanned space flight programs are approximately the same as for the current fiscal year. However, the lifetimes of the spacecraft are longer, thus requiring additional effort by the world-wide network of tracking stations. The program also provides for supplementing and maintaining the tracking and data acquisition capability of the network.

TECHNOLOGY UTILIZATION

The technology utilization program covers the dissemination of the scientific, technological and engineering information and concepts resulting from NASA programs so as to assist in the fullest use of this information for the benefit of the nation. In order to assure fulfillment of this objective, the program provides not only for the collection and dissemination of these data but also for: (a) establishing effective mechanisms and systems for assuring that all new knowledge is identified, collected and evaluated; and, (b) establishing effective mechanisms for announcing and disseminating this new knowledge in order to assure its wide application and utilization.

FINANCING

The FY 1968 Research and Development program plan, discussed in this volume, requires an estimated $4,384,500,000. Of this amount $60,000,000 will be made available from the FY 1967 appropriations held in reserve, thus requiring $4,324,500,000 of new FY 1968 authority. This compares with a program of $4,175,100,000 for FY 1967.

Research and Development expenditures for the current fiscal year are estimated at $4,680,800,000 and at $4,470,000,000 for FY 1968.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1968 ESTIMATES

SUMMARY OF RESEARCH AND DEVELOPMENT BUDGET PLAN BY BUDGET ACTIVITY AND RELATED FINANCING

	Fiscal Year 1966	Fiscal Year 1967	Fiscal Year 1968
Budget Activity:			
1. Manned Space Flight:			
(a) Gemini.....	$197,275,000	$21,600,000	---
(b) Apollo.....	2,940,985,000	2,916,200,000	$2,606,500,000*
(c) Apollo applications..	51,247,000	80,000,000	454,700,000
(d) Advanced mission studies.....	10,000,000	6,200,000	8,000,000
2. Scientific Investigations in Space:			
(a) Physics and astronomy.....	176,553,000	171,400,000	199,958,000
(b) Lunar and planetary exploration...	294,596,700	207,350,000	235,158,000
(c) Bioscience.....	43,900,000	41,550,000	48,800,000
(d) Launch vehicle development...	93,790,000	55,200,000	32,400,000
3. Space Applications....	102,853,000	99,000,000	147,284,000
4. Space Technology.....	248,500,000	233,850,000	262,200,000
5. Aircraft Technology...	41,496,000	35,900,000	66,800,000
6. Supporting Activities:			
(a) Tracking and data acquisition...	231,065,000	270,850,000	297,700,000
(b) Sustaining university program.....	46,000,000	31,000,000	20,000,000
(c) Technology utilization...	4,750,000	5,000,000	5,000,000
Total Budget Plan...	$4,483,010,700	$4,175,100,000	$4,384,500,000*

*Includes $60 million of prior year funds applied to FY 1968 budget plan.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1968 ESTIMATES

SUMMARY OF RESEARCH AND DEVELOPMENT BUDGET PLAN BY BUDGET ACTIVITY AND RELATED FINANCING

	Fiscal Year 1966	Fiscal Year 1967	Fiscal Year 1968
Financing:			
Appropriation.....	$4,531,000,000	$4,245,000,000	$4,324,500,000
Transferred to (79 Stat. 534 and 80 Stat. 676) -			
"Construction of facilities".....	-940,300	-2,000,000	---
"Administrative operations".....	-27,895,850	-7,900,000	---
Appropriation (adjusted).....	4,502,163,850	4,235,100,000	4,324,500,000
Unobligated balance, start of year - available to finance new budget plans..	---	---	60,000,000
Reprogramming to or from prior year budget plans...	-19,153,150	---	---
Unobligated balance, end of year - available to finance new budget plans.....	---	-60,000,000	---
Total financing of the budget plan.....	$4,483,010,700	$4,175,100,000	$4,384,500,000

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1968 ESTIMATES

SUMMARY OF RESEARCH AND DEVELOPMENT BUDGET PLAN BY PROGRAM BY COGNIZANT OFFICE

BUDGET ACTIVITY	OFFICE/PROGRAM	Fiscal Year 1966	Fiscal Year 1967	Fiscal Year 1968
	MANNED SPACE FLIGHT.....	$3,199,507,000	$3,024,000,000	$3,069,200,000
1a	Gemini.....	197,275,000	21,600,000	---
1b	Apollo.....	2,940,985,000	2,916,200,000	2,606,500,000**
1c	Apollo applications.....	51,247,000	80,000,000	454,700,000
1d	Advanced mission studies..	10,000,000	6,200,000	8,000,000
	SPACE SCIENCE AND APPLICATIONS.....	759,092,700	607,100,000	694,600,000
2a	Physics and astronomy.....	142,753,000	129,800,000	147,500,000
2b	Lunar and planetary exploration.....	204,300,000	169,400,000	142,000,000
2b	Voyager.....	17,096,700	10,450,000	71,500,000
6b	Sustaining university program.....	46,000,000	31,000,000	20,000,000
2d	Launch vehicle development	57,790,000	31,200,000	---
*	Launch vehicle procurement	178,700,000	122,400,000	165,100,000
2c	Bioscience.....	34,400,000	41,550,000	44,300,000
3	Space applications.....	78,053,000	71,300,000	104,200,000
	ADVANCED RESEARCH AND TECHNOLOGY.....	288,596,000	268,150,000	318,000,000
4	Basic research.....	22,000,000	21,465,000	23,500,000
4	Space vehicle systems.....	35,000,000	33,935,000	37,000,000
4	Electronics systems.....	32,300,000	33,597,000	40,200,000
4	Human factor systems.....	14,900,000	16,175,000	21,000,000
4	Space power and electric propulsion systems.....	45,200,000	40,440,000	45,000,000
4	Nuclear rockets.....	58,000,000	53,000,000	46,500,000
4	Chemical propulsion.....	39,700,000	33,638,000	38,000,000
5	Aeronautics.....	41,496,000	35,900,000	66,800,000
6a	TRACKING AND DATA ACQUISITION	231,065,000	270,850,000	297,700,000
6c	TECHNOLOGY UTILIZATION.....	4,750,000	5,000,000	5,000,000
	TOTAL BUDGET PLAN.....	$4,483,010,700	$4,175,100,000	$4,384,500,000**

*Funds for the procurement of launch vehicles are statistically distributed to unmanned flight programs (e.g. Physics and Astronomy, Space Vehicle Systems).
**Includes $60 million of prior year funds applied to FY 1968 budget plan.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1968 ESTIMATES

DISTRIBUTION OF RESEARCH AND DEVELOPMENT BUDGET PLAN BY INSTALLATION AND FISCAL YEAR

(In thousands of dollars)

PROGRAM OFFICE	TOTAL	J. F. KENNEDY SPACE CENTER, NASA	MANNED SPACECRAFT CENTER	MARSHALL SPACE FLIGHT CENTER	GODDARD SPACE FLIGHT CENTER	JET PROPULSION LABORATORY	WALLOPS STATION	AMES RESEARCH CENTER	ELECTRONICS RESEARCH CENTER	FLIGHT RESEARCH CENTER	LANGLEY RESEARCH CENTER	LEWIS RESEARCH CENTER	SPACE NUCLEAR PROPULSION OFFICE	HEAD
Office of Manned Space Flight														
1966	3,199,507	128,859	1,506,278	1,517,982	1,986	-	200	1,721	-	-	2,140	-	-	
1967	3,024,000	224,050	1,407,527	1,354,141	93	-	-	125	-	-	1,070	-	-	
1968	3,069,200	232,200	1,392,000	1,390,800	100	-	-	-	-	-	-	-	-	
Office of Space Science and Applications														
1966	759,093	4,647	18	8,500	184,181	149,767	2,050	40,414	1,335	5	75,436	183,755	-	1
1967	607,100	3,987	-	2,295	173,373	139,675	1,148	41,493	1,715	10	42,607	118,213	-	
1968	694,600	3,332	5,000	23,820	215,171	154,400	2,173	42,200	1,995	25	49,469	110,233	-	
Office of Advanced Research and Technology														
1966	288,596	193	3,011	20,010	9,676	20,788	-	19,454	7,325	15,828	43,431	68,023	50,431	
1967	268,150	-	4,040	15,910	10,166	18,344	-	20,531	12,694	8,011	46,460	51,946	47,985	
1968	318,000	100	4,925	21,942	10,115	21,840	-	25,788	20,375	23,590	56,095	59,770	39,350	
Office of Tracking and Data Acquisition														
1966	231,065	-	1,271	1,627	155,425	52,629	5,300	-	-	1,900	1,800	-	-	
1967	270,850	-	-	800	191,400	55,800	6,600	-	-	1,900	2,450	-	-	
1968	297,700	-	-	800	213,100	60,400	7,100	-	-	2,000	2,000	-	-	
Office of Technology Utilization and Policy Planning														
1966	4,750	-	-	-	-	-	-	-	-	-	-	-	-	
1967	5,000	-	-	-	-	-	-	-	-	-	-	-	-	
1968	5,000	-	-	-	-	-	-	-	-	-	-	-	-	
Total Budget Plan														
1966	4,483,011	133,699	1,510,578	1,548,119	351,268	223,184	7,550	61,589	8,660	17,733	122,807	251,778	50,431	1
1967	4,175,100	228,037	1,411,567	1,373,146	375,032	213,819	7,748	62,149	14,409	9,921	92,587	170,159	47,985	1
1968	4,384,500 1/	235,632	1,401,925	1,437,362	438,486	236,640	9,273	67,988	22,370	25,615	107,564	170,003	39,350	1

1/ Includes $60 million unobligated balance available to finance new program plan.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1968 ESTIMATES

DISTRIBUTION OF RESEARCH AND DEVELOPMENT BUDGET PLAN BY INSTALLATION AND FISCAL YEAR

(In thousands of dollars)

PROGRAM OFFICE	TOTAL	J. F. KENNEDY SPACE CENTER, NASA	MANNED SPACECRAFT CENTER	MARSHALL SPACE FLIGHT CENTER	GODDARD SPACE FLIGHT CENTER	JET PROPULSION LABORATORY	WALLOPS STATION	AMES RESEARCH CENTER	ELECTRONICS RESEARCH CENTER	FLIGHT RESEARCH CENTER	LANGLEY RESEARCH CENTER	LEWIS RESEARCH CENTER	SPACE NUCLEAR PROPULSION OFFICE	NASA HEADQUARTERS	WESTERN SUPPORT OFFICE
Manned Space Flight															
1966	3,199,507	128,859	1,506,278	1,517,982	1,986	-	200	1,721	-	-	2,140	-	-	36,631	3,710
1967	3,024,000	224,050	1,407,527	1,354,141	93	-	-	125	-	-	1,070	-	-	36,794	200
1968	3,069,200	232,200	1,392,000	1,390,800	100	-	-	-	-	-	-	-	-	54,100	-
Space Science and itions															
1966	759,093	4,647	18	8,500	184,181	149,767	2,050	40,414	1,335	5	75,436	183,755	-	100,201	8,784
1967	607,100	3,987	-	2,295	173,373	139,675	1,148	41,493	1,715	10	42,607	118,213	-	74,659	7,925
1968	694,600	3,332	5,000	23,820	215,171	154,400	2,173	42,200	1,995	25	49,469	110,233	-	72,417	14,365
Advanced Research and ogy															
1966	288,596	193	3,011	20,010	9,676	20,788	-	19,454	7,325	15,828	43,431	68,023	50,431	22,432	7,994
1967	268,150	-	4,040	15,910	10,166	18,344	-	20,531	12,694	8,011	46,460	51,946	47,985	24,324	7,739
1968	318,000	100	4,925	21,942	10,115	21,840	-	25,788	20,375	23,590	56,095	59,770	39,350	29,410	4,700
Tracking and Data tion															
1966	231,065	-	1,271	1,627	155,425	52,629	5,300	-	-	1,900	1,800	-	-	11,113	-
1967	270,850	-	-	800	191,400	55,800	6,600	-	-	1,900	2,450	-	-	11,900	-
1968	297,700	-	-	800	213,100	60,400	7,100	-	-	2,000	2,000	-	-	12,300	-
Technology Utilization icy Planning															
1966	4,750	-	-	-	-	-	-	-	-	-	-	-	-	4,750	-
1967	5,000	-	-	-	-	-	-	-	-	-	-	-	-	5,000	-
1968	5,000	-	-	-	-	-	-	-	-	-	-	-	-	5,000	-
get Plan															
1966	4,483,011	133,699	1,510,578	1,548,119	351,268	223,184	7,550	61,589	8,660	17,733	122,807	251,778	50,431	175,127	20,488
1967	4,175,100	228,037	1,411,567	1,373,146	375,032	213,819	7,748	62,149	14,409	9,921	92,587	170,159	47,985	152,677	15,864
1968	4,384,500 1/	235,632	1,401,925	1,437,362	438,486	236,640	9,273	67,988	22,370	25,615	107,564	170,003	39,350	173,227	19,065

ies $60 million unobligated balance available to finance new program plan.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1968 ESTIMATES

OFFICE OF MANNED SPACE FLIGHT — APOLLO PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The program goal for Apollo is to create a viable manned space flight capability, which will achieve and maintain a position of leadership in space for the United States. An immediate objective in acquiring this capability is landing men on the moon and returning them safely to earth within this decade. The Apollo program, as part of the overall manned space flight program, will not only meet the near-term objective, but will also build a broad base of operational capability in manned space flight and associated skills and technology; a valuable complex of development, manufacturing, test, and operational facilities; and an experienced Government and industrial team. In a real sense, the operational skills, resources, and technology that have been developed for Apollo bring the Nation to the threshold of a versatile and vigorous space program.

To accomplish the immediate goal of lunar landing and return, the Apollo program has focused on the development of a highly reliable spacecraft, which is capable of supporting three men in space for periods up to two weeks, docking in space, landing on and returning from the lunar surface, and safely reentering the earth's atmosphere. The program includes three large launch vehicles--the Saturn I, which completed its flight series in 1965; the Uprated Saturn I; and the Saturn V.

The Apollo program is divided into unmanned flights, manned earth orbital flights, and manned lunar flights. Unmanned Apollo Uprated Saturn I flights have demonstrated the structural integrity and the compatibility of the spacecraft and adapter with the launch vehicle; the firing and restarting of the spacecraft engines; the ability of the command module heatshield to withstand high speed re-entry; and the operational readiness of the ground support and recovery crews. The three unmanned flights conducted during 1966 have qualified the Uprated Saturn I for manned missions.

Manned earth orbital flights on the Uprated Saturn I, scheduled to begin in 1967, will include operations with the command and service modules and the lunar module. The command module will be manned in long-duration missions lasting up to 14 days. An unmanned lunar module will be remotely controlled and evaluated for the purpose of checking the reliability of its systems and the performance of the descent and ascent engines in the space environment. Rendezvous and docking of the command and service modules with a separately launched lunar module will also be accomplished. Rendezvous, docking, and post-docking maneuvering will be refined, and the guidance and navigation system, rendezvous trajectories and ground support network will be validated in subsequent earth orbital flights.

The Saturn V will be used initially for unmanned earth orbital qualification flights. Unmanned re-entry of the command module at 36,000 feet per second will be demonstrated to qualify the heat shield for re-entry conditions that will be encountered on the return to earth from a lunar mission.

During 1968, manned earth orbital flights, using the Saturn V launch vehicle, will be conducted with a fully loaded space vehicle to qualify the Apollo spacecraft for lunar flight and to simulate the lunar mission. All phases of crew operations and equipment performance will be validated during these Apollo Saturn V flights. Manned lunar flight is planned before the end of this decade.

Funds for FY 1968 are required to support a period of intensive flight activity. Manned earth orbital rendezvous operations will be conducted using the Uprated Saturn I launch vehicles. In addition, heavy emphasis will be placed on Apollo Saturn V flight qualification to demonstrate the efficiency of the ground support network and to validate the operational reliability of the spacecraft and launch vehicle systems. These steps lead to the complex lunar mission simulations which precede manned lunar landing and return.

SUMMARY OF RESOURCES REQUIREMENTS:

	1966	1967	1968
Spacecraft.....	$1,233,800,000	$1,250,300,000	$1,036,300,000
Uprated Saturn I.....	274,786,000	236,600,000	156,200,000
Saturn V.....	1,134,871,000	1,135,600,000	1,108,500,000
Engine development.....	133,200,000	49,800,000	24,500,000
Mission support.....	164,328,000	243,900,000	281,000,000
Total program plan.....	$2,940,985,000	$2,916,200,000	$2,606,500,000
Unobligated balance available to finance new program plan			-60,000,000
Total new authority requested.....			$2,546,500,000

Distribution of Program Amount by Installation:

John F. Kennedy Space Center, NASA.....	$128,109,000	$223,450,000	$228,500,000
Manned Spacecraft Center.....	1,279,394,000	1,350,073,000	1,160,400,000
Marshall Space Flight Center.....	1,506,935,000	1,314,096,000	1,188,100,000
Goddard Space Flight Center.....	425,000	93,000	100,000
Ames Research Center....	230,000	---	---
Langley Research Center.	---	170,000	---
NASA Headquarters.....	23,022,000	28,118,000	29,400,000
Western Support Office..	2,870,000	200,000	---

BASIS OF FUND REQUIREMENTS:

Spacecraft

	1966	1967	1968
Command and service modules.....	$612,799,000	$560,400,000	$494,000,000
Lunar module.....	362,615,000	472,500,000	373,100,000
Guidance and navigation...	137,169,000	76,654,000	55,400,000
Integration, reliability, and checkout.....	32,334,000	29,975,000	23,200,000
Spacecraft support.....	88,883,000	110,771,000	90,600,000
Total.....	$1,233,800,000	$1,250,300,000	$1,036,300,000

The Apollo spacecraft, which stands 54 feet high (excluding the launch escape system) and weighs approximately 95,000 pounds, is composed of three modules: the command module, the service module, and the lunar module.

The command module, which is the recoverable portion of the Apollo spacecraft, houses the three astronauts in a controlled environment. The cone-shaped command module is approximately 11 feet high and 13 feet in diameter at the larger end. Life support and communications systems, as well as control systems for in-flight and re-entry maneuvers, are contained in this module.

The service module, which is 14 feet high and 13 feet in diameter, contains the propulsion system used for mid-course corrections on the way to the moon, injection into lunar orbit, and ejection from lunar orbit for the return trip to earth. Additional utilities are also carried in the service module. The unit is jettisoned on the return trip after it has performed mid-course corrections required to place the command module into the proper moon-to-earth trajectory.

The lunar module, which is 20 feet high and 19 feet in diameter, is a self-contained vehicle comprised of a descent stage with landing legs and an ascent stage with a habitable two-man cabin. During the launch phase, the lunar module is enclosed in an adapter, which also serves as a structural support to join the Apollo spacecraft and the Saturn launch vehicle.

This spacecraft, launched by a Saturn V, will be used for manned lunar landing and return before the end of this decade. The mission plan for achieving this national goal is based on a step-by-step progression from one checkpoint to the next. After launch from the John F. Kennedy Space Center (KSC), the Apollo spacecraft, with the Saturn V 3rd Stage still attached, will be inserted into a 100 nautical mile earth-parking orbit, and tracked by the world-wide Manned Space Flight Network stations. As the spacecraft orbits the earth, a thorough crew and equipment checkout will be conducted to verify that the systems are operating effectively and are ready for the lunar mission. When the crew and systems readiness have been confirmed and the

precise translunar injection window has been determined, the Saturn V 3rd Stage (the S-IVB) will be restarted. The S-IVB will accelerate the spacecraft to the seven-mile-a-second velocity required to escape the earth's gravity, and move into a translunar path. After a detailed checkout procedure, the astronauts will separate the command and service module from the combination of the lunar module, S-IVB, and instrument unit, turn their craft around, and dock with the lunar module. The adapter section, S-IVB, and instrument unit, will be jettisoned after this docking maneuver is completed. The next step will involve mid-course corrections using the service module propulsion to keep the spacecraft on the right path to the moon. At the proper time, the service module propulsion system will again be fired to slow down the spacecraft and inject it into orbit around the moon. The astronauts, in communication with the ground stations on earth, will conduct a thorough checkout of all systems. Provided that the outlook is favorable, two of the three Apollo astronauts will transfer from the command module to the lunar module, separate from the command craft (which remains in lunar orbit) and prepare to land on the moon. The lunar module's descent engine will be fired to provide the deceleration required to escape from lunar orbit and descend to the surface of the moon. After collecting lunar samples and implanting experiment equipment and instrumentation, the two Apollo astronauts will return to the lunar module and perform an extensive systems checkout in preparation for the critical take-off from the moon's surface. The descent stage will serve as a launching pad for the ascent stage and cabin. Once the two astronauts safely rendezvous with the orbiting command module and re-enter it, the ascent stage will be jettisoned. The ascent stage will be left in lunar orbit to relay information on the systems lifetime back to earth. On-board guidance and navigation data, combined with deep-space tracking data transmitted from earth, will provide the crew with the references necessary to determine the return trajectory. The service module propulsion system will be used to escape from lunar orbit. Following a coasting period, the service module propulsion system will be ignited for the final time to perform any mid-course corrections required to place the command module into the correct re-entry corridor. The command module will come back into the earth's atmosphere at speeds up to 36,000 feet a second. The returning astronauts will be aiming at a narrow re-entry corridor about 26 miles wide. This brief description of the plan for manned lunar landing and return outlines the basic mission profile, but greatly simplifies the painstaking procedures that will be observed to maximize crew safety and mission success.

The Apollo spacecraft has been undergoing extensive development and qualification testing on the ground and on unmanned Uprated Saturn I flights. These ground and flight tests are conducted to detect procedural or technical problems before manned flights are attempted. As an example, this type of test was being conducted on October 25, 1966, when the propellant tanks failed in the service module that was to be launched on the first Saturn V mission. The failure was traced to the loss of structural integrity of the stressed titanium tank after prolonged exposure under pressure to the methyl alcohol used in cold flow testing, and led to a change in the procedural approach. Ground qualification tests on the environmental control unit revealed technical problems in operating the critical water boiler and resulted in modifications to the injector design. These experiences have confirmed the

value of rigorous ground testing and have illustrated the difficulties involved in developing a spacecraft as complex as Apollo. The problems bring home the point that the Apollo spacecraft must achieve a higher level of operational reliability and maturity than was required of the highly successful Gemini spacecraft, and reflect the significant differences between the requirements for systems operating in low earth orbit and those operating almost 240,000 miles from earth.

Manned earth orbital missions on Uprated Saturn I launch vehicles will begin in 1967. The manned missions are designed to demonstrate the effective operation of the spacecraft and the ground and flight crews for periods of up to 14 days, and to develop Apollo earth orbital rendezvous and docking techniques. The first manned command and service module will be flown on an Uprated Saturn I in early 1967. Current plans call for an unmanned lunar module development flight (designated AS-206) after the first manned earth orbit mission.

Unmanned Apollo spacecraft will be flown on Saturn V launch vehicles during 1967. The objectives of the unmanned flight phase are to qualify the space vehicle for manned flight and to demonstrate the heat shield reliability during high speed re-entry. Manned Apollo spacecraft, launched by the Saturn V, are scheduled to be flown in 1968. The spacecraft flown on these missions will be capable of lunar landing and return and will be used for earth orbital simulation of the lunar mission.

Command and Service Modules (CSM)

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

The command and service modules are produced and checked out at North American's Downey plant and then shipped to various ground test locations or directly to the Kennedy Space Center for pre-launch preparations, including altitude chamber test runs in the Manned Spacecraft Operations Building. The adapter, which surrounds the lunar module and connects it with the command and service module, is built at North American's Tulsa, Oklahoma Division, as is some of the spacecraft ground support equipment.

The command and service modules are built in three configurations: boilerplate models; Block I models; and Block II models. The boilerplate versions are outfitted or weighted for unmanned ground and flight qualification testing, including verification of the launch abort and landing systems, and

compatibility among the complex systems. Block I versions are the early configuration of the spacecraft which are also used for unmanned and manned ground and flight qualification of the systems and assessment of dynamic characteristics, such as high speed heatshield re-entry. The Block I models do not have the capability for rendezvous and docking; however, they are capable of long-duration missions in earth orbit. The Block II versions are equipped with a mechanism to permit the command module to dock with the lunar module and are equipped for lunar missions.

In line with the overall Apollo test philosophy, the command and service modules have been undergoing an exacting series of ground tests leading to certification for manned missions. During 1964 and 1965, boilerplate versions were subjected to a variety of dynamic, structural, and environmental tests to support Block I and II design and development. One boilerplate served as a ground test vehicle at North American to validate the effectiveness of flight systems. An additional boilerplate was used for Apollo Saturn I dynamic testing at the Marshall Space Flight Center to assess its structural integrity under simulated launch and flight conditions. Landing impact, parachute, and flotation tests were also conducted. In addition to the active ground test effort, boilerplate versions of the command and service modules were delivered for flight testing. Abort tests were conducted at White Sands, New Mexico, aiming at qualification of the launch escape system. Three boilerplates were delivered to the Kennedy Space Center and launched on the Saturn I Pegasus missions. Service module propulsion tests began at White Sands in February 1965.

Activity in FY 1966 was highlighted by a continuation of the ground test effort, peak activity in production of Block I command and service modules, delivery of the first flight article (CSM 009) to the Kennedy Space Center, and initiation of fabrication of the first Block II lunar-configured spacecraft. Acoustic tests, using a Block I command module, were completed in September, 1966, and Block I flotation and water impact tests were initiated. The launch escape system was qualified for manned flight on January 20, 1966, when the Little Joe II series was concluded at the White Sands Test Facility. The first flight command and service module (CSM 009) was flown on a suborbital, unmanned Uprated Saturn I mission on February 26, 1966.

Fiscal year 1967 has been marked by extensive ground and flight qualification testing. On August 25, 1966, a second Block I model (CSM 011) was successfully launched, orbited three-quarters of the way around the world, and recovered after withstanding high speed re-entry. The Block I spacecraft was qualified for manned flight as a result of this mission. The first command and service module (CSM 012) for manned flight on an Uprated Saturn I vehicle was delivered to Kennedy Space Center for checkout in August. In the same month thermal vacuum tests, simulating space conditions in support of the first manned flight, were completed at the Manned Spacecraft Center. The first Block I command and service module for the Saturn V flight series (CSM 017) was accepted at Downey and delivered to Kennedy Space Center in December, 1966.

The tempo of Block II activity is increasing and production has reached its peak. Two Block II flight articles, capable of rendezvous and docking, are scheduled for delivery to the Kennedy Space Center in late FY 1967, and nine additional Block II flight CSM will be undergoing assembly, systems installation, and checkout at North American.

Activity in FY 1968 will focus on manned command and service module flights on Uprated Saturn I vehicles to develop Apollo earth orbital rendezvous and docking techniques. Flight qualification of lunar-capable CSM will be emphasized on the Apollo Saturn V flights. Six Block II CSM are scheduled for delivery to the Kennedy Space Center in FY 1968. These spacecraft, plus the two delivered in late FY 1967, will undergo checkout in preparation for Uprated Saturn I and Saturn V flights. The remaining seven Block II CSM will be in various phases of assembly, systems installation, and in-plant checkout.

Lunar Module (LM)

Study and design effort for the lunar module was initiated by Grumman Aircraft Engineering Corporation, Bethpage, New York, in early 1963. The funding in this line item provides for the Grumman effort and related experiments and hardware that will be carried in the lunar module.

Since 1963, preliminary designs have been established and mock-up reviews were held. Subsystem development was started. The lunar module development program follows the command and service modules by roughly a year. The ground test program, which involves mock-ups, engineering test models, propulsion test rigs, and lunar module test articles, was initiated. A mock-up version has been used to determine the best location for equipment and to evaluate crew performance capabilities. Test models are required for further evaluation of crew mobility and visibility, thermal vacuum tests in the environmental test laboratory at the Manned Spacecraft Center, assessment of the descent and ascent stage interfaces and separation characteristics, and full scale drop tests to demonstrate the landing gear capability. Propulsion test rigs are used to conduct tests on the lunar module propulsion system at the White Sands Test Facility. During these test firings, the mission conditions, such as starts, stops, and throttling, are simulated to provide information on the subsystems performance. A "house" lunar module test article is used at the Grumman plant for installation, functional testing, and electrical integration of the subsystems, as well as for evaluation of equipment compatibility and performance, development of operations and procedures, and support of flight tests. Descent engine firings began, and heavy weight propulsion rigs for use in the test program were assembled and delivered. A lunar module test article was manufactured and used for structural tests with the LM/S-IVB stage adapter, and a second test article was used in the spacecraft/Uprated Saturn I dynamic tests conducted at the Marshall Space Flight Center.

Activity in FY 1966 included establishment of the final lunar module design following detailed review of a mock-up version at the Grumman plant. The final significant design decision involved use of a radar rather than an

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optical tracking system for rendezvous in lunar orbit. Major subsystem development, fabrication, and testing continued during this period. Ascent and descent propulsion system tests were in progress at the White Sands Test Facility. Interface tests with the Apollo spacecraft adapter were conducted at Tulsa, Oklahoma.

In FY 1967, the test article which had been used in the adapter tests was refurbished for flight on a Saturn V. The test article used in the spacecraft/launch vehicle dynamic test will also be refurbished and prepared for flight. Three lunar modules are scheduled for delivery to the Kennedy Space Center, and six others will be undergoing structural assembly, subsystem installation and factory checkout. The first flight article, designated LM-1, is being completed at Grumman. LM-1, launched by an Uprated Saturn I, is scheduled for unmanned development mission to verify the operational reliability of the systems. This key mission will be one of the most ambitious undertaken to date. In addition to verifying the equipment reliability, the propulsion system will be ignited to demonstrate start and stop capabilities during flight. A test article will be flown on the first Apollo Saturn V mission as part of the unmanned flight qualification test program.

In FY 1968, the refurbished lunar module test article will be launched on a Saturn V earth orbital flight. Five lunar modules are scheduled to be delivered to the Kennedy Space Center, and the remaining seven will be undergoing structural assembly, subsystem installation and factory checkout.

Guidance and Navigation (G&N)

The guidance and navigation system units for the Apollo spacecraft were designed by the Massachusetts Institute of Technology. The General Motors/A.C. Electronics Division in Milwaukee, Wisconsin, is the prime contractor for fabricating the inertial guidance, including the associated electronics, ground support, and checkout systems, and for assembling and testing all components of the system. The onboard navigational computer is being manufactured by the Raytheon Company, Waltham, Massachusetts, under a subcontract; the optical subsystem, including a space sextant, sunfinders, and navigation display equipment, is being built by the Kollsman Instrument Corporation, Elmhurst, New York, also under a subcontract. Ground qualification testing and delivery of flight units for Block I command modules was completed during FY 1966. Initial flight test occurred on February 26, 1966.

Design and development of lighter weight G&N units for the Block II command module and the lunar module was completed in FY 1966. G&N units for two Block II command modules and two lunar module ground test articles were delivered for environmental and qualification testing.

Nine Block II command module and seven lunar module G&N units are scheduled for delivery in FY 1967. The intensive ground test program, leading to system qualification and demonstration of reliability, will continue.

In FY 1968, six Block II command module and six lunar module G&N units will be delivered. By the end of the year, all but three G&N units will be undergoing manufacturing, subsystems installation, or checkout.

Integration, Reliability, and Checkout

Integration, reliability, and checkout funding provides for the engineering support required for spacecraft specification maintenance and review; systems performance analysis; reliability and quality assurance; trend analysis of failure reports; critical parameter studies and technical problem analysis; mission planning and analysis; post-flight data processing and analysis documentation; simulation and training; and interface control. As the program progresses, emphasis is shifting to support of hardware verification, mission accomplishment and analysis of flight results. Funding for FY 1968 continues this effort at a level consistent with the increased rate of hardware deliveries and frequency of Apollo missions.

The integration, reliability, and checkout funding also provides for automatic checkout equipment (ACE) stations, including design, development, fabrication, installation and operation. The spacecraft ACE is used at the contractor plants and at NASA test and launch sites for separate and combined checkout of the spacecraft systems. The basic design of ACE ground stations for each of the major elements of the program was completed in FY 1964. Five stations became operational during FY 1965: three at North American Aviation; one at the Manned Spacecraft Center; and one at the Kennedy Space Center. During FY 1966, five more stations became operational: two at Grumman; two at the Kennedy Space Center; and one at the Manned Spacecraft Center. Two final stations, one at Grumman and one at the Kennedy Space Center, became operational in FY 1967. In FY 1968, funding provides for operation of all the stations, as well as related engineering changes and spare parts to maintain the operational equipment.

Spacecraft Support

Spacecraft support funds provide for the requirements for test operations, crew equipment including space suits, logistics, instrumentation, and scientific equipment.

Funds for test operations are required to conduct spacecraft development tests at the Manned Spacecraft Center, the White Sands Test Facility, and other government test laboratories. Testing at the Manned Spacecraft Center facilities includes unmanned and manned thermal-vacuum testing in the environmental test laboratory, docking simulation tests, component and subsystem qualification, reliability and verification testing, and electronic systems compatibility tests.

Spacecraft launch escape systems tests, using Little Joe II vehicles, were completed at the White Sands Test Facility on January 20, 1966. Service module propulsion system testing and lunar module ascent and descent engine testing were emphasized at White Sands during FY 1966 and 1967. The lunar

module propulsion system and reaction control system testing, which is conducted in special test cells at the Arnold Engineering Development Center, Tullahoma, Tennessee, is scheduled for completion during FY 1968.

Spacecraft support funding also provides for development and procurement of spacesuits and related crew equipment, survival equipment, food, extravehicular activity umbilicals, personal hygiene systems, and bioinstrumentation. Major effort in FY 1968 relates to manufacture and test of a spacesuit and portable life support system, which is required on the lunar surface.

Logistic funding for FY 1968 is required for transportation of spacecraft between installations, reimbursement to the Department of Defense for inspection services, and procurement of spacecraft fuels and propellants used in the test programs at the Manned Spacecraft Center, the White Sands Test Facility, the Kennedy Space Center, the Arnold Engineering Development Center, and contractor sites.

Instrumentation and scientific equipment funding for FY 1968 provides for development and procurement of specialized flight research and test instrumentation for spacecraft development flight testing. Typical equipment includes signal conditioners, sensors, transmitters, antennas, ground support equipment, cameras, and radiation measuring devices.

Uprated Saturn I

	1966	1967	1968
1st stage (S-1B).....	$51,580,000	$43,100,000	$30,500,000
2nd stage (S-IVB).....	63,999,000	56,900,000	37,100,000
Instrument unit.....	47,660,000	40,600,000	22,600,000
Ground support equipment.	26,575,000	11,500,000	6,500,000
H-1 engines.....	10,150,000	8,050,000	5,200,000
J-2 engines.....	13,500,000	6,716,000	900,000
Vehicle support.....	61,322,000	69,734,000	53,400,000
Total.....	$274,786,000	$236,600,000	$156,200,000

The Uprated Saturn I is an improved version of the original launch vehicle in this class - the Saturn I. The Saturn I demonstrated the feasibility of large launch vehicle systems and, in July of 1965, completed a highly successful series of ten flights. The fabrication techniques, test concepts, transportation modes, and ground operational experience gained in the Saturn I series contributed significantly to the production progress and flight success of the uprated version.

The two-stage Uprated Saturn I stands 142 feet tall, excluding the Apollo spacecraft, and has a diameter of 22 feet. The 1st stage is 80 feet high; the 2nd stage - 59 feet; and the instrument unit - 3 feet. The 1st stage, which is powered by eight H-1 engines yielding about 1.6 million pounds of thrust, is an uprated version of the 1st stage used successfully on the

Saturn I. The 2nd stage, which has the same basic design as the 3rd stage of the Saturn V, is powered by a single hydrogen-fueled J-2 engine capable of over 200,000 pounds of thrust.

The Uprated Saturn I can place about 20 tons of payload into a low earth orbit and is used for unmanned, manned, long duration, and rendezvous flights in the development of the Apollo spacecraft. This payload capability, as compared with the 11-ton capability of the pioneer Saturn I, represents a major addition to the nation's inventory of large launch vehicles and offers a versatile means for carrying out a variety of operations in earth orbit. The Uprated Saturn I will be utilized for Apollo applications missions, as described under the Apollo Applications portion of the budget estimates.

The Apollo program includes a total of twelve Uprated Saturn I flight vehicles (AS-201 through 212). This series is designed to verify the reliability of the systems which will be incorporated into the Saturn V 3rd stage and instrument unit, and to provide a launch capability for manned earth-orbital rendezvous missions with Apollo spacecraft modules. The Uprated Saturn I was qualified for manned flight after three missions. The flight series began on February 26, 1966, with the successful launch of Apollo Saturn 201 (AS-201) from Launch Complex 34 at the Kennedy Space Center. An unmanned suborbital flight, AS-201, demonstrated the structural stability and operational characteristics of the launch vehicle systems, provided partial qualification of the spacecraft, and paved the way for the second unmanned qualification flight.

An Uprated Saturn I flight, designated AS-203, occurred on July 5, 1966, and provided valuable scientific and engineering data on the operational characteristics of the liquid hydrogen fueled upper stage and the guidance and control subsystems contained in the instrument unit. In addition, the restart capability of the upper stage J-2 engine, which will also be used on the Saturn V, was tested. The liquid hydrogen experiment conducted during the mission furnished critical flight test data on the storage and behavioral characteristics of cryogenic fuel under zero-gravity conditions. A third launch (AS-202)--the second qualification flight of an unmanned spacecraft--occurred on August 25, 1966. The launch vehicle was qualified for manned flight on this mission.

An Uprated Saturn I is scheduled to launch the first manned Apollo spacecraft in early 1967. Following this initial manned Apollo flight, another Uprated Saturn I will launch the first unmanned lunar module into earth orbit for development testing. The next two vehicles will be used for a dual launch, designated Apollo Saturn 205/208. In the first phase of this mission, a manned Apollo command and service module will be orbited by an Uprated Saturn I. Approximately one day later, an unmanned lunar module will be orbited by another Uprated Saturn I to support the development effort on the CSM/LM and provide experience in rendezvous maneuvers.

By the end of 1966, five Uprated Saturn I launch vehicles had been delivered to the Kennedy Space Center in support of the flight schedule. Five additional vehicles are scheduled for delivery during 1967, and two

are being fabricated and checked out for delivery during 1968. Procurement of follow-on vehicles will be financed from the Apollo Applications program. These requirements are discussed in the Apollo Applications program portion of the budget estimates.

1st Stage (S-IB)

The Chrysler Corporation Space Division is producing, assembling, checking out, and testing the S-IB stages. Production, assembly, and initial checkout are conducted at the government-owned Michoud Assembly Facility near New Orleans, Louisiana. The stage is then barged to the Marshall Space Flight Center, Huntsville, Alabama, for static testing. After testing, the stage is returned to Michoud for post-static checkout. The completed stage is then shipped to the Kennedy Space Center for pre-launch checkout.

In FY 1966, the 1st stage of the Uprated Saturn I entered a period of intensive ground test qualification. Emphasis was placed on the qualification of flight-critical components in preparation for initiation of the launch series. The first three flight stages were delivered to the Kennedy Space Center. Seven flight stages were in production, assembly, or checkout, and the long lead procurement began for the last two stages.

FY 1967 has been marked by an intensive production, checkout, test and delivery schedule. The fourth flight stage was delivered to the Kennedy Space Center for pre-launch checkout. Three additional flight stages are now scheduled for acceptance testing, post-static checkout, and delivery to the Kennedy Space Center by the end of this fiscal year.

During FY 1968, the remaining five stages for Apollo Uprated Saturn I vehicles, which are currently phased into fabrication, assembly, and in-plant checkout, are scheduled for completion of acceptance testing, post-static checkout, and shipment to the Kennedy Space Center. Funds requested support delivery and pre-launch checkout of the eighth and ninth flight stages; acceptance test, and shipment of the tenth and eleventh stages to Kennedy Space Center; and final assembly, in-factory checkout, acceptance test, and delivery of the last stage. Also covered are specific stage support activities, which encompass electrical and flight data measuring equipment, as well as propellants and special test equipment required for acceptance firings. Field support services for ground and flight test evaluations of the stage are also included.

2nd Stage (S-IVB)

Basic development costs for this stage are funded in the Saturn V project. Procurement and engineering design effort and modifications to adapt the stage to Uprated Saturn I requirements are funded in this budget line item. The stage, which is produced by the Douglas Aircraft Company, Missiles and Space Division, has the same basic design as the S-IV used in the Saturn I series. However, a single J-2 engine developing about 200,000 pounds of thrust has replaced the six RL-10 engines yielding 90,000 pounds of thrust. The Uprated Saturn I provides early experience with the S-IVB stage, which

will be used as the 3rd stage of the Saturn V. The S-IVB is manufactured, assembled, and checked out at the Douglas Huntington Beach, California, facilities. Hydrostatic tests to assess dynamic pressures are conducted at Huntington Beach. The flight stages undergo acceptance testing to verify performance specifications and launch readiness at the Sacramento Test Operations (SACTO) site.

Design and production of this stage began in the fall of 1963. During 1965, a dynamic test program was conducted to validate the overall structural design under simulated stresses of launch and maximum aerodynamic pressure. The stage ground testing was essentially completed in FY 1966. The S-IVB stage assemblies were subjected to loads in excess of design limits to validate structural integrity; over 2,500 seconds of battleship test firings were conducted to verify the operational reliability of the systems; and in excess of 15,000 tests were conducted to qualify individual flight-critical components. In addition, the first three S-IVB flight stages were shipped to the Kennedy Space Center and long lead procurement was initiated on the last flight stage (AS-212). The basic design of the S-IVB stage was verified on Uprated Saturn I flights and the stage was qualified for manned flight.

The fourth flight stage was delivered to the Kennedy Space Center for pre-launch checkout early in FY 1967. Three additional stages will be static tested at SACTO and shipped to the Kennedy Space Center by the end of this fiscal year. The remaining five flight stages will be in various phases of fabrication, test, and checkout by the close of FY 1967.

The FY 1968 funding supports delivery of the last five S-IVB flight stages for Apollo to the Kennedy Space Center. The eighth and ninth will arrive at the Center and undergo pre-launch checkout; the tenth and eleventh will complete acceptance testing at Sacramento and will subsequently be shipped to the Kennedy Space Center. The twelfth flight stage is scheduled to be through assembly, in-plant checkout, acceptance testing, and post-static checkout in preparation for shipment.

Instrument Unit (IU)

The instrument unit is the "nerve center" of the vehicle. It contains the all-important primary guidance, control, measuring, and telemetry systems which govern the engine gimballing, in-flight sequencing of the engine propulsion system, staging operations, and primary timing signals. These units are being assembled and tested by the International Business Machines Corporation in Huntsville, Alabama. The components and configuration are essentially the same as those used for the Saturn V.

During FY 1966, the instrument unit design was verified by extensive structural, dynamic, and vibration testing. Component qualification was also achieved during FY 1966 and Guidance and Control Laboratories were set up for field support at the Kennedy Space Center. Three flight units were completed, delivered to the Center, and flown on Uprated Saturn I missions.

Fiscal year 1967 activity has concentrated on completion of final assembly, checkout and shipment of flight units. Three instrument units have performed successfully on Uprated Saturn I missions and the unit has been qualified for manned flight. The fourth flight IU has been delivered to the Kennedy Space Center for the first manned Apollo mission. By the end of FY 1967, seven instrument units will have been delivered and the remaining five units will be in process.

Funding in FY 1968 supports completion of assembly and checkout, as well as delivery of the remaining five flight instrument units. In addition, the funds provide for IBM launch support at the Kennedy Space Center.

Ground Support Equipment (GSE)

The automatic ground support equipment used to checkout the Uprated Saturn I provides a transitional step to the even more complex procedures required for the Saturn V. This category includes electrical support equipment which is provided by the General Electric Corporation, and mechanical support equipment, which is provided by the Chrysler Corporation Space Division. Automatic ground checkout stations provide a means of protecting the investment in flight hardware and reducing the length of time and cost of manual checkout. Vehicle hardware is subjected to extensive checkout on the ground to verify systems reliability after assembly and static firing and during the pre-launch period at the Kennedy Space Center. In addition to these checkout stations, a GSE development system or breadboard is operated at the Marshall Space Flight Center to provide the capability to validate the computer programs used at the Kennedy Space Center. The basic computer is the RCA 110A.

During FY 1966, electrical and mechanical support equipment for vehicle-oriented requirements at Launch Complexes 34 and 37 was installed in preparation for Uprated Saturn I launches. An automatic checkout station operates at each complex to verify the flight worthiness of the launch vehicle. Activity in FY 1967 was highlighted by the activation of this equipment in support of Uprated Saturn I launches.

The FY 1968 funds support operation and updating of stage and vehicle ground support equipment, including mechanical and electrical support equipment, to satisfy the specific mission requirements for the scheduled Uprated Saturn I launches. Included are the checkout operations for the stages, instrument units, and assembled launch vehicles used for the earth orbital and rendezvous missions planned during this period.

H-1 Engines

The H-1 engine, developed and produced by the Rocketdyne Division of North American Aviation Incorporated, is used in clusters of eight to propel the first stage of the Uprated Saturn I. Development of the H-1 engine was initiated by the Department of Defense in September 1958 as a 165,000 pound thrust, improved version of the Thor-Jupiter engine. The responsibility for development of the engine was transferred to NASA in 1960. The 165,000

pound thrust engine was used successfully in the first four Saturn I launches, and a 188,000 pound thrust version of the engine was used on the remaining six Saturn I vehicles. The thrust of each liquid oxygen/kerosene H-1 was increased to 200,000 pounds for the Apollo Saturn 201 through 205. Beginning with the Apollo Saturn 206 mission, the thrust capability will be increased to 205,000 pounds per engine.

In FY 1966, the first of these 205,000 pound thrust H-1 engines was delivered and passed a series of ground tests to assess operational reliability at the increased thrust level. In June 1966, the uprated version completed the necessary requalification tests, including functional safety, and calibration tests of the components. The readiness of the engine for manned flight was also verified.

Fiscal year 1966 was the last full year of funding the contractor effort of the H-1 under the project line "engine development". Following completion of H-1 qualification in June 1966, the funding of contractor effort relating to field and engineering support for flight evaluation and problem solving, maintenance of test engines in a configuration for rapid solution of problems, component and engine system testing, and periodic verification of flight worthiness was transferred to this account.

Fiscal year 1967 marked the delivery of the twelfth and final set of H-1 engines. A total of 114 H-1 engines has been delivered to meet Uprated Saturn I requirements, including flight units, test units, and spares.

Funds for FY 1968 will provide for continued support of the flight program and for evaluation of flight data for use in subsequent missions.

J-2 Engines

The J-2 engine, which was developed and produced by the Rocketdyne Division of North American Aviation, is used in the upper stages of both the Uprated Saturn I and the Saturn V. A single J-2 is used in the 2nd stage of the Uprated Saturn I. This version of the J-2 engine utilizes liquid hydrogen and liquid oxygen as propellants and delivers up to 200,000 pounds of thrust.

The flight rating tests of the 200,000 pound thrust engine were completed in July, 1965. The J-2 engine was subjected to 25 tests for a total of 2,750 seconds of accumulated firing time. These flight rating tests were conducted to demonstrate engine reliability for initiation of the flight series. In December, 1966, the 200,000 pound thrust version completed the qualification test program which was a prerequisite to certifying the configuration for manned flight.

By the end of FY 1966, a total of thirteen J-2 engines were delivered for use in the Uprated Saturn I 2nd stage. The total included three ground test engines, one spare, and nine flight engines.

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By the end of the current fiscal year, all of the nineteen J-2 engines required for the Apollo Uprated Saturn I series will have been delivered.

In FY 1968, funds will cover J-2 field support, which provides for rapid response to any problems encountered in the flight series.

Vehicle Support

Vehicle support includes funds for studies, services, and equipment common to more than one stage of the Uprated Saturn I. Funding provides for engineering services; reliability tests; fabrication services; transportation; propellants; expendable supplies and equipment; and launch pad refurbishment. This funding also covers contract administration, audit, quality assurance and inspection services performed on a reimbursable basis by the Department of Defense.

During FY 1968, heavy emphasis will be placed on pre-launch and launch support at the Kennedy Space Center in preparation for highly complex dual launches from Complexes No. 34 and No. 37. The ability of the complete launch vehicle to function as an integrated, reliable system will be validated on the ground before the precision timed dual launches are attempted. Activities will include component and subsystem testing, analysis and correction of pre-launch problems, incorporation of flight data into reliability assessments, and development of an integrated reliability report for each mission. Guidance and control system studies will be conducted. In addition, the requirements cover refurbishment of the launch pad in preparation for the next mission. The FY 1968 vehicle support funds also include transportation of the flight stages and instrument units. Barges, sea-going vessels, and specially designed aircraft are used to carry the outsize stages and components.

Saturn V

	1966	1967	1968
1st stage (S-1C).....	$191,906,000	$184,900,000	$174,700,000
2nd stage (S-II).....	256,164,000	248,600,000	245,900,000
3rd stage (S-IVB).....	162,016,000	154,000,000	151,200,000
Instrument unit.....	67,760,000	72,900,000	75,100,000
Ground support equipment.	107,572,000	60,900,000	35,800,000
F-1 engines.....	66,200,000	92,307,000	105,300,000
J-2 engines.....	67,200,000	83,493,000	78,500,000
Vehicle support.....	216,053,000	238,500,000	242,000,000
Total.....	$1,134,871,000	$1,135,600,000	$1,108,500,000

The Saturn V, which is the most powerful member of the Saturn family of launch vehicles, is composed of three propulsion stages and an instrument unit. This vehicle is designed to boost payloads up to 140 tons into a low earth orbit and to accelerate payloads up to 48 tons to the seven-mile-a-second velocity required to escape the earth's gravitational field and

accomplish lunar or deep space missions. In its present configuration, the vehicle will provide a broad capability for manned space operations. Development of the versatile Saturn V began in January 1962 when management responsibility was assigned to the Marshall Space Flight Center. The decision to develop this version of the Saturn class vehicles was preceded by exhaustive studies on the most feasible configuration for a large launch vehicle with high performance and payload capability for earth orbital and lunar missions.

The physical characteristics of the Saturn V are as impressive as its mission. The assembled launch vehicle is 282 feet high. The 1st and 2nd stages (S-IC and S-II) measure 33 feet in diameter and stand, respectively, 138 and 82 feet high; the 3rd stage (S-IVB) is 22 feet in diameter and 59 feet high; and the instrument unit is three feet high. At lift-off, the Saturn V will weigh 6 million pounds. As an indication of the booster power, the Saturn V 1st stage yields about 7.5 million pounds of thrust in comparison with the 1.6 million pounds generated by the 1st stage of its predecessor, the Uprated Saturn I.

Consistent with the overall Apollo test philosophy, the Saturn V hardware and systems are subjected to rigorous testing on the ground before they are flown. As in the case of the Uprated Saturn I, this exhaustive ground test effort is necessary to protect the hardware investment and to maximize safety and reliability. Since no substitute stages will be available, the operational readiness of each of the hundreds of thousands of components must be proven in advance of a launch. The ground test series leading to unmanned and manned Saturn V launches has been progressing steadily. However, the loss of two S-II development stages over the past two years illustrates the difficulties inherent in accomplishing this highly complex R&D effort.

During FY 1966, an extensive ground test effort was carried on at numerous locations across the country. The three Saturn V stages and instrument unit underwent a series of critical tests to assess structural integrity, systems reliability, and simulated operational characteristics. For example, all three stages were subjected to battleship testing, which is conducted to verify the operational reliability of the propulsion system, and structural testing, which is required to evaluate the soundness of the design criteria. All design standards were achieved, although the S-II structural stage ruptured above this level. The instrument unit also passed its structural tests during this period. All systems testing on the Saturn V 1st stage (S-IC) was successfully completed at the Marshall Space Flight Center in December, 1965. A total of 842 seconds of static test firing was accomplished. The first 2nd stage test stand--the A-2 position test stand for the 2nd stage --was activated at the Mississippi Test Facility in early 1966. All systems firings with the 2nd stage were then conducted through the full duration flight requirements. However, the all systems test stage later failed when the liquid hydrogen tank was inadvertently overpressurized. The loss of this stage before the completion of ground development testing required adjustments within the ground test program. After the damaged stand at the Mississippi Test Facility was repaired, the first S-II flight stage was placed in the stand, fueled, and checked out for a full-duration acceptance

firing, which was successfully conducted on December 1, 1966. An additional full duration firing was conducted on December 30, 1966. The flight stage has been shipped to the Kennedy Space Center for the first Saturn V launch.

A major Apollo milestone was accomplished on May 25, 1966--five years to the day that the goal of manned lunar landing and return within this decade was established. The crawler transporter, which has a platform larger than a baseball diamond, moved the 365-foot Apollo Saturn V facilities checkout vehicle (the "500-F") and mated spacecraft from the Kennedy Space Center Vehicle Assembly Building at Launch Complex No. 39 along three miles of specially constructed roadway to the launch pad. This 500-F vehicle was required to complete a variety of tasks leading to the first Saturn V flight in 1967. It was used to activate the first set of facilities at Launch Complex No. 39, proving out the delivery, handling, checkout, vertical assembly, and transport procedures. It was used to verify the physical and electrical compatibility of the vehicle stages with each other and with the launch facility, to develop the automatic checkout procedures that will precede each launch, and to demonstrate the propellant loading techniques. It also provided actual test data on the ability of Saturn V to withstand high winds. This test series came to a close in November, 1966, when the 500-F was rolled back from the pad to the vehicle assembly building, clearing the way for the first Saturn V mission.

The component qualification test program, which was undertaken to certify through ground testing the flight readiness of some 3,500 different components, is also progressing. Approximately 2,500 components were qualified on the basis of reliable performance on previous systems; of the remaining 1,000, over 950 had been certified by December, 1966. An intensive drive to qualify the remaining components is in progress.

Saturn V dynamic testing or "shaking", which is conducted to monitor the reactions of the vehicle under simulated flight conditions, such as launch, maximum aerodynamic loading, and stage separation, is conducted at the Marshall Space Flight Center. Dynamic tests in support of the first unmanned Saturn V launch are scheduled for completion in early 1967. Additional dynamic testing will be conducted at Marshall during the year to support the initiation of manned Saturn V launches.

The Saturn V schedule provides for fifteen launch vehicles in support of Apollo unmanned qualification flights, manned lunar mission simulations, and manned lunar missions. Saturn V hardware production and deliveries are rapidly building up to meet the mission requirements. Peak production activity, based on hardware in process, will be reached during 1967. Work is already underway on all the fifteen Saturn V launch vehicles. Manufacture of the first five has been completed and long leadtime components for the last launch vehicles are being fabricated. By the end of the year, assembly of the fifteenth launch vehicle will be underway.

The first launch of a Saturn V vehicle from Complex No. 39 at the Kennedy Space Center will be in 1967. This mission, designated AS-501, will be an unmanned orbital flight to test the vehicle's dynamic characteristics, the reliability of the propulsion systems, and the accuracy of the guidance and

control sequencing system, as well as a spacecraft heatshield qualification test. The second unmanned qualification flight, AS-502, is also scheduled for 1967. Again, the operational reliability and performance characteristics of the vehicle will be validated. The mission will also be designed to demonstrate that the 3rd stage has the capability to provide the propulsion to eject the Apollo spacecraft out of earth orbit and on to the moon. Major emphasis during 1967 will be on flight qualification of the Saturn V. Assuming success with the initial flight tests, manned missions are planned for 1968.

1st Stage (S-IC)

The Saturn V 1st stage, which generates approximately 7.5 million pounds of thrust, is the most powerful developed by this country to date. The stage is powered by five liquid oxygen-kerosene F-1 engines, each developing about 1.5 million pounds of thrust. This large cylindrical stage is 138 feet high and 33 feet in diameter; its dry weight is approximately 290,000 pounds. The fuel tank has a capacity of 210,000 gallons of RP-1 (kerosene), while the oxidizer tank can hold 327,000 gallons of liquid oxygen. At launch, the S-IC will be lifting a total space vehicle weight of six million pounds. During flight the stage burns for two and a half minutes, consuming about 15 tons of propellant a second.

Development began in early 1962. The Marshall Space Flight Center, with the assistance of the Boeing Corporation, manufactured the structural test components, the first ground test stage, and the first two flight stages at Huntsville, Alabama. Manufacturing of the first flight stage began at Huntsville in July, 1964. Boeing was awarded the contract to manufacture two other ground test stages (dynamic and facilities checkout) and thirteen flight stages at the government-owned Michoud Assembly Facility near New Orleans, Louisiana.

During FY 1966, the all-systems test runs reached full duration status. Five-engine, automated test firings were completed at Marshall in December, 1965. This ground test program, consisting of 15 captive firings for a total of 842 seconds, verified the basic propulsion system. Structural testing was also conducted. The dynamic test stage and facilities checkout stage were completed. The facilities checkout stage was shipped from Michoud to the Kennedy Space Center in January, 1966. The first flight stage (S-IC-1) went through manufacturing, assembly, and acceptance testing, and post-static checkout at Marshall; and the second (and final Marshall-manufactured flight stage) completed acceptance testing. By the end of FY 1966, five S-IC flight stages were undergoing manufacturing, assembly, or in-plant checkout at Michoud.

Activity in FY 1967 has been highlighted by the delivery of the first flight stage to the Kennedy Space Center. The stage is undergoing pre-launch preparations in the vehicle assembly building at Launch Complex No. 39.

The second flight article completed post-static checkout and the third passed its acceptance test firing at Marshall. The fourth flight stage will be completed and delivered to the Mississippi Test Facility to inaugurate acceptance testing at this location. The fifth and sixth are scheduled to complete manufacturing, and the remaining nine will be phased into manufacturing or long-lead procurement.

The FY 1968 funds support completion of the S-IC structural test program and continuation of assembly, in-plant checkout, acceptance testing, and shipment of flight stages to the Kennedy Space Center. The fourth, fifth, and sixth stages will be put through post-static checkout at Michoud, delivered to the Kennedy Space Center, and prepared for flight. The seventh and eighth 1st stages are scheduled to complete assembly, in-plant checkout, and static testing; and the ninth and tenth are scheduled to be through manufacturing and checkout at Michoud. The five remaining stages are planned to be in manufacturing during FY 1968.

2nd Stage (S-II)

The 2nd stage of the Saturn V is powered by a cluster of five liquid oxygen-liquid hydrogen J-2 engines, producing a total thrust of approximately 1 million pounds at altitude. It is the nation's largest liquid-hydrogen powered stage. The cylindrical stage is approximately 82 feet high and 33 feet in diameter. The aluminum alloy skin on the initial stages is only .153 inches thick and will be reduced to .128 inches in subsequent stages. The structure contains two propellant tanks separated by an insulated common bulkhead. The top tank holds almost 290,000 gallons of liquid hydrogen; the lower tank, located below the common bulkhead, holds almost 94,000 gallons of liquid oxygen. Starting off on the launch pad, its gross weight, including engines, is about one million pounds - 90% of which consists of propellants. During flight the stage burns for six and a half minutes and withstands temperatures ranging from about +400 to -400 degrees Fahrenheit. The component qualification requirements for the S-II are particularly stringent because the stage stretches to the utmost existing hydrogen propulsion technology and related manufacturing techniques.

Design, production, and ground test of this stage are performed by the North American Aviation Space and Informations Systems Division. Manufacturing, assembly, and factory checkout are accomplished at government-owned facilities at Seal Beach, California. North American conducts developmental ground testing at its Santa Susana Static Test Laboratory. Flight stages are shipped through the Panama Canal to the Mississippi Test Facility to undergo acceptance firing before being delivered to the Kennedy Space Center.

Development of the 2nd stage began in January, 1962. The early test stages, including an electro-mechanical mock-up, as well as a battleship, a structural/dynamic, and a facilities checkout ground test stage, were all in progress during 1963 and 1964. The first flight stage entered fabrication in August, 1964.

During FY 1966, the production and ground development test efforts were building up at a rapid rate. Six flight stages were in fabrication and assembly at the North American Seal Beach facilities. Battleship testing to check out the propulsion system was also conducted at the company's Santa Susana Static Test Laboratory. These ground tests consisted of repeated firings of the cluster of five 200,000 pound thrust J-2 engines to demonstrate the performance capabilities of the propulsion system. In addition, a series of structural tests was performed to certify the design criteria. On September 29, 1965, the S-II structural stage failed while undergoing its final major test at Seal Beach. The stage had withstood pressure and temperature stresses in excess of design requirements, and had demonstrated structural integrity under simulated flight conditions before it ruptured.

During FY 1967, the development and qualification ground test program has been continuing. The facilities checkout stage was used for activation of the first set of facilities at Launch Complex No. 39 and shipped to the Marshall Space Flight Center for use in the Apollo Saturn V dynamic test program. The all-systems test stage was used to check out the first S-II test stand at the Mississippi Test Facility. Static tests had progressed through the point of a full-duration firing of approximately 390 seconds. The stage failed when the liquid hydrogen tank was inadvertently overpressurized, as tests leading to a second full-duration firing were being conducted.

A key milestone was passed on December 1, 1966, when the first flight stage (S-II-1) was successfully static fired at the Mississippi Test Facility. The stage, which will fly on the first Saturn V mission, was static tested for 384 seconds--approximately the length of time required to operate in flight. The test yielded about 800 critical measurements on the stage performance, including tank temperatures and pressures, propellant flow rates, and vibrations. The stage will be refurbished and shipped to the Kennedy Space Center in early 1967. To avoid delay in checking out the first Saturn V flight vehicle, an S-II spacer was furnished to the Kennedy Space Center. The spacer is a substitute structure for the stage which permits the balance of the vehicle to be stacked and checked out.

The production of flight hardware has increased during FY 1967. By the end of this fiscal year, the first two flight stages are scheduled for completion of acceptance testing, post-static checkout, and delivery to the Kennedy Space Center. The second S-II test stand (designated A-1) will be operational at the Mississippi Test Facility. Manufacturing or procurement activity for the remaining stages will be underway.

Fiscal year 1968 activity will continue to emphasize production of hardware in support of the Apollo Saturn V flight requirements. The third, fourth, fifth, and sixth flight stages are scheduled for completion of acceptance test, post-static checkout, and shipment to the Kennedy Space Center. Exhaustive pre-launch checkout procedures will be conducted at Kennedy to assure that these stages measure up to the stringent performance standards established for manned flight.

The tempo of hardware production for the following flights must also be sustained. The stages for the seventh through twelfth Saturn V vehicles will be in an intensive period of manufacturing, assembly, in-plant checkout, or acceptance firing to support the planned launch rate. In addition, procurement activity will be underway on the three remaining flight stages.

3rd Stage (S-IVB)

Basic development cost for this stage, which is also used on the Uprated Saturn I, are funded in this line item. The S-IVB is being developed, produced, and tested by the Douglas Aircraft Company, Missile and Space Systems Division, which also produced the upper stage of the Uprated Saturn I. The stages are manufactured and tested at the Douglas Space Center, Huntington Beach, California, and acceptance testing is conducted at the Sacramento Test Operations Site.

In addition to furnishing the final increment of velocity to put the Saturn V payload into orbit around the earth, this stage provides the stabilization for the spacecraft during the earth orbital coast period. During this time, the stage has to provide roll, pitch and yaw control. The stage attitude control system is also used to position the stage and spacecraft for the second burn of the single J-2 engine that injects the Apollo spacecraft into a lunar trajectory. Once out of the earth orbit, the S-IVB stabilizes the spacecraft until the accuracy of the lunar trajectory is confirmed and maintains the stability of the lunar module while the astronauts perform separation, turn-around, and docking maneuvers with the Apollo command and service modules.

During 1963 and 1964 production of the ground test development stages was underway. The first flight S-IVB stage entered fabrication in the fall of 1964. The steady progress on this stage can be traced in a sense to the bank of technology carried over from the previous Saturn projects. For example, the S-IVB has already demonstrated its operational reliability on Uprated Saturn I flights.

Fiscal year 1966 activity focused on the ground development test program. Battleship tests to verify the operational reliability of the stage propulsion system were conducted at the Sacramento Test Operations Site. The restart capability of the J-2 engine, burning liquid hydrogen and liquid oxygen, was demonstrated during these tests. The stage used for Uprated Saturn I dynamic testing was modified to add a flaired interstage section and readied for the Saturn V dynamic test program. The facilities checkout stage was also ready for use in the activation of the first set of facilities at Launch Complex No. 39. The first five flight S-IVB stages were undergoing manufacturing, assembly, or acceptance test.

During FY 1967, these ground test stages will be used for Saturn V dynamic testing at Marshall and for checking out Pad B in the second set of facilities at Launch Complex No. 39. The second and third flight stages are scheduled for completion and delivery to the Kennedy Space Center. The fourth will complete checkout at Huntington Beach and will undergo acceptance testing at the Sacramento Test Operations Site; and the remaining five flight stages will be phased into fabrication and assembly to meet flight schedule requirements.

Fiscal year 1968 activity will focus on continued production and delivery of flight stages to support the Apollo Saturn V schedule. The fourth flight stage will be shipped from the West Coast to the Kennedy Space Center for pre-launch checkout. The next two flight stages are scheduled to be through fabrication and in-plant checkout at Huntington Beach, as well as acceptance testing and post-static checkout at the Sacramento Test Operations Site; these stages are also scheduled for delivery to the Kennedy Space Center by the end of FY 1968. Fabrication, assembly, in-plant checkout, and acceptance testing of the seventh and eighth flight stages are planned, and the ninth and tenth will be through fabrication and assembly in preparation for acceptance firing at Sacramento. The remaining five stages will be in various phases of manufacture and assembly.

Instrument Unit (IU)

The Saturn V instrument unit is essentially the same as the one used on the Uprated Saturn I. The instrument unit contains the guidance and control system that issues commands to the attitude control devices of each stage during powered flight to guide the Apollo Saturn V. A major component of the IU guidance and control system is the launch vehicle digital computer. This computer is a micro-miniaturized liquid-cooled electronic device which performs a variety of operations during pre-launch checkout, launch, earth orbital operations, injection into a translunar path, and spacecraft separation. Another key component of the IU is the instrumentation system, which includes the measurement sensors, telemetry, and communications systems.

The instrument units are assembled and checked out by the International Business Machines Corporation in Huntsville, Alabama. During 1965, an intensive ground test program was underway to demonstrate its reliability for Saturn V flights. Structural and dynamic testing was conducted. Procurement activity for the first flight unit (S-IU-501) was started in January 1965.

During FY 1966, the development test effort was intensified. The systems test unit was subjected to a series of development tests to validate the guidance and control, instrumentation, and electrical power equipment. The facilities checkout unit was shipped to the Kennedy Space Center and used for checkout and activation of Launch Complex No. 39. Procurement activity for the second, third, and fourth flight units began.

Effort in FY 1967 has focused on assembly and inspection of flight units to meet the delivery schedule. The IU for the first Saturn V flight was delivered to the Kennedy Space Center in August,1966. Checkout of the second flight unit was completed at IBM, Huntsville, for delivery to Kennedy in early 1967. Assembly and factory inspection of the third flight IU has been completed, and checkout is underway. By the end of FY 1967, the third flight unit will be ready for delivery to KSC.

Fiscal year 1968 will also be marked by a steady delivery rate in support of the scheduled Apollo Saturn V missions. The fourth, fifth and sixth flight units will be checked out and delivered to the Kennedy Space Center. Assembly, inspection and checkout of the seventh flight unit will be completed.

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Ground Support Equipment (GSE)

The Saturn V ground support equipment consists of electrical and mechanical support equipment required to test and check out the stages, instrument units and associated hardware. The checkout procedures developed for the Saturn V are based on the concept that improved vehicle reliability and minimum time at the launch site can be attained by using a computer-controlled system in which the operational soundness of components is automatically verified. Automatic checkout equipment is used at the manufacturing, static test, and launch sites.

The General Electric Company is under contract for design, fabrication, checkout, and logistic support of the Saturn V electrical support equipment. The Boeing Company is contractor for a Saturn V equipment management system, which provides a master record for all vehicle ground support equipment. Boeing is also responsible for the integration and logistic support of all mechanical support equipment. The Radio Corporation of America is providing the computer systems and Sanders Associates the display systems for use at Launch Complex No. 39.

Fiscal year 1964 and 1965 funds were used for design and initiation of long leadtime procurement of electrical and mechanical checkout equipment for use at Launch Complex No. 39. In addition, installation and testing of an electrical checkout equipment and flight hardware simulator (breadboard) was in progress at the Marshall Space Flight Center. Funds were also used to develop and procure special test equipment and components, such as hardware for the umbilical/swing arm test facility.

During FY 1966, installation and checkout of the equipment for the Saturn V breadboard was completed at Marshall. This equipment was used to develop and test operating procedures for the electrical ground support equipment. In addition, delivery, installation and checkout of the vehicle-oriented GSE for use on the first launch umbilical tower, the first high-bay and the low-bay of the vehicle assembly building, the first firing room of the launch control center, the first launch pad and the necessary support areas were completed. Saturn V — oriented GSE for the second launch umbilical tower, high-bay area, firing room, and launch pad was also procured.

Activity in FY 1967 includes preparation and verification of computer tapes for the initial Saturn V flight missions. In addition, the vehicle GSE for the second set of facilities at Launch Complex No. 39 will be installed and checked out to support the site activation and flight schedule. Delivery and installation of vehicle-associated GSE for the third launch umbilical tower, high-bay, and firing room will also be underway during the year.

Funds in FY 1968 support preparation and verification of computer tapes for the manned Saturn V missions and also provide for completion of Saturn V - related GSE for the third launch umbilical tower, high-bay, and firing room at Launch Complex No. 39.

F-1 Engines

The F-1 engine is being developed and produced by North American Aviation/ Rocketdyne Division at Canoga Park, California. Engine testing is conducted at Edwards Air Force Base, California. Five liquid oxygen/kerosene F-1 engines are clustered in the first stage of the Saturn V. Each engine generates approximately 1.5 million pounds of thrust, for a total thrust of approximately 7.5 million pounds.

The initial contract for the F-1 was awarded to Rocketdyne in January, 1959. The first full thrust, full duration firing was conducted at Edwards in June, 1962. In December, 1964, the engine was certified for flight. The first clustered engine firing was conducted in April, 1965, and was followed in May by the delivery of the first set of flight engines.

By the end of FY 1966, a total of forty F-1 engines had been delivered to support Saturn V requirements. This total included spares, stage test, and flight engines. Fiscal year 1966 was the last full year of funding the contractor development of the F-1 under the project line "Engine Development." Following completion of qualification in September, 1966, the funding of contractor efforts for field and engineering support was transferred to this account. Field and engineering support for flight evaluation and problem solving, maintenance of test engines in a configuration for rapid solution of problems, component and engine system testing, and periodic verification of flight worthiness are included in this category.

Activity in FY 1967 has also emphasized the delivery of flight engines to meet the Apollo Saturn V schedule. By the end of the current fiscal year, twenty-three additional F-1 engines will have been delivered for the ground test and flight program.

Funds in FY 1968 provide for continued engine deliveries to meet flight requirements. Thirty-four F-1 engines are scheduled for delivery during this period. The funds also cover quick response to any F-1 problems encountered in the flight missions.

J-2 Engines

The J-2, which was developed and is being produced by North American Aviation, Rocketdyne Division, is used in the two upper stages of the Saturn V. The second stage is powered by five J-2 engines, each producing over 200,000 pounds of thrust. The third stage is powered by a single J-2 engine with restart capability.

The J-2 entered development in September, 1960, and the first flight demonstration was achieved in February, 1966. Qualification of this engine at a thrust level of 230,000 pounds was recently completed in support of the Saturn V flight missions.

The last full year of funding for the contractor effort under the project line item "Engine Development" was in FY 1966. Following completion of engine qualification at the 230,000 pound thrust level, the funding of contractor field and engineering support was transferred to this account. The field and engineering support activity includes flight evaluation and problem solving, maintenance of test engines in a configuration for rapid solution of problems, component and system testing, and periodic verification of flight worthiness.

During FY 1966, the engine delivery rate intensified to meet the schedule requirements. By the end of that fiscal year a total of 57 J-2 engines, including ground test and flight articles, had been delivered.

During FY 1967, an additional 39 engines are scheduled for delivery.

The funds in FY 1968 will provide for delivery of 36 more engines and for rapid response to any problems encountered during the Saturn V flights.

Vehicle Support

Vehicle support funds are required to provide services and equipment that are common to more than one stage of the vehicle. Funding in FY 1966 and FY 1967 included instrumentation, recording and data reduction equipment for the Saturn V dynamic test stand at Marshall Space Flight Center; transportation costs, which include use of marine vessels and aircraft for movement of stages, engines and components; activation and operation of the Mississippi Test Facility; operation of the Slidell Facility; range safety and tracking devices; propellants; systems integration; and computation services, engineering services, quality control and inspection, contract administration, audit and property administration services by other government agencies. In FY 1968, emphasis will be placed on static test activities at the Mississippi Test Facility and vehicle support at the Kennedy Space Center. Systems integration will continue to insure proper interface control of all stages, systems, and structures and reliability and flight evaluation programs will also be funded.

Engine Development

	1966	1967	1968
Engine development.....	$133,200,000	$49,800,000	$24,500,000
Total.....	$133,200,000	$49,800,000	$24,500,000

Development effort on the family of engines used in the Saturn launch vehicles was initiated in September, 1958, by the Department of Defense under a contract with the Rocketdyne Division of North American Aviation to develop an improved version of the Thor-Jupiter engine. Responsibility for this development activity was transferred to NASA in 1960. The improved version, designated the H-1, was the 165,000 pound thrust liquid oxygen/kerosene

engine that was used on the first Saturn I development flights. This engine was successively uprated to 188,000 pounds; to 200,000 pounds; and finally to the 205,000 pound thrust engine that will be used in clusters of eight in the first stage of Uprated Saturn I launch vehicles after AS-205. Qualification of the 205,000 pound thrust version of the H-1 was accomplished in June, 1966.

The development of the F-1 and J-2 engines was also awarded to the Rocketdyne Division of North American Aviation. The initial contract for the F-1, a 1.5 million pound thrust, liquid oxygen/kerosene engine, was awarded in January, 1959. The F-1 was certified as a qualified engine, at its rated capacity, in September, 1966. This engine is used in clusters of five in the first or booster stage of the Saturn V launch vehicle. The first flight demonstration of the engine will occur in 1967 when the Apollo Saturn V flight series is initiated.

The J-2 engine is used in a cluster of five on the second stage of the Saturn V, and as a single engine on the third stage of the Saturn V and the second stage of the Uprated Saturn I. The J-2 uses liquid oxygen and liquid hydrogen as propellants. The development contract was let in September, 1960, and the first flight demonstration was accomplished in February, 1966, on Apollo Saturn 201. Qualification of the engine at a rated thrust of 230,000 pounds has just been completed.

Fiscal year 1966 was the last full year of funding for contractor effort on H-1, F-1 and J-2 engine development under the Engine Development project. Upon completion of engine qualification, funding of contractor effort is transferred to the respective engine accounts of the Saturn launch vehicles. This transfer covers all field and engineering support for evaluation and problem solving. Included are static testing for quick response in support of flight requirements; component and engine system testing; periodic verification of flight worthiness; and maintenance of test engines in a configuration required for problem solution. Transfer dates for these efforts were July, 1966, for the H-1; October, 1966, for the F-1; and January, 1967, for the J-2. Fiscal year 1967 funding after these dates provides for government-furnished propellants and ancillary chemicals; services and equipment associated with contractor effort; contract, audit and property administration; and quality assurance and inspection services.

During FY 1968, the funds requested will provide for government-furnished propellants, reimbursement to the Department of Defense for contract administration and quality assurance services, and a continuing program of government in-house and independent contractor evaluation and analysis of prime contractor-produced hardware. The major activity in this area is the J-2 engine environmental test program conducted at the Air Force Arnold Engineering Development Center, Tullahoma, Tennessee. Other activities include operating limits investigation, materials investigation, and quality and reliability studies. The total evaluation and analysis program is directed toward identification of those materials and components which have the greatest operational restrictions or least confidence. Improvements, which

will result in a launch vehicle of greater operational flexibility, reliability, or safety, are then incorporated into the engines.

Mission Support

	1966	1967	1968
Operations.....	$112,928,000	$196,900,000	$229,000,000
Systems engineering.....	20,000,000	20,000,000	20,000,000
Supporting development...	31,400,000	27,000,000	32,000,000
Total.....	$164,328,000	$243,900,000	$281,000,000

Mission support provides for the over-all launch, flight, crew and recovery operations; program-wide systems engineering; and supporting development necessary for the successful accomplishment of manned space flights.

Operations

Operations include those activities at the Kennedy Space Center and the Manned Spacecraft Center directly concerned with the launch and flight of Apollo missions. Funding for the Kennedy Space Center covers the operation of checkout, launch, and instrumentation facilities. These requirements also provide for contractor services, equipment and supplies, and reimbursement for services performed by the Air Force. At the Manned Spacecraft Center, activity includes mission control for Apollo flights; support of astronaut training and flight crew requirements; operation and updating of mission simulation; mission planning and analysis; contractual development of real-time computer programs for flight missions and flight monitoring; remote site operations; and recovery equipment and activities, including reimbursement to the Department of Defense for recovery operations.

Funds for FY 1967 are supporting Apollo Uprated Saturn I unmanned and manned flights and the initial Saturn V unmanned flights. FY 1967 funds also provide for intensified training of astronauts for Apollo missions and procurement of lunar landing training vehicles.

The increase in the FY 1968 fund requirements is directly related to the increase in the Apollo flight rate. At the Kennedy Space Center, the contractor effort for launch instrumentation and operational support of launch activities, and at the Manned Spacecraft Center, the contractor effort for operational support of the mission control center, will increase directly in relation to the number of flights planned.

Systems Engineering

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

effectiveness; and technical documentation. Bellcomm and General Electric are the principal systems engineering contractors.

During FY 1967, emphasis is being placed on developing and maintaining a quick response capability for validation and analysis of flight data on a time scale compatible with the turn-around time of Apollo flight missions. The FY 1967 funding also provides for contract administration and related services of the Department of Defense, as well as non-recurring maintenance and rehabilitation of government-owned industrial plants.

The systems engineering requisite for trajectory analysis, checkout effectiveness, analysis of flight mission results, detailed studies of specific lunar landing areas and constraints, and technical documentation will continue through FY 1968 to support the increased flight activity.

Supporting Development

Supporting development is a continuing program which involves individually selected engineering efforts to eliminate potential deficiencies in on-going programs and to provide a firm base for hardware decisions pertinent to extension of the program. The end objectives are to remove identified deficiencies, and to provide backup solutions where required. Supporting development also covers development of improved hardware or manufacturing, test, and evaluation techniques to reduce cost and to upgrade performance and confidence. In addition, supporting development includes the identification of marginal components, systems or techniques and the development of modifications that could also be used in new projects. The character of the work varies with each work unit, depending on the state of development of the hardware or technique, and is strongly influenced by the nature of the mainstream program problems or long leadtime system requirements for program modifications or extensions. In some cases, the potential problem may best be overcome by developing new hardware or techniques; and, in other cases, by modification of the mainstream approaches through better definition of specifications.

Work initiated during previous years is providing developed hardware during FY 1967. For example, a wide band telemetry system, designed to meet a data transmission requirement which could not be handled by the restricted channel capacity of existing telemetry, was recently incorporated into the mainstream Apollo program. A constant bandwidth FM system with four times the data capability formerly available has been developed and has come into standard industry use. In another supporting development area, an electrical device designed to activate Apollo spacecraft pyrotechnics, was found to be dangerously sensitive to the effects of static electricity and radio frequency energy. A new initiator that eliminated these deficiencies was developed and qualified.

The supporting development requirements remain substantially constant to provide for the solution of potential Apollo mainstream deficiencies. These solutions will also be incorporated into the development of hardware and techniques associated with probable new projects. The supporting development

efforts will be concentrated largely in the S-II stage area and tasks related to the Apollo spacecraft. In the S-II stage area, continued work to develop alternate approaches to the difficult fabrication techniques is considered essential. In the Apollo spacecraft area, there are still some remaining materials compatibility problems, and a requirement to provide for the possibility of additional on board data storage.

In the long leadtime development area, increased effort is planned to investigate the exploitation of the inherent capabilities of the current Apollo/Saturn systems and facilities. Application of these capabilities for long term low and synchronous earth orbital and extended lunar effort will require such tasks as development of multiple restart capability for upper stages, improved insulation for propellant storage in space, and improved guidance and navigation systems.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1968 ESTIMATES

OFFICE OF MANNED SPACE FLIGHT — APOLLO APPLICATIONS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

In 1961, the United States undertook the first step toward a major manned space flight capability by selecting the goal of a manned lunar landing within the decade. The Apollo and Saturn systems have been developed to meet that goal, and the successful Gemini program has provided the necessary early experience in maneuver, rendezvous, docking, extravehicular activity, and 14-day flight. The Apollo Applications program is the second significant step toward that capability and represents an effort even more important and far-reaching in its implications than the Apollo effort upon which it is based. The program will carry out a full investigation of man's role in the effective exploitation of the environment of space to meet man's needs on the earth and in the long term exploration of the universe.

The Apollo Applications program proposed for initiation in the FY 1968 budget is based on an average annual launch rate of 4 Uprated Saturn I and 4 Saturn V flights per year following those required for the manned lunar landing. The planned program will avoid any hiatus in the continued development of United States' manned flight capability, will continue the availability of the nation's two most powerful rocket vehicles, and will not affect the on-going Apollo effort. Maximum economy will be achieved through the full utilization and extension of Apollo and Saturn developments. The experimental payloads included in the Apollo Applications program are designed to provide significant data on the capabilities of man and equipment, and on their potential ability, as promptly and as economically as possible. These plans have the flexibility of employing for new missions any spacecraft and launch vehicles currently on order for the Apollo program that, in the event of early successes, are not required to meet Apollo objectives.

The Apollo Applications missions will build upon the strong base of flight experience, ground facilities, and trained manpower developed in past and current programs. Each mission is designed to take full advantage of the Saturn-Apollo system to make significant contributions to a wide range of objectives. Missions are planned to concurrently gain experience, test theory, perform experiments, and collect data. By establishing multiple objectives for each flight mission, a program limited to a minimum economical launch rate can achieve rapid progress and make great gains at low cost. Key elements of this planning include the decision to use, modify, and expand present Apollo systems capabilities rather than move toward whole new developments, the strategy of reusing basic hardware for many missions by storing it in orbit and returning later with fresh crews and expendables, and the approach of designing experiments that will gather important data while at the same time testing the experimental concepts themselves.

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The program of investigations and development to be carried forward in the Apollo Applications program will meet two basic objectives: to make unique contributions to practical applications, operational capabilities, science, and technology; and, at the same time, to place the nation in a position to assess, on the basis of valid scientific experimentation and actual experience, the value and feasibility of future space flight and the interrelated roles of manned and unmanned systems.

In support of these objectives, the principal areas toward which the FY 1968 effort will be directed are the development of an extended flight capability, the conduct of manned astronomical and earth observations from space, and the continued exploration of the moon.

The early development of long duration flight capability is clearly one of the most important areas to be pressed forward, in that it is a key requirement for most of the possible significant advances in manned flight. Apollo Applications flights of up to one year or more in duration will represent a significant increase in the nation's operational capabilities in space and opportunities for important scientific and technological experimentation. Extended duration flight experience is also necessary to provide a sound basis for those future decisions on manned programs of the greatest interest and potential, such as permanent manned facilities in space or manned flights to the planets.

Apollo Applications experiments will permit important and unique observations of the sun starting in 1969 and will at the same time provide experience that is essential for the design and operation of future large telescopes in space (manned, man-tended, or unmanned) which will open up a whole new chapter in the exploration and understanding of the universe.

Apollo Applications experiments with a wide variety of sensing devices will test the feasibility and utility of advanced types of meteorological observations and earth resource surveys from space. These experiments will provide the data for decisions on future systems--unmanned or manned--to derive additional practical benefits from space observations.

Saturn V flights in the Apollo Applications program will provide for following up the first Apollo landings with additional lunar exploration missions of up to 14 days on the surface and for observation and mapping from lunar orbit. These missions will yield important additional scientific data about the moon and will also provide the information necessary for deciding whether our manned capabilities for exploration of the moon should be further developed and exploited.

Within this framework, specific program elements have been selected for initiation in FY 1967 and 1968 that, in combination, provide the greatest contribution to the nation's space objectives at the lowest cost. These are:

The spent, orbiting second stage of an Uprated Saturn I will be converted into a habitable, 10,000 cubic foot orbital workshop. Provided with an airlock, the workshop will provide in 1968 an economical long duration manned shelter for many experimental activities and will be revisited and reused during the course of the program.

The support systems of the basic Apollo command and service modules will be modified for long duration operations.

The lunar module will be modified to serve as a base for manned lunar investigations of up to two weeks.

The Apollo developed lunar mapping and survey system will be used to complete the cartography of the moon.

The command module will be modified to carry up to 6 men for short duration ferry and resupply missions and will be provided a land landing capability, thereby reducing costs and increasing operating flexibility.

Specialized payloads will be developed for operation in various orbits and on the moon, including multispectral earth and weather sensors, biological and biomedical experiments, mobile lunar vehicles, and communications systems.

A manned solar telescope system, forerunner of long-lived orbital astronomical facilities, will be flown during the peak of solar activity.

SUMMARY OF RESOURCES REQUIREMENTS:

	1966	1967	1968
Space vehicles.....	$8,500,000	$38,600,000	$263,700,000
Experiments.....	40,347,000	35,600,000	140,700,000
Mission support.....	2,400,000	5,800,000	50,300,000
Total.....	$51,247,000	$80,000,000	$454,700,000

Distribution of Program Amount by Installation:

	1966	1967	1968
John F. Kennedy Space Center, NASA.....	$250,000	$250,000	$3,300,000
Manned Spacecraft Center..	28,109,000	32,604,000	228,200,000
Marshall Space Flight Center.....	5,352,000	37,445,000	199,600,000
Goddard Space Flight Center.....	1,561,000	---	---
Wallops.....	200,000	---	---
Ames Research Center.....	1,491,000	125,000	---
Langley Research Center...	1,590,000	900,000	---
NASA Headquarters.....	11,954,000	8,676,000	23,600,000
Western Support Office....	740,000	---	---

BASIS OF FUND REQUIREMENTS:

Space Vehicles

	1966	1967	1968
Command and service module procurement.....	---	---	$43,300,000
Uprated Saturn I procurement.....	$1,000,000	$24,000,000	78,500,000
Saturn V procurement.....	---	---	45,600,000
Spacecraft modification.....	7,500,000	14,600,000	91,300,000
Launch vehicles modification.....	---	---	5,000,000
Total.....	$8,500,000	$38,600,000	$263,700,000

Procurement

Phasing of space vehicle procurement and deliveries by the Apollo Applications program is compatible with the present Apollo hardware production schedule. Incremental procurement fund requirements for FY 1968 are based on detailed study of individual procurement schedules and review of the cost and trend histories of each major Apollo hardware contractor as well as on an assessment of the minor contract support required by the planned program.

The FY 1968 budget request provides for continued incremental funding of the follow-on Uprated Saturn I procurements initiated in FY 1966 and 1967 and for the initial funding for follow-on Saturn V vehicles and command and service modules (CSM). The first follow-on Uprated Saturn I will be delivered in late 1968. The delivery of the first follow-on CSM is planned late in 1969. The first follow-on Saturn V will be delivered in mid-1970.

Modification

Apollo Applications missions require a growth in the orbital stay-time capability of the spacecraft.

Fiscal year 1968 funds will provide for the continuation of the design and development efforts, begun in FY 1966 and FY 1967, required to furnish modified Apollo spacecraft systems for the planned missions. Apollo spacecraft systems, including the electrical power, life support and environmental control systems, are currently being subjected to extensive tests to determine their ability to operate in the environments and for the durations proposed for the Apollo Applications missions. To minimize the cost of this phase of the program, the plan is to incorporate only those changes required by the planned missions.

A longer duration electrical power system, consisting of the present Apollo fuel cells with upgraded components and increased cryogenic fuel storage and an off-the-shelf solar cell power subsystem, will be provided for support of spacecraft stored in orbit and for long-term experiment support.

A two-gas (oxygen/nitrogen) atmosphere life support and environmental control system, a modification of the Apollo system, is also planned. Effort will include development of nitrogen storage tanks, partial pressure atmosphere sensors, and controls, and the integration of associated hardware in the spacecraft.

Fiscal year 1968 funding includes the initiation of development of a land landing capability for the command module. The initial flight is planned for 1970. Land landing will allow elimination of water landing as the primary recovery mode, thereby providing greater operating flexibility, allowing refurbishment and re-use of command modules, and reducing recovery and new procurement costs. The changes to the spacecraft that permit incorporation of the land landing capability will also allow the interior of the command module to be rearranged to accommodate up to three additional astronauts for short duration ferry and resupply missions.

Limited development of a lunar module (LM) shelter/taxi to extend lunar surface exploration time beyond that planned for the Apollo program will commence in FY 1968. The LM shelter, carrying scientific exploration equipment such as a lunar mobility vehicle and drill, is intended to be landed unmanned on the lunar surface where it will remain quiescent. The manned LM taxi, launched up to three months later, will land near the LM shelter. This shelter/taxi combination and its equipment will be used as a base for lunar exploration for periods of up to two weeks.

Experiments

	1966	1967	1968
Definition.....	$34,447,000	$12,000,000	$33,700,000
Development.....	5,900,000	23,600,000	107,000,000
Total.....	$40,347,000	$35,600,000	$140,700,000

Apollo Applications experiments cover a wide range of objectives in the fields of space medicine, science, applications, technology, and engineering. The definition and development of experiment payloads to meet these objectives will include activity by elements of NASA, other government agencies and the scientific and industrial communities.

Effort in FY 1966 and FY 1967 was primarily confined to definition of experiments and experiment hardware for use in the early Apollo Applications missions. Included in these efforts were studies which led to the Apollo telescope mount (ATM) and the spent-stage S-IVB orbital workshop, now under development.

The FY 1968 effort will continue the development of the Apollo telescope mount and the orbital workshop and will define and develop other experiment payloads for follow-on Apollo Applications missions. The following description highlights the scientific and technical areas in which effort is planned in FY 1968.

The Apollo telescope mount provides a new capability for a variety of solar and stellar scientific experiments to be performed above the earth's atmosphere, where the sun and stars can be clearly observed without being obscured by the earth's atmosphere. For the first time, film can be returned from a space astronomy mission, and the role of the astronaut in astronomical observations can be evaluated. The ATM provides a stabilized platform which will be carried on Apollo Applications missions to accommodate instruments requiring finely controlled pointing. The ATM will be mounted in a structural rack attached to a lunar module ascent stage.

Five experiments using 13 separate instruments to obtain solar data during the period of maximum solar activity have been selected for development for the initial ATM mission. These experiments are: Intensity of solar flares; ultraviolet spectrometer; X-ray telescope; solar atmosphere photography; and white light coronagraph.

The orbital workshop permits astronauts to work and perform experiments in the empty hydrogen tank of a spent second stage of the Uprated Saturn I. A 65-inch diameter airlock and docking adapter provides the connection between the Apollo spacecraft and the spent stage. A hatch in the airlock permits the astronauts to go into space without depressurization of the workshop or the spacecraft. In orbital flight, the command and service

module docks with the airlock and the crew activates systems to pressurize the workshop for habitation. The experiment equipment for use in the workshop is stored elsewhere and carried into the workshop for operation.

An extensive list of experiments is planned for operation within the orbital workshop. Some are directed at evaluating the habitability of the workshop for long duration flight, the work capability and mobility of astronauts in zero-g, and the effect of long duration zero-g on man. Others are directed at engineering and technology experiments which utilize the large enclosed volume of the workshop.

Medical experiments during 1968 and 1969 will concentrate on the biomedical effects of long duration flight on men. A biomedical laboratory is planned for flight in 1970. This laboratory will consist of an Apollo spacecraft module equipped with biomedical and behavioral apparatus to test and record human responses during long duration space flights, to various stresses such as: physical exercise, variable gravity, and the performance of complex tasks.

Bioscience and biotechnology laboratories are planned to extend earlier investigations on various life forms ranging from simple cells to primates. In these laboratories, greater stresses can be applied to specimens than are normally planned for human subjects, and the results will benefit both the bioscience community and manned space flight technology.

The extended lunar exploration missions planned for Apollo Applications include both orbital mapping missions and extended lunar surface exploration. The objective is to extend knowledge of the moon beyond that achieved in the earlier Ranger, Surveyor, Lunar Orbiter missions, and Apollo missions, and to provide the basis for the decisions on the establishment of semi-permanent or extensive research facilities or manned stations on the moon.

The lunar orbital missions are planned to acquire high quality mapping and survey photography from polar or near-polar lunar orbits. This will allow the detailed study of the geological features of the total lunar surface. Lunar surface missions are planned to provide up to two weeks stay-time at selected lunar sites for extensive geological, geophysical and biological exploration. Equipments planned for these missions include small vehicles to perform traverses at moderate distances from the landed spacecraft; drills for subsurface sampling and vertical profile measurements; and deployed instrumentation for acquiring geophysical data to be transmitted back to earth by radio frequency link for up to a year after departure of the astronauts. One extended lunar surface mission per year is planned, beginning in 1971.

Applications experiments are planned to develop techniques for, and to measure the effectiveness of, man's participation in such fields as orbital meteorology, communications, and remote sensing of earth resources. Low-altitude orbits at medium and high inclinations have been studied for meteorology and natural resources missions during 1969 and 1970. An initial synchronous orbit mission is planned to test man and spacecraft operation in that operational mode. Also planned is a test of operational techniques for communicating between the low altitude manned spacecraft, synchronous spacecraft, and ground control stations. Later synchronous orbit missions are under study for continued operational use, as well as for experiments in astronomy, space physics, meteorology and advanced communications techniques.

Technology and engineering experiments planned for Apollo Applications missions are focused generally toward the development of equipment and techniques which are fundamental to the accomplishment of the next generation of space flight missions. During 1968 and 1969, emphasis will be placed on conducting related experiments in and with the orbital workshop. Resupply and crew transfer flights are planned to extend mission duration, rotate crews, and to test orbital rescue operations. Orbital assembly of complex structures and in-flight maintenance of vehicles and experiment apparatus are also planned.

Mission Support

	1966	1967	1968
Payload integration.....	$100,000	$4,400,000	$40,000,000
Operations.....	2,300,000	1,400,000	10,300,000
Total.....	$2,400,000	$5,800,000	$50,300,000

Payload integration includes the system analysis and development effort required to assemble experiments into mission compatible payloads, and the effort required to physically install and qualify them for flight readiness. This activity includes definition, design and development, modification, and installation. The definition phase of payload integration was initiated during FY 1966 and will be essentially completed by the end of FY 1967. Design and development includes control documentation, interface, qualification and acceptance test specifications, and testing plans. Modification and installation provide for changes to space vehicles and experiment carriers to accommodate experiments and physical installation of experiments into applicable carriers. The FY 1968 effort will provide for the analyses of payloads to determine detailed payload integration requirements and the implementation of design and development activities for the initial Apollo Applications flights.

Operations include efforts at the Kennedy Space Center and the Manned Spacecraft Center that are directly concerned with launch, flight crew and recovery activity. Basic support is provided in the Apollo program for those missions currently scheduled as alternate Apollo Applications flights. In FY 1967 operations efforts are related to accomplishing definition of Apollo Applications requirements peculiar to launch, mission planning and mission control. FY 1968 funding will also provide for initiation of operations support for missions including the augmentation of the mission control center located at the Manned Spacecraft Center required to support the increased data demands resulting from the enlarged experiment and operational activity associated with the Apollo Applications program.

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RESEARCH AND DEVELOPMENT

FISCAL YEAR 1968 ESTIMATES

OFFICE OF MANNED SPACE FLIGHT — ADVANCED MISSIONS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

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

SUMMARY OF RESOURCES REQUIREMENTS:

	1966	1967	1968
Advanced missions studies.....	$10,000,000	$6,200,000	$8,000,000
Distribution of Program Amount by Installation:			
John F. Kennedy Space Center, NASA.....	500,000	350,000	400,000
Manned Spacecraft Center.....	1,900,000	3,250,000	3,400,000
Marshall Space Flight Center.	5,695,000	2,600,000	3,100,000
Langley Research Center.....	550,000	---	---
NASA Headquarters.....	1,255,000	---	1,100,000
Western Support Office.....	100,000	---	---

BASIS OF FUND REQUIREMENTS:

Advanced Missions Studies

	1966	1967	1968
Advanced studies.....	$10,000,000	$6,200,000	$8,000,000

Advanced studies provide a firm foundation for planning and selecting future manned space flight missions. Specific areas of investigation include manned earth orbital, lunar, and planetary missions and launch vehicles. Fiscal year 1966 and 1967 studies provided support for the evolving Apollo Applications program, including both the definition of experiments and other mission payloads and the cost-effectiveness examination of alternate flight equipment approaches. The FY 1966 and 1967 studies also examined the feasibility of a long duration space station module.

In addition to the varied potential applications for earth orbital missions, the space station study includes analysis to identify design features common to manned planetary flight requirements.

Earth Orbital Studies

During FY 1967, advanced studies in the earth orbital area emphasize alternate steps to the Apollo Applications program, including a one-year earth orbital workshop which could evolve into a continuous-operation space station. Alternative approaches for an eventual one-year workshop included module configurations utilizing the third-stage structure of the Saturn V; a Saturn V-launched module containing all expendables for a one-year duration; and a system based on a flexible subsystem module. In addition, the studies are defining rescue concepts and space station re-supply and logistic systems. Efforts are continuing on the selection and definition of candidate experiments for advanced missions. This selection considers the constraints placed on the space station and logistic system by the experiments. The potential economic benefits that can be derived from space station operations are also being assessed. Based on the results of the conceptual studies, a preliminary definition of a one-year workshop module will be initiated, together with the preliminary definition of a modular spacecraft capable of supporting earth resources experiments and astronomy activities. The FY 1968 studies will concentrate on the definition of a space station which will furnish the basis for conducting a large variety of earth applications, astronomy, biology and research as well as interplanetary exploration.

Planetary Mission Studies

Manned planetary mission studies have examined a number of mission modes and systems concepts for manned Mars and Venus reconnaissance, sample retrieval from Mars, and ultimately, for Mars landing missions. Studies identified the practicability of using Apollo space vehicle hardware for sample retrieval or reconnaissance missions, and developed spacecraft concepts for ultimate manned Mars landing missions.

The FY 1968 study program will emphasize further definition of the technology requirements and concepts for a Mars sample retrieval mission. This manned mission would have the unique capability of returning to earth samples of the Mars surface and atmosphere for scientific analysis by means of an unmanned sample return probe targeted, launched, and retrieved by the manned spacecraft. Additional orbiting and landing probes could be launched for obtaining more definitive scientific data on the Mars environment. The studies will include preliminary definition of the mission spacecraft, associated propulsion stages and onboard experiments that might be conducted by the crew members during the mission. The studies will define the total system for Mars sample retrieval in enough depth to permit definitive planning of the funding requirements, of the technological development program required to support this mission, and of the total program support required within NASA.

Lunar Mission Studies

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

Studies in FY 1968 will provide for updating the current plan for lunar exploration to develop the accompanying conceptual designs. This exploration plan will review the basis for a continuing series of manned and unmanned missions. Studies will define various alternatives for improving and extending the capabilities of Apollo-type systems for extended mobility. Future direct flight systems which can meet extended lunar exploration requirements will also be studied.

Launch Vehicle Studies

Launch vehicle studies to support earth orbital, planetary and lunar manned missions will be continued during FY 1968. These studies will stress preliminary definition of improved Saturn vehicles. Efforts will continue on reusable re-entry spacecraft. The related facilities and support requirements will also be studied.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1968 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS — PHYSICS AND ASTRONOMY PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

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

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

SUMMARY OF RESOURCES REQUIREMENTS:

	1966	1967	1968
Supporting research and technology/Advanced studies	$20,594,000	$19,900,000	$19,900,000
Solar observatories.....	19,052,000	9,800,000	11,900,000
Astronomical observatories...	22,300,000	27,700,000	40,600,000
Geophysical observatories....	28,215,000	24,000,000	20,000,000
Pioneer.....	12,700,000	7,200,000	7,500,000
Explorers.....	18,592,000	19,200,000	21,600,000
Sounding rockets.....	19,300,000	20,000,000	22,000,000
Sunblazer.....	---	---	2,000,000
Data analysis.....	2,000,000	2,000,000	2,000,000
Total.....	$142,753,000	$129,800,000	$147,500,000

Distribution of Program Amount by Installation:

	1966	1967	1968
Marshall Space Flight Center....	$25,000	$125,000	$100,000
Goddard Space Flight Center.....	100,753,000	95,061,000	108,911,000
Jet Propulsion Laboratory.....	759,000	338,000	300,000
Wallops Station.....	1,610,000	996,000	1,800,000
Ames Research Center.....	15,219,000	10,502,000	10,100,000
Electronics Research Center.....	---	60,000	75,000
Flight Research Center.....	5,000	10,000	25,000
Langley Research Center.....	1,869,000	1,230,000	3,139,000
NASA Headquarters.....	22,513,000	21,478,000	23,050,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology/Advanced Studies

	1966	1967	1968
Particles and fields.....	$6,305,000	$6,400,000	$6,400,000
Ionospheres and radio physics...	994,000	1,100,000	1,100,000
Interplanetary dust and cometary physics.....	1,423,000	1,300,000	1,300,000
Solar physics.....	3,518,000	3,500,000	3,500,000
Astronomy.....	3,686,000	3,700,000	3,700,000
Spacecraft technology.....	848,000	490,000	500,000
Interdisciplinary space science.	3,211,000	2,910,000	2,900,000
Advanced studies.....	609,000	500,000	500,000
Total.....	$20,594,000	$19,900,000	$19,900,000

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

Particles and Fields

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

Ionospheres and Radio Physics

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

Interplanetary Dust and Cometary Physics

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

Solar Physics

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

Astronomy

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

Spacecraft Technology

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

Interdisciplinary Space Science

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

Advanced Studies

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

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

Interplanetary mission studies include the development of a concept and preliminary design of a Galactic-Jupiter Probe of the Pioneer class spacecraft. It would be capable of extending interplanetary exploration through the asteroid belt and the space environment near the planet Jupiter and beyond. Also included are studies leading to the development of small probes capable of transmitting signals and a limited amount of data back to earth from distances as close as 0.4 AU to the sun. Studies of scientific payloads for these small probes include solar corona studies, interplanetary plasma studies, and comet simulation studies.

Solar Observatories

	1966	1967	1968
Orbiting Solar Observatory (OSO):			
Spacecraft	$6,584,000	$6,963,000	$7,904,000
Experiments	3,104,000	2,837,000	3,996,000
Subtotal OSO	$9,688,000	$9,800,000	$11,900,000
Advanced Orbiting Solar Observatory (AOSO):			
Spacecraft	$8,114,000	---	---
Experiments	978,000	---	---
Ground operations	272,000	---	---
Subtotal AOSO	$9,364,000	---	---
Total OSO and AOSO	$19,052,000	$9,800,000	$11,900,000
Delta (Launch Vehicle Procurement Program)	(1,000,000)	(2,000,000)	(4,200,000)
Total (including Launch Vehicles)	($20,052,000)	($11,800,000)	($16,100,000)

The objective of the Solar Observatory program is to advance the study of solar physics by orbiting a spacecraft above the earth's atmosphere to permit observations of portions of the electromagnetic spectrum which are normally absorbed in the atmosphere. The solar observatories are designed to provide a thorough investigation of the sun, especially of both rapid and long-term changes in solar radiation during a complete solar cycle; and to probe the underlying causes of these changes by observations of the regions of activity on the solar surface. The Orbiting Solar Observatories (OSO) have operated

during a period of decreasing solar activity with the flight of OSO-I and OSO-II in 1962 and 1965, respectively. Continuous program effort will be pursued with OSO through the period of increasing and maximum solar activity to 1970. Orbiting Solar Observatories are stabilized satellites capable of pointing scientific instrumentation with an accuracy of greater than one arc minute at the center of the solar disc in order to study solar ultraviolet radiation, gamma rays, and X-rays. Five additional OSO's are scheduled to be launched between 1967 and 1970 to provide continuous coverage of solar phenomena as the sun reaches the period of maximum activity. The first solar observatory, OSO-I, launched on March 7, 1962, provided over 2,000 hours of observation of the solar spectrum in the UV, gamma and X-ray regions. OSO-II was successfully launched on February 3, 1965. All of its spacecraft systems operated at or above their design goals, and the spacecraft was commanded off after more than nine months and 4,100 orbits of near perfect operation. Seven months later the spacecraft was successfully turned on and operated until the stabilization gas supply was exhausted. Eight of the nine experiments on board OSO-II returned data during the lifetime of the observatory. Preliminary analyses of these data have been made and further analysis is being accomplished. OSO-C, the third solar observatory, was launched August 25, 1965. However, a malfunction in the third stage of the Delta launch vehicle prevented the booster from placing the observatory in orbit. Using spare OSO-C experiments and a spacecraft under construction for a later flight, a replacement observatory was built and launch of the mission is scheduled for early 1967. Experiment selection for the five OSO missions scheduled for flight up to 1970 has been completed; and development of the instrumentation is underway. Planning is underway for experiments for possible missions beyond these five.

Project management responsibility for the OSO has been assigned to the Goddard Space Flight Center. The spacecraft are being procured through contracts with the Ball Brothers Research Corporation of Boulder, Colorado. FY 1966 funds provided for continuing the work on the fourth and fifth observatories and for initiation of work on the three follow-on spacecraft and experimental packages. FY 1967 funds provided for completion of data analysis on OSO-II; completion of work, launch, and initial data analysis on the fourth and fifth observatories; and for continuing the hardware effort on the follow-on OSO's. FY 1968 funds will provide for completion and launch of the sixth observatory; for continuing work on the two follow-on spacecraft and experimental packages; and for data analysis on the fourth, fifth, and sixth observatories. FY 1965 and prior funding for the OSO project, including launch vehicles, was $48,187,000. FY 1969 and later funding required to complete an eight flight program, including launch vehicles, is estimated at $17,400,000.

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Astronomical Observatories

	1966	1967	1968
Spacecraft and support.....	$16,366,000	$23,239,000	$36,208,000
Experiments.....	5,934,000	4,461,000	4,392,000
Total Spacecraft and Support..	$22,300,000	$27,700,000	$40,600,000
Atlas-Agena (Launch Vehicle Procurement Program).....	(8,500,000)	(5,400,000)	---
Centaur (Launch Vehicle Procurement Program).....	---	(6,617,000)	(10,000,000)
Total (including Launch Vehicles).....	($30,800,000)	($39,717,000)	($50,600,000)

The Orbiting Astronomical Observatory (OAO) program will provide a capability for obtaining fundamental astronomical information outside the narrow boundaries of the visible portion of the electromagnetic spectrum where earth-based optical telescopes studies are constrained. High resolution observations made in space by OAO of our solar system, our galaxy, and the universe as a whole, using infrared, ultraviolet, X-ray, and gamma ray spectral regions, can greatly enhance our understanding of the origin, evolution, present condition, and future life of the solar system, the galaxy, and the universe. The OAO is a stabilized spacecraft that can be precisely pointed to any object in the celestial sphere for long observational times. It can carry telescopic instruments up to about three feet in diameter by 10 feet in length and weighing over 1,000 pounds.

In addition to the fine pointing stabilization and control system, the spacecraft includes power, thermal control, and communication and data handling subsystems. Extensive ground facilities are provided for orbital operations. The OAO missions currently scheduled will carry instruments of increasing capability to investigate the ultraviolet spectrum of celestial bodies starting with exploratory sky mapping surveys using low resolution instruments and progressing to larger aperture instruments with higher resolution capable of viewing faint celestial objects.

The first OAO (OAO-I) was launched as scheduled on April 8, 1966, and was placed in a nearly perfect orbit by an Atlas-Agena vehicle. However, technical problems associated with the power system adversely affected the mission and the spacecraft operation ceased on April 10, 1966, after the twentieth orbit. During the spacecraft life, successful spacecraft operations were performed in several complex areas. No data were obtained from either the University of Wisconsin experiment or the X-ray and gamma ray instruments developed by Lockheed Missiles and Space Company, the Goddard Space Flight Center, and the Massachusetts Institute of Technology. Thorough analysis and review of the OAO-I operation identified problem areas and has resulted in a detailed plan for design modification, additional testing

(including the re-establishment of a Prototype Observatory for qualification tests) and improved operation which will assure success for the follow-on OAO missions. In order to proceed logically to the missions with increased stabilization and control requirements, the mission sequence has been changed as follows:

		Flight Sequence	
Mission	Pointing Accuracy	Previous Plan	Current Plan
OAO-I	±1 arc. min.	First	Launched
OAO-A_2	±1 arc. min.	Third	Second
OAO-B	±2 arc. sec.	Second	Third
OAO-C	±0.1 arc. sec.	Fourth	Fourth

The Prototype Observatory for qualification testing of all flight missions will be reinstated as recommended during the review of the OAO-I failure. This will be accomplished by utilizing a flight model structure and other available hardware. Use of an available flight structure is required since the original prototype spacecraft was assigned to the OAO-A_2 flight in 1965 upon completion of the scheduled qualification test sequence and cannot be returned to the prototype configuration at this time and still meet the schedule goal.

The second OAO (OAO-A_2), to be launched in 1968, will consist of the original prototype spacecraft refurbished to carry the Smithsonian Astrophysical Observatory and the University of Wisconsin experiment. The Smithsonian experiment utilizes four telescopes with imaging photometers to map the sky in the ultraviolet portion of the spectrum. The Wisconsin experiment equipment will be identical to the equipment flown on OAO-I.

The third OAO (OAO-B), scheduled for a 1968 flight, will carry the Goddard Space Flight Center 36-inch aperture telescope. This telescope is designed to obtain spectrophotometric data on stars, nebulae, and galaxies in the ultraviolet spectral region with a capability of resolution up to two angstroms.

The fourth OAO (OAO-C), to be launched in 1970, which will require fabrication of a new structure since one of the flight structures was assigned to the prototype model, will fly the Princeton University 32-inch aperture reflecting telescope with a grating spectrograph to study the composition of interstellar material and to obtain high dispersion ultraviolet spectra of stars with a resolution up to 0.1 angstrom. This observatory will also carry telescopes developed by the University College, London, England, in conjunction with the University of Leicester to study the X-ray emission of stars and nebulae.

Management responsibility for the OAO project has been assigned to the Goddard Space Flight Center. The spacecraft are being developed under prime contracts with the Grumman Aircraft Engineering Corporation. Integration of experiments into the spacecraft, environmental tests of the observatories, and in-orbit operation will be accomplished at Goddard.

Development of the OAO was initiated in 1960. Funding prior to FY 1966 provided for the design and development of the basic spacecraft; fabrication and testing of a prototype; fabrication, integration and test efforts on two flight spacecraft; and development, fabrication, and initiation of tests of experiments for four flight missions.

In FY 1966, the first OAO flight (OAO-A1) was launched. The refurbishment of the original prototype observatory was started in FY 1966 to provide another flight opportunity (OAO-A2). Development and test of the Smithsonian experiment assigned to the OAO-A2 continued and work was initiated to provide a second Wisconsin experiment for this mission. Also, FY 1966 funds provided for the continuation of fabrication and test of the OAO-B spacecraft and for the manufacture of components for the OAO-C spacecraft, as well as continued support for manufacture of experiments for these latter two missions.

Fiscal year 1967 funds provided for the completion of the analysis of the OAO-I operation, thus determining the improvements for the follow-on OAO missions. Remaining effort in FY 1967 will be concentrated on revising the OAO-A2 spacecraft in preparation for delivery in FY 1968. The prototype of the OAO-A2 spacecraft has been delivered to Goddard for training personnel in test and flight operation procedures and for electromagnetic compatibility tests. The instruments for the Smithsonian and Wisconsin flight experiments were completed and acceptance tests performed. To accomplish the program within the funding limitations, work at the prime contractors on the OAO-B and OAO-C spacecraft was essentially stopped for the later part of FY 1967. In addition, Princeton was directed to continue the development of the prototype experiment hardware for OAO-C, but essentially to stop work on the flight experiment.

Fiscal year 1968 funds will provide for integration of the experiments and observatory tests for the prototype and the OAO-A2 mission as well as for initiation of launch preparations for the OAO-A2 flight. Development, fabrication, and test of the OAO-B and OAO-C spacecraft will be reactivated as well as construction of the flight hardware for the Princeton experiment on OAO-C. Acceptance tests of the OAO-B experiment will be accomplished in FY 1968.

Fiscal year 1965 and prior funding, including launch vehicles, was $169,648,000. FY 1969 and later funding required to complete four missions is estimated to be $55,701,000 including launch vehicles.

Geophysical Observatories

	1966	1967	1968
Spacecraft.....	$12,593,000	$16,434,000	$12,839,000
Experiments.....	15,622,000	7,566,000	7,161,000
Total Spacecraft and Support..	$28,215,000	$24,000,000	$20,000,000
Thor-Agena (Launch Vehicle Procurement Program).....	(2,600,000)	(1,400,000)	(5,500,000)
Atlas-Agena (Launch Vehicle Procurement Program).....	(5,500,000)	(4,400,000)	(900,000)
Total (including Launch Vehicles).....	($36,315,000)	($29,800,000)	($26,400,000)

The Orbiting Geophysical Observatory (OGO) program has as a prime objective the accomplishment of a series of scientific measurements to correlate the geophysical phenomena occurring in the near-earth environment with the effluent activity of the sun and with phenomena in interplanetary space. Early satellite measurements of the near-earth environment indicated its general nature. As knowledge of this region has progressed, the picture that unfolds is one of dynamic environment with a fine structure of electromagnetic fields and particles which is strongly dependent on events and processes occurring at other locations. Correlated interdisciplinary measurements obtained aboard a single satellite and by several satellites at different spatial locations are required to better understand the near-earth environment. Successful accomplishment of the OGO program will undoubtedly contribute substantially to this understanding and thus to evaluation of the hazards of manned space travel.

Support of these scientific objectives requires the development of spacecraft capabilities to accommodate the many diversified instruments used for the correlative studies. In essence, this requirement establishes the need for a laboratory-like satellite in which viewing direction, electric power, thermal control, and data handling systems are shared by many experimenters.

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

OGO missions were launched into the highly elliptical orbit in September 1964 (OGO-I) and June 1966 (OGO-III) and into the low altitude, nearly-polar orbit in October 1965 (OGO-II). The OGO-III mission was the first to achieve extended operation in three-axis stabilization as planned. After forty-six days, the failure of an electronic component disabled portions of the attitude control system. Therefore, the spacecraft was commanded to the secondary mode of stabilization, spin-stabilization. All three OGO missions are still operational in the spin-stabilized mode and forty-seven of the total

of sixty-one experiments assigned to the three missions are providing useful data. From September 1964 (coinciding with the period of minimum solar activity) to the current period of increased solar activity, over 300,000 hours of experiment data have been acquired, much at the high data rates important for detailed time resolution of rapid fluctuations. Seventy-four reports and presentations have been made by the OGO experimenters. The more significant results relate to geomagnetic control of the ionosphere, the first global magnetic survey in space, magnetic field and particle fluctuations, and the propagation of very low frequency (VLF) noise.

The next mission will be OGO-D which is in the final phase of environmental testing. OGO-D carries essentially the same complement of instruments as OGO-II and will be placed into a similar low altitude polar orbit during the second quarter of 1967.

The fifth (OGO-E) and sixth (OGO-F) are scheduled for launch in 1968 and 1969, respectively. The OGO-E is in the first stages of integration and will carry a new complement of experiments into a highly elliptical orbit similar to OGO-I. The OGO-F mission will be placed in a polar orbit during solar maximum. Modification of spacecraft hardware and fabrication of experiment hardware for this mission are in progress. Activity directed toward possible missions beyond OGO-F during the scientifically important period of maximum solar activity is currently being held to the planning level only.

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

Funding prior to FY 1967 provided for design and development of the basic spacecraft, including design modifications required following OGO-I in-orbit operations; the preparation and launch of the first three missions; fabrication and integration of spacecraft for the OGO-D and OGO-E missions; development and fabrication of experiment instrumentation for the first four missions; initiation of experiment development for the OGO-E mission; and support of data analysis for the first two missions.

Fiscal year 1967 funds provided for continuation of preparations for the OGO-D and OGO-E missions, including the incorporation of several technical modifications; completion of experiment instrumentation fabrication for OGO-E; initiation of experiment hardware development for the OGO-F; and continued data analysis support for the three operational missions.

Funds in FY 1968 provide for completion and launch of OGO-E and integration and test of OGO-F. They will also provide for completion of first run data analyses for OGO-I and II; continuation of data analysis for OGO-III; initiation of data analysis for OGO-D and E; and completion of OGO-F experiment hardware fabrication.

Fiscal year 1965 and prior year funding for OGO was $157,628,000, including launch vehicles. FY 1969 and subsequent funding needed to complete six missions is estimated to be $15,985,000, including launch vehicles.

Pioneer

	1966	1967	1968
Spacecraft.....	$6,973,000	$1,698,000	$3,332,000
Experiments.....	4,779,000	4,673,000	2,948,000
Ground operations.....	948,000	829,000	1,220,000
Total Spacecraft and Support..	$12,700,000	$7,200,000	$7,500,000
Delta (Launch Vehicle Procurement Program).....	(3,999,000)	(1,217,000)	(2,000,000)
Total (including Launch Vehicles).....	($16,699,000)	($8,417,000)	($9,500,000)

The objectives of the Pioneer program are to investigate the interplanetary environment and the propagation of solar and galactic phenomena through this medium. Correlation with similar measurements made near the earth by satellites are required to attain the full objective.

The current series of Pioneers weigh about 140 pounds and are launched with the Thrust-Augmented Improved Delta (TAID). The first of these, Pioneer VI, was launched successfully in December 1965 and continues in operation. Pioneer VII was launched in August 1966 and also is operating successfully. Three additional Pioneer spacecraft are scheduled for missions approaching as close to the sun as 0.8 AU and going away as far as 1.2 AU. (1 AU is equal to the mean earth-to-sun distance, 92,900,000 miles). Planning is underway for experiments for possible follow-on missions.

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

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

Funds in FY 1966 provided for testing, launch and post-launch operations for Pioneer VI, and the assembly and testing of Pioneer VII. Funds for FY 1967 cover the launch of Pioneer VII and post-launch operations for VI and VII, and the initiation of the subsystems for the third, fourth and fifth

spacecraft. Funds requested for FY 1968 will continue to support the post-launch operations for Pioneer VI and VII, final testing and launch of the third spacecraft, and initial integration and testing for the fourth spacecraft.

Funding for FY 1965 and prior, including launch vehicles, amounted to $40,175,000. FY 1969 and later funding required to complete the first five flight programs, including launch vehicles, is estimated at $9,368,000

Explorers

	1966	1967	1968
Geophysical and interplanetary explorers.....	$13,843,000	$13,050,000	$14,762,000
Astronomy explorers.....	4,749,000	6,150,000	6,838,000
Total Explorers.....	$18,592,000	$19,200,000	$21,600,000
Scout (Launch Vehicle Procurement Program).....	(6,300,000)	(4,300,000)	(4,600,000)
Delta (Launch Vehicle Procurement Program).....	(4,817,000)	(13,683,000)	(12,900,000)
Thor-Agena (Launch Vehicle Procurement Program).....	(1,100,000)	(200,000)	---
Total (including Launch Vehicles).....	($30,809,000)	($37,383,000)	($39,100,000)

The Explorer satellites are the smallest of the NASA's scientific spacecraft and are launched on Scout, Delta and Thor-Agena vehicles.

The Explorers are specifically designed and instrumented to provide for specialized scientific investigations and are flown in orbits especially selected for these investigations. The Explorer spacecraft and their experiments are developed by NASA centers, universities, industry and cooperating foreign countries, and are used for investigations of the earth's environment, solar-terrestrial relationships, solar-interplanetary relationships, and for astronomical observations.

A substantial portion of the scientific data obtained and many new discoveries are attributable to instruments carried in Explorer spacecraft. Thirty-three U.S. and five international cooperative Explorer missions have been successfully accomplished since the founding of NASA through 1965.

These missions have provided substantial portions of our present knowledge about the earth's environment, including the ionosphere, the atmosphere, micrometeoroid environment, the radiation belts, the earth's magnetic

field and some of the principal effects of solar radiation on the atmosphere. As a result of these efforts and other related investigations, the picture of the interactions between solar activity, the interplanetary medium, and the immediate environment of the earth is becoming clearer.

During 1967, it is planned to launch four U.S. Explorers; IMP-E and F, RAE-A and NRL Solar Explorer-B; and four cooperative international explorers; UK-E, San Marco-B and ESRO I and II. These spacecraft will provide investigations of many of the space science disciplines during the period of high solar activity.

Some increase in emphasis during FY 1967 is being given to Astronomy Explorers with continued development of the Radio Astronomy Explorer (RAE) and the initiation of Scout-size X-ray Astronomy Explorer and Solar Radio Explorer. Development of Geophysical and Interplanetary Explorers is being continued. Two IMP spacecraft are scheduled for 1967 and one per year thru the 1968-1971 time period is planned for a variety of orbits. A Scout launch vehicle is also being provided for the launch of a Solar Explorer developed by the Naval Research Laboratory.

The FY 1968 funds provide for an essential level of effort program with initiation of follow-on missions emphasizing radio and X-ray astronomy.

Sounding Rockets

	1966	1967	1968
Experiments.....	$7,318,000	$6,699,000	$7,891,000
Rocket development.....	808,000	1,375,000	1,669,000
Attitude control systems.....	3,553,000	3,962,000	3,648,000
Engineering support.....	588,000	440,000	640,000
Test and evaluation.....	245,000	275,000	325,000
Ground instrumentation.....	2,843,000	3,178,000	3,581,000
Rocket procurement.....	3,945,000	4,071,000	4,246,000
Total.....	$19,300,000	$20,000,000	$22,000,000

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

Sounding rockets have been used to measure atmospheric density and temperature; to analyze the various gases present in the upper atmosphere, and responses of the atmosphere to varying solar activity. Chemicals released

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

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

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

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

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

Ninety-nine highly successful major sounding rockets of the Nike Cajun/Apache/Tomahawk, Aerobee and Javelin types, and nine of the Arcas type were launched during 1966 from sites in the United States, Canada, Brazil, India, and Norway. These include seven Arcas rockets launched from a ship into a solar eclipse near Koroni, Greece, as part of a cooperative USA/Greece expedition in May and five Nike-Apaches launched into a solar eclipse from the beach at Cassino, Brazil, as part of a NASA/DASA/AEC-Brazil cooperative expedition in November. These flights also include the successful flight in August of the new Aerobee 350 which has been developed in-house by Goddard to lift large payloads (100-500 lbs.) to high altitudes (200-500 miles) as well as the first two successful flights of the Stellar Tracking and Positioning Control System (STRAP), developed by Goddard to point rocket payloads with a spatial resolution of 10-20 arc. sec. Two flights conducted in September as part of a cooperative U.S./Germany program were successful barrium release experiments which allow visual observation of the earth's magnetic field. An Aerobee flight in April resulted in the discovery of a new X-ray source "star."

Sounding rocket projects are planned to be continued in FY 1967 and FY 1968 in many areas where experimentation has begun, including atmospheric and ionospheric measurements, cosmic dust collections, chemical releases in the upper atmosphere; and X-ray, ultraviolet, and infrared observations of celestial sources and the sun. Increases in the program for FY 1967 and FY 1968 are largely due to the development and increased use of improved attitude control systems and to an increased use of the larger, more expensive vehicles to carry stabilized payloads, as well as heavier payloads, with several instruments for a number of simultaneous measurements.

Sunblazer

	1966	1967	1968
Spacecraft.....	---	---	$1,200,000
Experiments.....	---	---	800,000
Total Spacecraft and Support..	---	---	$2,000,000
Scout (Launch Vehicle Procurement Program).....	---	---	($1,500,000)
Total (including Launch Vehicles).....	---	---	($3,500,000)

Sunblazer, the small interplanetary probe program, has as its objective the study of the solar corona by a propagation experiment, magnetic field mapping and the observations of solar particle fluxes. The Sunblazer program will place small, relatively inexpensive, scientific spacecraft into heliocentric orbits. These small sun-oriented or spin-stabilized spacecraft will weigh 15 to 60 pounds and will be placed around the sun into orbits lying between earth distance and 0.4 earth distance from the sun by a 5-stage Scout or equivalent launch vehicle. The initial missions are to measure the electron density and other features of the solar corona by use of a radio propagation method based on the observation of multi-frequency transmissions. The satellite will achieve superior conjunction, the point directly opposite the sun from the earth, in approximately one and one-half years. The use of both light weight spacecraft and low cost solid propellant launch vehicles make it economically attractive to launch several spacecraft per year so that systematic measurements of the corona and electron density profile, which is known to fluctuate markedly with solar activity, can be made.

FY 1968 funds will initiate the procurement of components, fabrication and assembly, integration, test and preparation for launch of an engineering model of the spacecraft on the first test shot of the 5-stage Scout launch vehicle. Experiment funding will allow for the pre-launch formating and programming of the propagation experiment. Other funds are required for spacecraft launch support and post-launch analysis. FY 1969 and later funding required to fund the first five missions, including launch vehicles, is estimated at $13,500,000.

Data Analysis

	1966	1967	1968
Operation of the data center....	$300,000	$500,000	$700,000
Research tasks.....	1,700,000	1,500,000	1,300,000
Total.....	$2,000,000	$2,000,000	$2,000,000

A National Space Science Data Center has been established at the Goddard Space Flight Center to provide for the collection, cataloging, storage and dissemination of data obtained from space sciences flight experiments. Data collected will be made available at a cost commensurate with reproduction and distribution to those interested in using the data for further research. To encourage the full use of the data obtained on NASA flight programs, support will be provided for scientific research efforts which make use of the data. Proposals for research are competitively evaluated, and support is provided for those efforts which can be expected to contribute most to the total advancement of knowledge in space science. Fiscal year 1968 funds will provide for operation of the Data Center at a level consistent with the input of data and for support of data analysis efforts.

OFFICE OF SPACE SCIENCE AND APPLICATIONS

LUNAR AND PLANETARY EXPLORATION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

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

The lunar program consists of three types of missions. The first of these, the Ranger program, has now been completed, yielding over 17,000 photographs which have provided a much better understanding of the nature of the surface of the moon. The current series of lunar missions involve a total of seven soft landing Surveyor spacecraft and five orbiting spacecraft which will conduct scientific measurements on the lunar surface and provide detailed high and low resolution photography of the moon. Four of these missions were attempted during 1966 and three were successfully completed. The initial Surveyor spacecraft accomplished the first soft landing on the moon and transmitted over 11,000 high resolution television pictures back to earth. This mission indicated the bearing strength of the surface where it landed to be sufficient for a safe landing. Surveyor II impacted the moon as a result of a vernier engine failure. Lunar Orbiters I and II returned very detailed photographs of candidate Apollo landing sites covering thirty thousand square miles of the lunar surface, including wide angle coverage of twenty-two Apollo sites with high resolution (down to one meter) detail on thirteen of these sites, and photographs of four million square miles of the far side of the moon, which indicates that the surface is much rougher than the side which faces earth. Lunar Orbiters also have obtained data on the micrometeoroid flux and radiation environment near the moon. Analysis of Orbiter tracking data improves our knowledge of the moon's gravitational field. Subsequent Surveyor and Orbiter missions will photograph and examine other potential Apollo landing sites and determine surface and subsurface physical and chemical properties.

The planetary programs have experienced a high degree of success with the Mariner II flyby of Venus and the Mariner IV photographic mission to Mars. These planetary missions have yielded a wealth of scientific information. Mariner II provided new data on the physical characteristics of the atmosphere of Venus. Mariner IV produced the first close up photographs of the surface of Mars and, in addition, performed many important scientific measurements permitting a considerably better understanding of the nature of that planet. The next steps in the evolution of planetary exploration will be Mariner flyby missions to Venus in 1967 and to Mars in 1969 and 1971 respectively, prior to the Voyager orbiting and landing missions to be made beginning in 1973. Present plans call for launching a capsule probe into the Martian atmosphere during the 1971 mission.

SUMMARY OF RESOURCES REQUIREMENTS:

	1966	1967	1968
Supporting research and technology/advanced studies.....	$23,000,000	$20,900,000	$20,900,000
Surveyor.....	104,634,000	84,500,000	42,200,000
Lunar orbiter.....	58,081,000	28,800,000	10,000,000
Mariner.....	17,585,000	35,200,000	68,900,000
Ranger.....	1,000,000	---	---
Total.....	$204,300,000	$169,400,000	$142,000,000

Distribution of Program Amount by Installation:

	1966	1967	1968
Marshall Space Flight Center.	$630,000	$635,000	$400,000
Goddard Space Flight Center..	1,119,000	800,000	1,000,000
Jet Propulsion Laboratory....	131,668,000	129,184,000	120,500,000
Ames Research Center.....	668,000	480,000	500,000
Electronics Research Center..	---	40,000	50,000
Langley Research Center.....	58,842,000	29,425,000	10,500,000
NASA Headquarters.....	11,373,000	8,836,000	9,050,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology/Advanced Studies

	1966	1967	1968
Lunar and planetary science....	$13,495,000	$11,305,000	$12,000,000
Advanced technical development.	7,085,000	7,495,000	6,800,000
Advanced studies.....	2,420,000	2,100,000	2,100,000
Total.....	$23,000,000	$20,900,000	$20,900,000

Supporting Research and Technology and Advanced Studies programs are the research activities which provide the base for defining the scientific objectives of future missions, establish the technological criteria essential to these missions, and supply the scientific and engineering capability for performing flight programs.

The science program consists of activities involving laboratory, astronomical, and theoretical research. It is under this program that new concepts and experiments for scientific investigation of the moon and planets are conceived and developed. These activities also provide scientific data essential to the design and calibration of flight instruments for the analyses of the results of experiments already performed.

Observations of the moon and planets are being carried out with optical and radio instruments to supply data essential for the design of spacecraft and the selection of experiments for lunar and planetary investigation. Research activities concerned with the characteristics, specifically the bearing strength of the lunar and Martian surface, and the nature of the surface environment continue to be the most important problems currently under investigation. More information about the physical nature and the topography of the lunar surface is essential to the safety of manned exploration and for the successful performance of soft landing automated scientific payloads on Mars. The physical characteristics and properties of the Martian atmosphere are of major concern due to observations made in recent years which indicated a lower surface pressure and possibly much higher velocity surface winds than previously accepted. Further studies by astronomical spectroscopic techniques are being conducted this year and will be continued in FY 1968 to provide more precise values of the parameters defining the Martian atmosphere to permit the designs of efficient entry vehicles. Laboratory, theoretical, and observational research under this program are being conducted at NASA centers, other government facilities, universities, and industrial concerns throughout the country.

The Advanced Technical Development program is directed toward developing and improving performance of subsystems, components, and techniques required for the spacecraft to perform future missions to the moon and the planets. Successful completion of these missions requires the development of reliable equipment that will survive the rigors of sterilization and long exposure in deep space. In the FY 1967 program primary emphasis has been in the areas of communications, power, landing technology, and the sterilization of spacecraft components to prevent contamination of Mars. Mariner IV data, indicating a low atmospheric pressure on Mars, has confirmed the need for intensive effort to be given to landing technology to ensure safe landing on the surface of the planet. The FY 1968 funds will be used to continue the efforts in support of Mars missions and initiate activities related to Venus and the other planets.

The Advanced Studies effort is essential to future lunar and planetary mission planning. The evaluation of possible missions to the planets is a continuing process as new information is obtained about the planets, and as new flight techniques and increased booster capabilities evolve. Fiscal year 1967 funds were utilized in initiating such studies as a multiple planet mission, which would examine the potential of utilizing gravity assist maneuvers at Jupiter, Saturn, and Uranus for the scientific investigation of these plants and Neptune. Fiscal year 1968 funds will be used to conduct conceptual designs of spacecraft for such a multiple planet mission, study the design requirements for large Mars entry vehicles with surface mobility and sample return capability. In addition a series of advanced studies are planned for advanced system concepts to further explore the moon from lunar orbit and by means of automated landers and surface stations.

Surveyor

	1966	1967	1968
Spacecraft.....	$99,891,000	$79,100,000	$36,900,000
Experiments.....	1,980,000	2,500,000	2,500,000
Ground operations.....	2,763,000	2,900,000	2,800,000
Total Spacecraft and Support	$104,634,000	$84,500,000	$42,200,000
Atlas-Centaur (Launch Vehicle Procurement Program).....	(15,000,000)	(7,600,000)	(3,800,000)
Total (including Launch Vehicles).....	($119,634,000)	($92,100,000)	($46,000,000)

The objectives of the Surveyor program are to develop the technology required to accomplish successful soft landings at predetermined sites on the moon, and to conduct scientific measurements on the lunar surface. Studies to determine the optimum strategy for verifying Apollo landing sites, considering both safety and economic aspects, indicate the desirable use of the Surveyor and Lunar Orbiter spacecraft acting as a team. Operational plans call for Surveyor landings at various lunar sites with "aerial survey" of these sites and surrounding areas by Lunar Orbiters. This combination of coverage provides detailed measurements on the surface by Surveyors which can be extended to larger areas with Orbiter photographs.

Surveyor I made the first controlled descent to the surface of the moon and transmitted over 11,000 high resolution television pictures back to the earth. Surveyor instrumentation showed that the lunar surface where it landed has a dynamic bearing resistance of 6 to 10 pounds per square inch, which should be sufficient for a safe Apollo landing.

Surveyor II crashed into the moon after one of its vernier engines failed to ignite properly during the mid-course maneuver. Subsequent Surveyors will examine other potential Apollo landing sites and determine the lunar surface and subsurface physical and chemical properties. These data are essential to ensure a high confidence that the topographic and structural characteristics of alternate sites are suitable for manned landings before these missions are attempted.

The Office of Space Science and Applications, NASA Headquarters, is responsible for overall management of the Surveyor program. Responsibility for project management is assigned to the Jet Propulsion Laboratory. The Surveyor spacecraft system was developed by the Hughes Aircraft Company. Major subcontractors are Thiokol/Elkton for the main retro motor, Thiokol Reaction Motors Division for the vernier engine thrust chamber assemblies, and Ryan Electronics for the radar altimeter and doppler velocity sensor.

In addition to completing analysis of the data obtained from the first Surveyor flight, which was conducted close to the end of last fiscal year, current year funds provide for the final testing, launch and post-launch operations for the second, third, and fourth Surveyors, and will allow for initiation of subsystem testing and assembly of the fifth, sixth, and seventh spacecraft.

The funds requested for FY 1968 are required to complete assembly, systems environmental and flight acceptance tests for the sixth and seventh Surveyors, and for launch and post-launch operations for the fifth, sixth, and seventh Surveyor missions.

Fiscal year 1965 and prior Surveyor program expenditures were $388,877,000 for both spacecraft and launch vehicles. Funding requirements beyond FY 1968 for completion of the program are estimated to be $1,000,000.

Lunar Orbiter

	1966	1967	1968
Spacecraft	$56,667,000	$26,750,000	$8,780,000
Experiments	178,000	250,000	220,000
Ground operations	1,236,000	1,800,000	1,000,000
Total Spacecraft and Support	$58,081,000	$28,800,000	$10,000,000
Atlas-Agena (Launch Vehicle Procurement Program)	(14,500,000)	(9,300,000)	(800,000)
Total (including Launch Vehicles)	($72,581,000)	($38,100,000)	($10,800,000)

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Lunar Orbiter, operating as a team with the soft landing Surveyor, provides detailed information about the lunar surface and the near lunar environment. Each Lunar Orbiter spacecraft serves as an orbiting platform for a photographic system designed to take extended area photographs of the lunar surface for use in the selection and certification of suitable Apollo landing sites, and to increase our scientific understanding of the moon. The first two Lunar Orbiters returned high resolution (one meter) photographs of thirteen candidate Apollo landing sites covering an area of four thousand square miles and wide angle pictures of twenty-two candidate Apollo landing sites covering an area of thirty thousand square miles. These photographs are being carefully screened in order to locate suitable sites for Surveyor and Apollo landings. In addition, these two spacecraft provided photographs of about four million square miles of the hidden face of the moon, which differs substantially in appearance from the side that always faces the earth.

Lunar Orbiter I was the first American spacecraft to orbit a body other than the earth. The actual orbital parameters of Lunar Orbiters I and II were extremely close to those planned. The precision is comparable to the best achieved by earth-orbiting satellites. A total of nine velocity changes have been commanded in the two missions and in each case the actual change achieved was exactly what was commanded. Lunar Orbiter I and II have contributed enormously to the quantitative definition of the moon's gravitational field. As one noted astronomer stated; "We learned more in the first seven days of Lunar Orbiter I than in all the previous fifty years!" This information, which is of prime scientific interest, is also useful for refinement of guidance requirements for Apollo missions. Environmental experiments on the Lunar Orbiters have provided measurements of radiation and the micrometeoroid flux near the moon.

Although the first two missions have provided significant quantities of data in support of manned landings and in scientific exploration of the moon, much additional work remains. The third mission is planned primarily for additional landing site search, since it is necessary to have a number of alternate sites across the Apollo zone of interest near the lunar equator. To the extent that the Apollo requirements are satisfied, following missions might allow a shift in emphasis toward scientific exploration of the numerous areas of interest in other parts of the moon. More than four hundred specific areas of high scientific interest have been delineated by members of the scientific community.

The Office of Space Science and Applications, NASA Headquarters, is responsible for the overall direction of the Lunar Orbiter project. Responsibility for project management is assigned to the Langley Research Center. The prime contractor is the Boeing Company which designed and developed the Lunar Orbiter spacecraft and performed the systems integration and testing. Major subcontractors are the Radio Corporation of American for the power systems and communications, and Eastman Kodak for

the photo system. The missions are tracked and controlled by the Deep Space Network of the Jet Propulsion Laboratory. The Lewis Research Center is responsible for management of the launch vehicle system.

Current year funds are being used for the assembly, integration, and systems testing of the spacecraft, and for mission operations and analysis of photographs, selenodetic and other lunar environmental data for the first three missions.

Funds requested for FY 1968 will provide for the systems testing and mission operations of the last two spacecraft. These funds are also required to complete the analysis of data obtained from the later missions. Fiscal year 1965 and prior expenditures for Lunar Orbiter were $87,200,000 including launch vehicles. Subsequent to FY 1968 about $1,000,000 will be needed to complete final data analysis and project reports.

Mariner

	1966	1967	1968
Mariner-Mars 1964.....	$2,335,000	$200,000	---
Mariner IV.....	250,000	1,000,000	$600,000
Mariner-Venus 1967.....	10,900,000	11,000,000	4,200,000
Mariner-Mars 1969.....	4,100,000	23,000,000	54,000,000
Mariner-Mars 1971.....	---	---	10,100,000
Total Spacecraft and Support	$17,585,000	$35,200,000	$68,900,000
Atlas-Agena.....	(8,700,000)	(200,000)	(---)
Atlas-Centaur.....	(---)	(1,420,000)	(14,438,000)
Total (including Launch Vehicles).....	($26,285,000)	($36,820,000)	($83,338,000)

The objective of the Mariner program is to conduct the early exploration of the planets and interplanetary medium with spacecraft in the 400 to 1200 pound class, and to provide the scientific and technological basis for detailed exploration by spacecraft of the Voyager class. Mariners II and IV measured the magnetic fields, charged particle fluxes, and cosmic dust in interplanetary space and in the vicinity of Venus and Mars respectively. On December 14, 1962, Mariner II observed microwave brightness temperatures of approximately 800°F on Venus, but did not detect a magnetic field when it passed within 22,000 miles of the planet's surface. Mariner-Venus 1967 is designed to obtain additional information on the field and particle environment, to detect atomic hydrogen and oxygen, and to obtain a density profile of Venus' atmosphere by means of occultation experiments as it passes within 2000 miles of the planet in October 1967. The Mariner-Venus 1967 spacecraft is the flight qualified Mariner-Mars 1964 back-up spacecraft

modified for the Venus mission. Mariner IV transmitted to earth the first close-up photographs of another planet after it passed within 6200 miles of the surface of Mars on July 15, 1965. Mariner IV's television pictures, with a resolution of 1500 meters, showed a cratered surface much like that of the moon. At the flyby distance, Mariner IV could have detected a magnetic field a thousand times weaker than earth's, but such a field was not perceptible. The occultation experiment found the atmosphere to be much less dense than previously indicated. The 1969 Mars mission will take advantage of the greater payload weight capability provided by the Atlas-Centaur launch vehicle to examine the surface with an improved television system and measure the spectrum of the planet in both the infrared and ultraviolet wavelengths.

The mission planned for 1971 will use the same basic spacecraft designed for the 1969 mission with the modifications required to not only obtain higher resolution pictures of the surface than those to be obtained by the 1969 Mars mission but, also, to eject from the flyby spacecraft a scaled-down Voyager entry capsule into the Martian atmosphere. The probe will telemeter qualitative data on atmospheric constituents and structure to the spacecraft during entry and descent to the surface. This mission will not only yield significant scientific results but will also provide the scientific information and technological advancements that will enable a much greater return from the Voyager program and enhance the efficiency of its development program.

The Jet Propulsion Laboratory is responsible for Mariner project management under the overall guidance and direction of the Office of Space Science and Applications. The early Mariners were designed, fabricated, assembled and tested in-house at JPL, with extensive subcontracting at the assembly and component level for such items as the Canopus sensor, gyros, solar panel structures, solar cells, batteries and tape recorders. JPL will perform the systems integration function of the prime contractor for Mariner-Mars 1969, but subcontracting will be for complete subsystems, such as attitude control, power, and propulsion. Subcontracting will be even more extensive in the Mariner-Mars 1971 project, with perhaps a systems prime contractor for the complete spacecraft, and contracts for subsystems on the atmospheric probe.

Current year funds will cover the cost of completion of fabrication, assembly, test and launch of Mariner-Venus 1967. They will also finance subsystem breadboarding and engineering model testing on Mariner-Mars 1969, and complete the design of the spacecraft to permit initial flight hardware procurement in July 1967. Current year funds also will cover the cost of operations associated with the reacquisition of Mariner IV.

The funds requested for FY 1968 will finance post-launch operations for Mariner-Venus 1967 through encounter, and analysis of scientific and engineering data. Fiscal year 1968 funds requested for Mariner-Mars 1969 will also provide acquisition of flight hardware, financing to initiate

assembly of the flight spacecraft, and to complete type approval tests of prototype subsystems and environmental systems tests of the prototype spacecraft. Fiscal year 1968 funds will be used to establish the functional specifications for Mariner-Mars 1971 and to complete systems design. There will be extensive testing of prototypes of critical subsystems, such as relay communications, sterilizeable batteries, and aeroshell and experiment instrumentation. Flight experiments and the spacecraft system contractor will be selected. Fiscal year 1968 funds requested for Mariner IV will be used to complete reacquisition, for data analysis, and for preparation of final reports.

Fiscal year 1965 and prior year expenditures for Mariner are $196,259,000 for both spacecraft and launch vehicles. Funds required beyond FY 1968 for completion of the Mariner program are estimated to be $238,442,000 of which $205,900,000 is for Mariner-Mars 1971.

OFFICE OF SPACE SCIENCE AND APPLICATIONS VOYAGER PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Voyager is a major new program for which full-scale design and development will start in FY 1968. The Voyager will provide the first opportunity for man to obtain sufficiently detailed data concerning the planets of our solar system to permit a significant step in the understanding of planets and to apply this information to the earth itself. The objective of the Voyager program beginning with the missions planned for the 1973 and 1975 Mars opportunities is to obtain information relevant to the existence and nature of extraterrestrial life, the atmospheric, surface and body characteristics of the planet Mars, and the nearby space environment.

The overall requirements to be placed upon post-Mariner missions to the planets have been under careful study for several years. To perform meaningful planetary exploration, detailed measurements of the planetary environment, atmosphere, and surface characteristics must be made. In addition, such missions must have the capability to detect life, if present; to characterize it chemically and physiologically; to determine its relation to terrestrial life forms, if any; and to aid in establishing the evolutionary path of such life. The missions should also have the capability to look for fossil life; and if only fossil life were found, to examine those factors that might have been associated with the extinction of extraterrestrial life.

After careful consideration of the type of scientific investigations to be performed in a planetary exploration program, four main capabilities are identified that any follow-on program to Mariner must have. The first is the ability to observe the planet both from orbit and on the planetary surface. Data on extraterrestrial life will only be obtained conclusively from observations made on the planetary surface. However, the scientific understanding of a planet, its origin, and evolution will be heavily dependent upon correlating surface measurements and large-scale survey-type measurements obtained by observations from planetary orbit.

The second capability needed on post-Mariner missions is the high instrument weight. Thus, either heavy single experiments or groups of complementary experiments can be supported during each mission to obtain the multidisciplinary types of scientific information required.

The third capability is long-lifetime at the planet; that is, the spacecraft should operate on the surface of the planet and in orbit about the planet for long periods of time. This is particularly important for Mars

since seasonal variations have been observed and an understanding of such variations and their effects are critical to the scientific understanding of the planet.

The fourth capability is for a large amount of data. This will permit high quality visual data similar to that obtained of the moon by Lunar Orbiter and Surveyor and high quality spectroscopic type data which is needed for chemical and physical investigations.

The requirements noted above are being used to define the Voyager mission capability. The Voyager capability far exceeds that of the Mariners and represents a major step in this country's planetary exploration capability. The Saturn V, developed for Apollo, will be used as the Voyager launch vehicle.

Three primary objectives will shape the Voyager missions: To gain knowledge about the origin of the solar system, to gain knowledge about the origin of life, and to apply both to a better understanding of terrestrial life. Not only do these objectives directly bear on man's place in the universe, but they are closely related to the origin of the universe itself.

In pursuit of these goals, beginning with the 1973 Mars opportunity, Voyager will orbit, and soft-land on the planet and search for evidence of forms of life. The first Voyager mission will provide data on the physical, thermal, and chemical properties of the planet, transmit to earth high resolution photographs of Mars' surface. It is planned to design the Voyager spacecraft so that many of its basic systems, such as the spacecraft, can be used with a minimum of modification for exploration of planets other than Mars. This would minimize development costs for possible future planetary missions, such as landing on Venus, which are currently being studied.

SUMMARY OF RESOURCES REQUIREMENTS:

	1966	1967	1968
Voyager.....	$17,097,000	$10,450,000	$71,500,000
Total.....	$17,097,000	$10,450,000	$71,500,000

Distribution of Program Amount by Installation:

Marshall Space Flight Center...	$210,000	$1,000,000	$21,300,000
Jet Propulsion Laboratory.....	15,502,000	8,200,000	31,000,000
Ames Research Center.....	200,000	250,000	500,000
Langley Research Center.....	585,000	1,000,000	18,000,000
NASA Headquarters.....	600,000	---	700,000

BASIS OF FUND REQUIREMENTS:

Voyager

	1966	1967	1968
Spacecraft system.....	$8,191,000	$1,300,000	$21,400,000
Capsule bus system.....	} 7,622,000	} 8,100,000	21,600,000
Surface laboratory system.....			24,000,000
Voyager biological laboratory..	1,000,000	450,000	2,500,000
Launch vehicle system.....	210,000	500,000	1,500,000
Mission operations.....	74,000	100,000	500,000
Total.....	$17,097,000	$10,450,000	$71,500,000

Initially, Voyager will investigate the closest planets, beginning with Mars. The first flight missions are planned for Mars during the 1973 and 1975 opportunities. In pursuit of its objectives, the Voyager will place an automated spacecraft in orbit and soft land an automated laboratory on the surface of Mars. One Saturn V launch vehicle will carry two Voyager planetary vehicles mounted in tandem at each of the two launch opportunities. Each planetary vehicle consists of a spacecraft and a landing capsule. The spacecraft will accomplish the transit to Mars, deliver the capsule into orbit, and conduct scientific observations of Mars from orbit over a period of several months. The landing package includes a capsule bus system and a surface laboratory system. The landed surface laboratory system will include instruments to study the chemistry of the atmoshpere and surface; measure radiation, temperature, and seismic activity; and search for evidence of extraterrestrial life to the maximum extent possible on the early Voyager missions.

It is anticipated that changes will be made to the surface laboratory from mission to mission as the scientific understanding of Mars is increased. As this progression occurs, it is expected that adaptive and reprogrammable experiments will be conducted and the surface laboratory will evolve into the Voyager Biological Laboratory (VBL). The VBL concept is based upon the conviction that a flexible scientific laboratory type spacecraft will be required to provide results capable of unambiguous interpretation. It will be an integrated set of experiment packages and be capable of performing these experiments in a near real time programmable fashion rather than having completely discrete experiments aboard. The VBL will contain a reprogrammable computer capable of controlling and commanding its own operations based on data feedback from previous experiments, or by command from earth.

The results of the preliminary design of the Voyager orbiting spacecraft completed in FY 1966 confirmed its feasibility and that it would achieve the assigned mission objectives. Funds for FY 1967 provide for preliminary design of the capsule (capsule bus and surface laboratory), continuing in-house effort on the capsule to bring the understanding of this system to a

level comparable with that of the spacecraft, and maintaining a supporting development program in critical, long leadtime subsystems.

During FY 1968, system design and development will be initiated for the spacecraft, capsule bus, and surface laboratory systems. A single prime contractor will be chosen for each of the three systems to initiate final system design and to begin the development of long leadtime subsystems.

The system design effort will culminate in completed system specifications and in preliminary detail specifications for each subsystem and critical component. Examples of long leadtime developments which are expected to be initiated in FY 1968 are:

Spacecraft System

High power S-band amplifiers and large steerable antennas
Long life cycleable batteries
Data compression, block coding, and data storage

Capsule Bus System

Sterilizable, throttlable liquid retropropulsion
Terminal guidance subsystem
Sterilization cannister and actuating mechanisms

Surface Laboratory System

Sterilizable S-band and VHF amplifiers
Sterilizable power supply
Command storage, programmer, and receiver

In addition, it is expected that advanced development of scientific instruments which are candidates for the 1973 mission will be conducted in FY 1968. These will include visual imaging devices, mass spectrometer/gas chromatograph, various types of spectrometers, and life detection instruments.

During FY 1968, the VBL and its objectives will be defined in detail. The scientific community will be actively involved in this definition. In addition, subsystem design of the VBL will be initiated. It is also expected that breadboarding of critical VBL subsystems will be undertaken.

During FY 1968 development of the launch vehicle nose fairing and shroud required for the Voyager missions will be continued. In addition, studies of Voyager launch criteria and planning of mission operations will be continued.

Funding during FY 1965 and prior years for Voyager amounted to $7,593,000. The total cost of the 1973 and 1975 missions is estimated to be $1,800,000,000 including four sets of flight hardware, prototypes, development, and spare hardware.

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RESEARCH AND DEVELOPMENT

FISCAL YEAR 1968 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS — SUSTAINING UNIVERSITY PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

NASA depends upon universities to conduct portions of the basic research in support of the space program. To improve this support, the universities are strengthened by the Sustaining University Program. The Sustaining University Program encourages the universities by supporting graduate students in space-related disciplines. It also assists universities in the acquisition of facilities suitable for the effective conduct of space research. Its accomplishments contribute to the replenishment of the national supply of highly trained manpower, to an increase in the scope of research leading to advances in fundamental knowledge, and to improvement of the physical facilities for the conduct of both training and graduate research at universities.

SUMMARY OF RESOURCES REQUIREMENTS:

	1966	1967	1968
Training.....	$25,290,000	$16,000,000	$7,000,000
Research.....	12,860,000	11,000,000	10,000,000
Research facilities.....	7,850,000	4,000,000	3,000,000
Total.....	$46,000,000	$31,000,000	$20,000,000

Distribution of Program Amount by Installation:

NASA Headquarters.....	$46,000,000	$31,000,000	$20,000,000

BASIS OF FUND REQUIREMENTS:

Training

	1966	1967	1968
Training.....	$25,290,000	$16,000,000	$7,000,000

As the national space effort proceeds towards attainment of its program goals, training activities conducted under NASA's Sustaining University Program have been reviewed and reassessed to ensure consonance with the new conditions and tasks the Agency will encounter in the years ahead. In fields with the characteristically long lead times associated with doctoral and postdoctoral training, a timely review of the training requirements for future space activities is especially necessary.

In the past, the largest effort has been devoted to predoctoral training. The NASA predoctoral program was initiated in 1962. Its initial target was to sponsor the annual production of 1,000 Ph.D.'s in space-related science and technology. This was estimated to require the annual entry into the universities of some 1,335 new predoctoral candidates for three years of training toward the doctorate. In FY 1966 NASA reached this input goal for the first time, with the addition of 1,335 new entrants to the previous years' candidates, making a total of 3,681 NASA sponsored trainees now in the program.

The FY 1967 budget for training is $16 million. With this amount of money, about 800 NASA sponsored trainees will enter the program in September 1967. In FY 1968, the program level will be $7 million, and the number of new predoctoral students will be about 350.

With this decline in the number of predoctoral trainees, greater emphasis is being placed upon special training activities. Critical in this effort is NASA's Summer Faculty Fellowship Program to help young faculty members keep up with the latest technical developments in engineering and science. Originally established with the assistance of the American Society for Engineering Education, these 10-week summer sessions are cooperative endeavors undertaken in conjunction with one or more universities located near NASA Research Centers. Faculty members spend their summer at the Centers where they choose problems of common interest to themselves and the Centers. In 1967, seven such programs are being planned, with an increased number of participants over the 1966 program. It is planned to continue this effort at the same level in FY 1968.

A faculty program in Systems Engineering Design was begun in 1966, under which faculty members from different engineering disciplines are brought together to work on broad space-related problems requiring an integrated or team approach. Two or three are usually selected from the same university, so that they can introduce new techniques in the teaching of systems engineering design at their parent institution at the conclusion of the program. As in the Summer Faculty Fellowship Program above, these activities are carried on in cooperation with one or more universities located near a NASA Center and NASA Center personnel having special competence in the area of systems engineering lend strong support. Three such summer programs are planned for 1967 and continuation in 1968.

In 1967, NASA plans to sponsor four Summer Institutes for upper division undergraduates to acquaint them with some of the current substantive problems encountered in space sciences and engineering. As in previous years, the student participants will be especially talented young men and women who show promise of continuing these studies at the graduate level. In 1968, continuation at the same level is planned.

NASA supports two small post Medical Doctors' training programs in aerospace medicine. Their purpose is to help provide a few carefully chosen medical doctors with special advanced training to work in direct or supporting roles in manned space flight efforts. Physicians trained in this program have already been employed by NASA at the Manned Spacecraft Center at Houston in space medicine operations. The 1968 level of effort will be the same as that of previous years.

Research

	1966	1967	1968
Research.....	$12,860,000	$11,000,000	$10,000,000

Multidisciplinary research grants under the Sustaining University Program augment NASA's project research by giving universities increased encouragement to extend and enhance their space-related research capabilities. Through the use of broadly based research grants with long-term funding stability, NASA has been able to increase the response from those universities already participating in space research and offer new opportunities to many universities which wish to participate for the first time. The net result has been to strengthen the efforts of those universities which are the chief suppliers of talent and fresh ideas to the space program, and at the same time foster innovations and the development of skills which are so necessary to the continuation of a strong and vital space effort. Additionally, these grants have served to interest scholars and students throughout the nation in critical areas of space science and technology.

The flexibility and relative stability of these special purpose research grants permit universities to build research programs responsive to national space needs within the framework of balanced and creative institutional development. Thus NASA, in sharing the management of these efforts with the university, allows them to take full advantage of their research competence and ingenuity without distorting their traditional academic values. Further, the breadth of support provided induces the formation of multidisciplinary teams which are so necessary to the solution of the problems inherent in many undertakings of national scope, of which the space program is but one. This special purpose research is now underway at 48 universities in 29 states. Each institution has different capabilities, interests, and talents, but all have helped NASA bring to the attention of their regions the challenges of the national space program.

Through this program, groups are evolving which should become increasingly able to bring the sum of the institutions' talent and knowledge closer to national needs. Effective channels of communication have been opened between NASA researchers and their university counterparts. The universities have made significant contributions to NASA's current research progress and some are beginning to look into the more difficult long-range problems. Each institution has increased its research capabilities in areas of interest to NASA and has involved both faculty and students. Some have begun to establish

themselves as regional and even national centers of aeronautical and space research. Finally, significant growth and changes have occurred in the development of forward-looking curricula and training activities.

For the continuation of this special purpose research program with emphasis on newly developing institutions, approximately 50 universities will be supported during FY 1968 at a cost of $10 million. Work at approximately 45 universities will be continued and five institutions will participate for the first time.

Research Facilities

	1966	1967	1968
Research facilities.....	$7,850,000	$4,000,000	$3,000,000

The conduct of research and training in space-related science and technology in direct support of NASA's mission is being impeded by lack of suitable laboratory space at many educational institutions. The provision of adequate space is essential if the universities are to contribute their knowledge and experience to the solution of problems being encountered in the exploration of space. In a fundamental sense, these contributions of university activity may be regarded as the sole means for maintaining or augmenting the intellectual and creative resources upon which the whole superstructure of the space program may ultimately rely. Therefore, where additional research facilities are urgently needed to support the national space program, NASA intends to provide a limited amount of funds for their acquisition.

The research facilities to be acquired by universities with this support must first have met one of three general requirements. The first category includes construction of multidisciplinary space research and engineering laboratories which serve project research and the training supported by the Sustaining University Program. Half of the facilities grants to date have been for this type, where there has been an urgent need to house individuals and combined research groups from several departments. Universities developed and organized along the lines of the classical disciplines do not have adequate laboratories to accommodate activities organized to meet the requirements of a multidisciplinary approach to space-related research and training.

Universities have another need for new facilities in which researchers are able to develop, fabricate and test experiments to fly on satellites, rocket probes and balloon flights. The need for unique laboratory buildings for these purposes is large and growing, and is not being met by any source of funds other than NASA. Adequately equipped laboratories and shops for the design and initial testing of flight packages must be available on campus if the space program is to involve the best experimenters in the country, since conscientious faculty members insist on participation by graduate students.

The third type includes the highly specialized facilities for research and training unique to astronautics and aeronautics. Examples in this category include accommodations for solid and liquid propulsion research, astronomical observatories, exobiological laboratories, high Mach number wind tunnels, and a human centrifuge. By no means does every university need structures of this type, but if basic research in the areas vital to NASA is to be done in universities, and if graduate students are to be trained for the national space program, then NASA must help fund and develop highly technical research facilities which are not normally available to universities. At this time, the interested universities have more requirements for facilities than NASA alone can provide.

A large fraction of future university laboratory requirements will result from growing opportunities for flight experiments. Approximately 45 universities are now concerned with NASA space flight programs, of which probably less than a third have fully equipped laboratories for preparation of experiments and interpretation of data. Post-Apollo manned and automated flights will have the capability of carrying many times the present number of experiments, and if more institutions are to participate, more laboratories will be required.

Some of these facilities may be expected to become focal points for centers of excellence around which universities may mobilize their total capabilities for the benefit of the nation. All facilities are intended to put universities in a position to undertake the work for which they have competence and which is required if this competence is to support the space program properly.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1968 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS LAUNCH VEHICLE DEVELOPMENT PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objective of the Launch Vehicle Development program is to provide for the availability of a launch vehicle capability for automated mission requirements in a timely and economical manner. Advanced studies are conducted to analyze future mission requirements and to define methods of achieving the required performance characteristics. Supporting Research and Technology investigates the new technological developments required to support these methods. New launch vehicles are developed when it is determined that a new vehicle or stage is required to support automated mission requirements. The Scout and Delta vehicles developed under this program became operational during FY 1963. In a similar manner, the Centaur Development effort will be completed during FY 1967.

Since no major new vehicle development effort will be conducted during FY 1968, support for the on-going Advanced Studies and Supporting Research and Technology efforts is budgeted under the Launch Vehicle Procurement Program.

SUMMARY OF RESOURCES REQUIREMENTS:

	1966	1967	1968
Supporting research and technology/Advanced studies.....	$4,000,000	$4,000,000	---
Centaur development.....	53,790,000	27,200,000	---
Total.....	$57,790,000	$31,200,000	---

Distribution of Program Amount by Installation:

John F. Kennedy Space Center, NASA.....	$470,000	$200,000	---
Marshall Space Flight Center.	7,205,000	---	---
Jet Propulsion Laboratory....	140,000	---	---
Electronics Research Center..	600,000	1,025,000	---
Langley Research Center.....	890,000	487,000	---
Lewis Research Center.....	48,125,000	28,988,000	---
NASA Headquarters.....	360,000	500,000	---

BASIS OF FUND REQUIREMENTS:

No funds are being requested in FY 1968 for Launch Vehicle Development.

OFFICE OF SPACE SCIENCE AND APPLICATIONS LAUNCH VEHICLE PROCUREMENT PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objective of the Launch Vehicle Procurement program is to provide launch vehicles, with their related supporting equipment and services, to support automated mission requirements. The program includes a broad spectrum of activity including Advanced Studies to analyze future mission requirements for determining and defining methods of achieving the required performance and Supporting Research and Technology to investigate new technological developments required to support these methods. In addition, the program includes the procurement of vehicles, maintenance and operation of support equipment, vehicle related services, and the Sustaining Engineering and Maintenance effort required to support the operational vehicles. The operational vehicles currently being procured and supported are: Scout, Delta, Thor Agena, Atlas Agena, and Centaur.

Operational vehicles are procured in support of current mission requirements. In order to identify total project requirements, the launch vehicle procurement activity associated with specific projects is shown parenthetically with each project. Procurement levels are adjusted to maintain required inventory levels. The factors considered in determining the quantity of vehicles to be ordered are: (1) current and projected inventory which includes vehicles ordered but not delivered; (2) launch schedules; and (3) procurement lead times required for vehicle delivery.

In addition to the procurement of vehicle hardware, various services associated with each launch are also included in the program. These include such items as trajectory studies, mission modifications to the support equipment and vehicle, launch crew services, guidance services, range reimbursable support, and propellants.

The Sustaining Engineering and Maintenance effort associated with each operational vehicle is not directly related to a specific mission and these costs are not included in the parenthetical notations shown with each project. This effort, in this sense, is general in nature and beneficial to all projects associated with a particular type vehicle. Through this effort, a means is provided for maintaining high levels of performance and reliability in operational vehicles and ground support equipment. These goals are achieved through product improvement programs which provide for the updating of vehicle systems and components, maintenance of ground support equipment, vehicle system engineering, and other supporting services.

In previous budget submissions, Launch Vehicle Development and Launch Vehicle Procurement have been presented as separate programs. Since there

will be no major launch vehicle development effort in progress during FY 1968, the remaining development activities, Supporting Research and Technology and Advanced Studies have been consolidated with the Launch Vehicle Procurement Program.

SUMMARY OF RESOURCES REQUIREMENTS:

	1966	1967	1968
Supporting Research and Technology/Advanced studies..	---	---	$4,000,000
Scout.....	$11,700,000	$9,400,000	16,800,000
Delta.....	27,729,000	20,900,000	32,600,000
Agena.....	70,669,000	37,100,000	24,700,000
Centaur.....	65,000,000	55,000,000	87,000,000
Atlas.....	3,602,000	---	---
Total.....	$178,700,000	$122,400,000	$165,100,000

Distribution of Program Amount by Installation:

John F. Kennedy Space Center, NASA.....	$4,177,000	$3,787,000	$3,332,000
Marshall Space Flight Center...	---	---	1,100,000
Goddard Space Flight Center....	11,879,000	12,563,000	18,400,000
Electronics Research Center....	---	---	1,270,000
Langley Research Center.....	12,090,000	9,400,000	16,900,000
Lewis Research Center.....	135,430,000	88,725,000	109,233,000
NASA Headquarters.....	6,340,000	---	500,000
Western Support Office.....	8,784,000	7,925,000	14,365,000

The overall mission plan for launches during this period is:

Vehicle	Calendar Year 1966	Calendar Year 1967	Calendar Year 1968
Scout.....	1	6(+2 B/U)*	8(+1 B/U)*
Delta.....	4	7	9
Agena.....	7	5	4
Centaur.....	4	4	3
Total.....	16	22(+2 B/U)	24(+1 B/U)

* "B/U" indicates backup missions.
Above table includes Advanced Research and Technology missions.

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BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology
Advanced Studies

	1966	1967	1968
Advanced studies.....	---	---	$1,000,000
Propulsion.....	---	---	75,000
Guidance, control and navigation	---	---	1,070,000
Instrumentation and electronics.	---	---	200,000
Structures and materials.....	---	---	955,000
Vehicle engineering.....	---	---	700,000
Total.....	---	---	$4,000,000

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

The FY 1966 and FY 1967 Advanced Study efforts have been directed at mission requirements for very high velocity launch vehicles. Particular efforts in technology were directed at a high energy upper (kick) stage to be used with existing lower stages. FY 1968 efforts will be directed at mission analyses, investigation of vehicle and stage alternatives, and program planning.

Supporting Research and Technology efforts are being conducted in the FY 1967 program on upper stage propellant systems, FW4S rocket propellant characterization, alignment and calibration of strapdown guidance systems, investigation of existing aerospace computers for strapdown guidance system applications, preparation of a test program for a state-of-the-art strapdown guidance system, gyroscope and accelerometer evaluation, elimination of initial launch azimuth errors, insulation and penetration of cryogenic tanks, cocooning of solid propellant flight vehicles, pressurization and dynamics of cryogenic tanks, and tests of insulated liquid hydrogen tanks. In FY 1968 work will continue on the definition of capabilities and limitations of strapdown guidance systems for launch vehicles for science and applications missions. Tasks will also be directed at studies of launch vehicle astrionics systems, launch vehicles for very high velocity missions, launch vehicle family studies, mission analyses, ullage control screen for Delta second stage restart, fiberglas filament damage in rocket cases, deep flaws in thin wall tanks, self-evacuated insulation applications, storage of hydrogen in space vehicles, longitudinal dynamics of the Atlas booster, and a module to

test advanced componentry in space on spent Delta vehicle stages.

Scout Procurement

	1966	1967	1968
Vehicles.....	$5,025,000	$2,400,000	$9,600,000
Motors.....	2,300,000	2,000,000	1,500,000
Logistics and spares.....	375,000	1,000,000	700,000
Sustaining engineering and maintenance.....	4,000,000	4,000,000	5,000,000
Total.....	$11,700,000	$9,400,000	$16,800,000

Scout Procurement provides for the production, checkout, field processing, and launch of the Scout vehicle. The Scout is the smallest launch vehicle in the basic NASA vehicle family and provides a reliable, relatively inexpensive vehicle system which is capable of meeting the requirements of a variety of small payloads for orbital, probe, and re-entry missions.

The Office of Space Science and Applications has assigned management of the Scout Project to the Langley Research Center and Ling-Temco-Vought is the prime contractor for the production, checkout, and launch of Scout vehicles. There are two Scout launch sites: One is at the Western Test Range, California, and one at Wallops Station, Virginia.

The Scout vehicle was first launched on July 1, 1960. There have been 49 launches through December 1966, fulfilling the requirements of a variety of missions for NASA, DOD, AEC, and international users.

The FY 1968 funds for Scout Procurement will be utilized to continue the current Scout vehicle and systems management contracts. Funds are also required for the Scout launch services, logistics requirements, and for vehicle adaptation to meet individual mission requirements.

Scout Sustaining Engineering and Maintenance funds provide for requirements in the areas of environmental testing, data reduction and analysis, engineering support, maintenance of Scout standard GSE at Dallas and both launch sites, publication and maintenance of Scout standard procedures, and other related requirements.

Delta Procurement

	1966	1967	1968
Delta stages.....	$9,044,000	$8,725,000	$14,500,000
Thor boosters.....	10,450,000	7,000,000	10,700,000
Propellants.....	616,000	695,000	920,000
Third stages.....	790,000	480,000	480,000
Sustaining engineering and maintenance.....	6,829,000	4,000,000	6,000,000
Total.....	$27,729,000	$20,900,000	$32,600,000

Delta procurement provides an economical, reliable launch vehicle for a wide variety of medium-size satellites and small space probes. The Delta vehicle has proven to be one of the most versatile members of the national launch vehicle stable by successfully launching an assortment of communications, meteorological, and scientific satellites.

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

On October 2, 1966, the operational weather satellite ESSA III was successfully launched by Delta from the Western Test Range. This was the first Delta launched from the Western Test Range, which will be used for Delta launches into polar and nearly polar orbits. Delta operations at the Eastern Test Range will continue as before for lower inclination orbits.

FY 1968 funds for Delta Procurement will be utilized to incrementally fund the procurement of Delta second stages, the procurement of 14 long tank Thor (THORAD) boosters ordered on Air Force contracts, and the procurement of FW-4D and TE-364 third stage motors. These funds are required to meet the launch schedule for the Delta vehicle. Launch services funds are planned to support launch requirements at the two launch sites.

Fiscal Year 1967 Sustaining Engineering and Maintenance funds were used to continue the maintenance and support effort and to initiate two major product improvement efforts. These were the adaptation of the TE-364 (Surveyor retro-motor) as a third stage for Delta and the effort required for the utilization of the Long Tank Thor (THORAD) as a booster for Delta. Each of these improvements will increase the payload capability of the Delta vehicle by approximately 100 pounds.

The FY 1968 Sustaining Engineering and Maintenance funds are required to complete the TE-364 and THORAD efforts and to continue maintenance and updating of ground support equipment, mission analysis, and performance studies in support of the Delta vehicle program.

Agena Procurement

	1966	1967	1968
Agena production.....	$11,695,000	$6,800,000	$5,000,000
Agena mission modifications.....	24,617,000	9,100,000	8,500,000
Thor procurement.....	3,895,000	2,800,000	6,500,000
Atlas procurement.....	23,230,000	11,600,000	1,100,000
Propellants.....	663,000	800,000	200,000
Sustaining engineering and maintenance.....	6,569,000	6,000,000	3,400,000
Total.....	$70,669,000	$37,100,000	$24,700,000

The Agena launch vehicle is a versatile second stage employed extensively by NASA in combination with Thor and Atlas boosters. With its versatility, proven reliability, and capability to restart in space, the Agena provides considerable latitude in performing various earth orbital and lunar or planetary missions.

The Thor Agena configuration provides the capability for polar or nearly polar orbits from the Western Test Range. Nimbus, PAGEOS, and the international satellite Alouette II were launched by this configuration.

NASA uses the Atlas Agena for many automated missions. It was utilized in the Ranger, Mariner Venus, Mariner Mars, and Lunar Orbiter missions. It was also used for the heavier scientific and applications satellites such as the Geophysical Observatories, the Astronomical Observatory, and the Applications Technology Satellite. Atlas Agena is normally launched from the Eastern Test Range in support of NASA missions, although capabilities for its launch also exist at the Western Test Range.

The Lewis Research Center has been assigned project management of the Agena Project by the Office of Space Science and Applications. Lockheed Missiles and Space Corporation is the prime contractor for the Agena. Douglas Aircraft Company and General Dynamics/Convair are the prime contractors for the Thor and Atlas boosters which are procured for NASA by the Air Force.

The funds requested for FY 1968 will provide continued procurement of the basic Agena stages and the Thor and Atlas boosters. They will provide the necessary mission peculiar adaptation of the Agena and the total mission integration effort, i.e., that effort associated with the integration of a particular booster, a modified Agena, and a spacecraft into a complete space vehicle capable of performing its specific mission. Launch support at the launch base such as launch services, propellants, etc., as well as launch support at the factory will also be funded.

Fiscal Year 1968 Sustaining Engineering and Maintenance funds are planned for continuation of maintenance of launch pad ground support equipment at

both ranges and miscellaneous engineering support services not attributable to any one mission.

Centaur Procurement

	1966	1967	1968
Vehicle production.....	$37,635,000	$29,900,000	$55,100,000
Atlas booster procurement.....	9,291,000	9,600,000	9,600,000
RL-10 engine procurement.....	2,260,000	4,400,000	6,000,000
Propellants.....	814,000	1,100,000	2,300,000
Sustaining engineering and maintenance.....	15,000,000	10,000,000	14,000,000
Total.....	$65,000,000	$55,000,000	$87,000,000

The Centaur vehicle is a versatile, high energy second stage employed by NASA in conjunction with the Atlas booster. The development phase was completed during 1966 resulting in the introduction of the first operational rocket employing liquid hydrogen/liquid oxygen propellants into the national launch vehicle family. The high energy propellants and the ability to restart in space make the Centaur uniquely suited to high velocity deep space missions as well as various earth-orbital, lunar, and near planet missions. The present procurement of operational Centaur vehicles is programmed to meet the requirements of lunar, planetary, and earth-orbital projects, including Surveyor, Mariner, Orbiting Astronomical Observatories, and Advanced Technology Satellites.

The Office of Space Science and Applications has assigned project management to the Lewis Research Center and the prime contractor is General Dynamics/Convair, San Diego, California. Pratt and Whitney Division of United Aircraft Corporation, West Palm Beach, Florida, is an associate contractor for the liquid hydrogen engines, and Honeywell, Inc., St. Petersburg, Florida, is an associate contractor for the Centaur guidance system.

Funds requested for FY 1968 will provide for the continued procurement of hardware and supporting services necessary to provide a launch vehicle capability for the above missions. The FY 1968 hardware procurement will include incremental funding of Centaur stages, Atlas boosters, guidance, RL-10 engines, and spares support for Centaur launch vehicles AC-16 through AC-20, now under contract, and for other new procurement. The supporting services include the maintenance of production equipment, sustaining engineering and maintenance at the contractors' plants, operation and maintenance of a combined systems test stand and a launch capability at the Eastern Test Range during this period.

Fiscal year 1968 Sustaining Engineering and Maintenance funds will provide for maintenance of ground support equipment, preflight and postflight engineering analyses of performance and reliability, and for product improvement effort in support of the operational Centaur vehicle. The product improvement effort will be directed at increased system simplicity and versatility with an attendant increase in reliability and decrease in production and operational cost.

OFFICE OF SPACE SCIENCE AND APPLICATIONS BIOSCIENCE PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Bioscience program has two principal objectives. The first is the search for extraterrestrial life, with the primary emphasis directed initially to the planet Mars. The specific aims of this objective include: (a) physical and chemical evaluation of the martian surface as a possible environment for life; (b) determination of whether or not life exists, or has existed on Mars; (c) if life in some form exists, determination of its characteristics; and (d) if no life exists on Mars, investigation of the pattern of chemical evolution in order to evaluate the probability of its future occurrence either spontaneously or by contamination. The planetary quarantine program has the objective of minimizing the possiblity that terrestrial organisms could contaminate Mars and thus destroy its scientific value as a means of testing the various hypotheses regarding the existence of extraterrestrial life. The Voyager spacecraft will provide the first capability for landing a sterilized scientific package on the surface of Mars. Continuous effort will be made before initiation of the Voyager flights to assure an adequate understanding of and solution to the very complex problems associated with this planetary quarantine effort.

The second objective is directed towards attaining a thorough understanding of the effects of the space environment on terrestrial organisms. Its implementation includes ground-based research, the Biosatellite project, and development of flight experiments for other missions. The first Biosatellite was successfully launched on December 14, 1966, and was flown for three days with all experiments being operated successfully. However, the spacecraft was not recovered due to failure of the retro-rocket system to function. This first flight and the back up, scheduled for March, 1967, both have the same payload and the objective of determining the effects of space environment on biological payloads of seedlings, plants, and simple forms of life, expecially with reference to interaction of weightlessness with a known intensity of ionizing radiation. This first flight checked out most of the engineering aspects of the spacecraft system and its flight capability. All systems responded effectively except the retro-rocket system which did not fire. The Biosatellite project has as its purpose the study of the biological effects of weightlessness, the effects of an environment dissociated from the influence of the earth's rotation, and the combined effects of radiation and weightlessness. Nineteen experiments have been assigned to the respective payloads of the Biosatellite spacecraft. Each of the three payloads has a back up in the event of failure or to repeat the experiments for confirmation of the results.

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

SUMMARY OF RESOURCES REQUIREMENTS:

	1966	1967	1968
Supporting research and technology	$11,100,000	$11,550,000	$14,300,000
Biosatellite	23,300,000	30,000,000	30,000,000
Total	$34,400,000	$41,550,000	$44,300,000

Distribution of Program Amount by Installation:

Marshall Space Flight Center	$60,000	$100,000	$120,000
Goddard Space Flight Center	420,000	369,000	350,000
Jet Propulsion Laboratory	1,151,000	1,784,000	2,300,000
Wallops Station	100,000	25,000	153,000
Ames Research Center	24,127,000	30,161,000	31,000,000
Langley Research Center	30,000	160,000	200,000
NASA Headquarters	8,512,000	8,951,000	10,177,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1966	1967	1968
Exobiology	$3,800,000	$4,425,000	$4,900,000
Environmental biology	2,400,000	2,000,000	2,600,000
Behavioral biology	2,100,000	2,000,000	2,400,000
Physical biology	1,800,000	1,800,000	1,900,000
Planetary quarantine	1,000,000	1,325,000	2,500,000
Total	$11,100,000	$11,550,000	$14,300,000

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Exobiology

The Exobiology program has as a primary purpose the search for extraterrestrial life. In connection with this mission ground-based analytical studies of the origin of life on earth and its adaptation to the earth's environment are being conducted. Similar studies of life in a simulated Mars environment are in progress. The ground-based studies are directly related to the search for extraterrestrial life since the data from these studies may lead to the development of testable hypotheses regarding the origin and nature of planetary life.

One of the methods of evaluating the earth for analysis of the origin and nature of life is the study of fossil remains. One of the oldest sedimentary rocks that we know of, the Fig Tree Chert, Sudan in Africa, is computed to be 3.1 billion years old. It contains fossil bacteria which have been demonstrated to have been living in the rock at the time of fossil formation. This puts the origin of life on earth back 3/5 of the estimated age of the earth.

In recent simulation studies of the Jovian atmosphere in the laboratory, electrical discharges have been applied to the presumed Jupiter primitive atmosphere of methane, ammonia, and water, colored molecules have been produced which appear similar to the colored regions, such as the "red spot" on Jupiter. A red chromophore is possibly produced from ammonium cyanide (produced from methane and ammonia) in the presence of ammonia.

In automated life detection studies, broadening the analyses made on a single sample will increase the reliability of the data. Chemical analysis, metabolic activity, and evidence of growth in the same sample of material would be most convincing evidence of biological activity. The chamber in which organisms from a soil sample are induced to grow can also be monitored for metabolic activity by gas chromatography, and samples removed for chemical analysis. Positive data from all three experiments would be very convincing. Such experiments can be completely automated for a Voyager biological laboratory.

Environmental Biology

Living organisms, from bacterial forms to man, are very responsive to their environment. Research in Environmental biology is concerned with the response or interaction of living earth systems with the variables of the space environment. Knowledge of this nature is required to establish expeditious and efficient means for using a variety of living organisms to assist in the biologic exploration of space.

There is a real need for identifying and understanding the effects on living systems of such space flight factors as weightlessness, acceleration, vibration, radiation, and magnetism. In a study of the influence of very low or no magnetism, a consistent difference has been observed in the growth of shoots and roots of wheat seedlings. The seedlings grown in the zero field were larger and more robust than their controls grown in the earth's field.

Accurate information is required concerning the ability of earth organisms to live, grow and repopulate in planetary environments. Our effort in studying as much alien environment (by human standards) as possible on earth is generating some intriguing observations. For instance, evidence has been accumulated to contradict the unfortunate generalization that "strong ultraviolet (UV) light on Mars would prevent any earth-type life from existing on the planet's surface....." Tarantulas, spiders, and turtles survived simulated martian UV conditions for eleven days without any physiologic impairment for months after exposure. The turtle absorbed a dose in the cornea of the eye that would normally blind a human.

With the extension of space missions to the planets, regenerative life support systems will be needed. Research on hydrogen-fixing bacteria indicates an ability to supplement current systems with living or bioregenerative organisms that can utilize animal wastes and carbon dioxide to synthesize protein, fat, and other nutrients. This bacterium, known as Hydrogenomonas, fulfills its energy requirements with hydrogen from the electrolysis of water. Electrolysis makes pure oxygen available for respiration for man. A significant spin-off from this research is that this and related micro-organisms may be a source of dietary supplements for populations lacking a nutritional abundance and adequacy.

Based on our present knowledge of current problems resulting from exposure to the space environment, we must continue to pursue basic research that will expeditiously and effectively provide some of the answers. A continued insight into the biochemical and biophysical mechanisms may help us to explain and prevent physiologic complications due to prolonged space flight such as bone mineral mobility and loss, cardiovascular problems, reduction in red blood cell mass, and losses in muscle mass.

Behavioral Biology

Current research has emphasized ground-based studies preparatory to in-flight experiments on the effects of low gravity and weightlessness and other conditions peculiar to the space environment on the behavior of organisms. Emphasis has been placed on the capacity of organisms to adjust to alterations in gravity, particularly the determination of responsiveness of gravity receptors to transient and prolonged stimulation. Ground-based studies have been conducted on the orientation of biological organisms in time and space in the absence of terrestrial cues. During FY 1968, several Aerobee launches are scheduled to study gravity level preference of animals in space.

Research has involved neurophysiological, biochemical, and behavioral analyses which have further elucidated brain-behavior relationships of importance to organisms in environmental adaptation. These studies have emphasized those neurobehavioral relationships which maintain activation and alertness. Other research has been concerned with problems of information storage and retrieval in living systems, using biochemical, biophysical, and electrophysiological approaches. Related studies on processes such as attention, discrimination, perception, and motivation, as well as complex sensori-motor functions have been productive of new insights into the mechanisms of behavior and their interactions with the space environment.

Physical Biology

The Physical Biology program supports research in comparative physiology, bio-instrumentation and molecular biology. Research in comparative physiology includes studies on living organisms which specifically lend themselves to investigations in orbiting biological vehicles, on the nutritional requirements of living organisms for prolonged space travel, and on the phenomena and dynamics of various physiological and behavioral systems. Basic data have been accumulated on desert pocket mice which are uniquely suited to space experiments especially on rhythmicity phenomena.

The dynamics of the body temperature regulatory system, the blood flow (cardiovascular system), and the hormonal system are being studied by physical modeling and analysis in an attempt to understand the mechanics of these systems under normal conditions as well as in stress situations. Physiological oscillatory activity has been demonstrated in these systems.

Various types of biological instrumentation are being developed to measure and analyze biological, biochemical, and biophysical phenomena. In biological telemetry, work is proceeding on the development of a multichannel sensing implantable device in order to measure, simultaneously, a number of biological and behavioral activities, and to enable measurement of normally inaccessible physiological activities under a variety of conditions. This is especially important in space flight experimentation where data have to be telemetered and acquired under conditions not normally found in earth laboratories.

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

Planetary Quarantine

The search for extraterrestrial life has the prerequisite that terrestrial organisms must not be transported to the planets prior to the time scientific life detection payloads are landed. It is also mandatory that life detection

instruments be devoid of earth organisms when they land on the planet to prevent the possibility of obtaining false positive information related to life on the planets. In order to achieve the goal of preventing the transmission of earth organisms to the planets, various methods have undergone rigorous and intensive study. Current evidence indicates that the conditions encountered in space flight (cold, vacuum, ultraviolet, solar radiation, etc.) will not reduce microbial life to undetectable levels.

With the accomplishment of each successful flight mission relative to the probing of space, the United States is increasing the scientific knowledge about the moon and planets of the solar system. In the immediate future there will be manned landings on the moon, the Mariner 1967 Venus mission, and the Mariner 1969 Mars mission.

A primary objective of the scientific exploration of space is the search for life or life-related molecules. Information thus far obtained has neither verified nor denied the possible existence or pre-existence of life on Mars, Venus, or the subsurface of the moon. Until positive evidence has been obtained relative to this scientific question, it is absolutely necessary that measures be taken to prevent the introduction of terrestrial biological macromolecules into these environments. Of particular importance is the need to assure that life-detection instruments which are to perform the scientific experiments are free from contamination in order to prevent false positive information from being obtained.

A moral obligation to prevent introduction of terrestrial organisms which may radically affect the ecology of the planets rests with all nations engaged in space exploration. If the landed terrestrial organisms should find a favorable extraterrestrial environment to permit growth and spread which would result in extinction of the indigenous life forms, an opportunity for scientific exploration would be lost for all time. Although it is believed that the possibility of reproduction of terrestrial organisms in these environments is extremely unlikely, until such a possibility is ruled out the exercise of caution is necessary. The policy of the National Aeronautics and Space Administration is that outbound planetary spacecraft must have either trajectory controls to assure that the probability of unsterile spacecraft impacting or entering a planet's atmosphere is 0.00003, or that the spacecraft is sterile with a certainty of 0.9999.

During the past year, work has been directed at the problem of developing realistic methods for reducing the microbial load on a spacecraft during assembly and reduction of physical degradation of spacecraft components from the stress placed upon them by the terminal heat sterilization process immediately prior to launch. An example of the progress made in this area as a result of laboratory research is the reduction in time and temperature constraints for the sterilization cycle. Previously, based on studies of garden soil, it was determined that 4.4 hours at a temperature of 125 degrees C were required to reduce the number of microorganisms by one decade. The research results from studies of organism deaths inside plastics treated

with heat have reduced this time to at least 3.5 hours. This is significant when applied to the treatment time required for a spacecraft having 10^5 organisms as the burden when subjected to the heat cycle. During these investigations, the kill kinetics indicated that a full decade reduction occurred during the period of heat-up of the material to the holding temperature.

A further reduction in the time required to subject the spacecraft to sterilization temperatures can be achieved by the application of clean assembly techniques in the spacecraft manufacture and test facilities.

Biosatellite

	1966	1967	1968
Spacecraft.....	$15,585,000	$22,446,000	$19,400,000
Experiments.....	7,431,000	7,007,000	10,100,000
Operations.....	284,000	547,000	500,000
Total Spacecraft Operations..	$23,300,000	$30,000,000	$30,000,000
Thor-Delta (Launch Vehicle Procurement Program).....	(9,500,000)	(---)	(4,500,000)
Total (including Launch Vehicles).....	($32,800,000)	($30,000,000)	($34,500,000)

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

The first two flights (3 days' duration) have the purpose of investigating the biological effects - on seedlings, plants, and simple forms of life - of weightlessness, and the effects on plants, animal cells, and insects of the combination of weightlessness and radiation. Biosatellite A was successfully launched on December 14, 1966, but was not recovered due to failure of the retro-rocket system. Biosatellite B is currently scheduled for launch in March 1967. The third and fourth flights, of 30 days' duration, will investigate the effects of weightlessness on a primate's general metabolic behavior and performance, and cardiovascular and nervous systems. The fifth and sixth flights, of 21 days' duration, consist of general biology experiments to determine the effects of weightlessness on plant growth and development, growth of isolated human cells, gross body composition and function in mammals, and circadian (24-hour) rhythms.

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

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

FY 1965 and prior years' funding for this six-flight program including launch vehicles amounted to $28,915,000. Funding for FY 1966 provided for design, fabrication, and testing of the spacecraft, and continued funding for experiment development. Funding for FY 1967 provides for fabrication and testing of the spacecraft, subsystem and system acceptance and qualification tests of the prototype vehicle, assembly and functional testing of the 3-day and 30-day flight vehicles and continued funding for experiment development with primary emphasis on the 3-day flight. Funding for FY 1968 will emphasize fabrication, qualification, and systems testing of the 30-day and 21-day spacecraft, and continued funding on experiment development for these two spacecraft. Funding requirements subsequent to FY 1968 for completion of this effort, including launch vehicles, are estimated to be $31,312,000.

RESEARCH & DEVELOPMENT

FISCAL YEAR 1968 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS SPACE APPLICATIONS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

This program combines the Communications and Applications Technology Satellites and Meteorological Satellites programs shown separately in the FY 1967 and prior budgets. It also includes the Geodetic Explorers project, which was previously funded under the Physics and Astronomy program. The Meteorological Flight Experiments project, previously identified separately, is now made a part of the appropriate Space Applications flight project.

The objectives of the Space Applications Program are to: (1) develop a capability to expand human knowledge of the phenomena in the atmosphere and space, and support the exploration and utilization of space, by conducting a broad-based program of applications-oriented research and technology development (National Aeronautics and Space Act of 1958); (2) develop and test procedures, instruments, subsystems, spacecraft, and interpretive techniques in the various applications areas; (3) accomplish long-range studies of the potential benefits to be gained from, and the problems involved in, utilization of space activities for peaceful and technological purposes for the benefit of mankind; (4) fulfill NASA's responsibilities under the Communications Satellite Act of 1962; and (5) develop and implement for the Environmental Science Services Administration (ESSA), Department of Commerce, the operational meteorological satellite system.

The democratic countries throughout the world have traditionally looked to the U.S. for economic, scientific, and technological leadership. By pursuing a comprehensive and meaningful space applications program, the U.S. can demonstrate this leadership in terms readily understandable by everyone. Applications Technology Satellites offer great potential to mankind in the areas of communications, meteorology, navigation, geodesy, and earth resources survey; by developing and extending technology commonly required for all these types of applications and by providing flight testing of promising applications and techniques. Communications Satellites offer the possibility of direct voice broadcast to all or parts of the world by economical means. Meteorological Satellites offer the possiblity of predicting weather conditions on a global basis, and provide data on hurricanes, typhoons, cyclones, and other destructive weather disturbances. Navigation Satellites could provide location, traffic control, search and rescue, and communication systems for aircraft and ships. Geodetic satellites offer the means to determine the size and shape of the earth and the vector properties of its gravitational field. Earth Resources Survey via satellite would offer valuable data in such areas as agriculture and forestry, geology and mineralogy, hydrology and water resources, geography and cartography, and oceanography.

SUMMARY OF RESOURCES REQUIREMENTS:

	1966	1967	1968
Supporting research and technology	$10,839,000	$11,630,000	$16,600,000
TIROS/TOS improvements	2,500,000	3,100,000	7,500,000
Nimbus:			
Nimbus A-D	22,560,000	23,400,000	29,500,000
Nimbus E-F	---	---	5,000,000
Meteorological soundings	2,730,000	3,000,000	3,000,000
French satellite (FR-2)	---	100,000	100,000
Applications technology satellites:			
ATS A-E	34,431,000	28,470,000	19,800,000
ATS F and G	---	---	15,700,000
Geodetic satellites (A-E)	4,993,000	1,600,000	4,700,000
Voice broadcast satellite	---	---	2,300,000
Total	$78,053,000	$71,300,000	$104,200,000

Distribution of Program Amount by Installation:

Manned Spacecraft Center	$18,000	---	$5,000,000
Marshall Space Flight Center	370,000	$435,000	800,000
Goddard Space Flight Center	70,010,000	64,580,000	86,510,000
Jet Propulsion Laboratory	547,000	169,000	300,000
Wallops Station	340,000	127,000	220,000
Ames Research Center	200,000	100,000	100,000
Electronics Research Center	735,000	590,000	600,000
Langley Research Center	1,130,000	905,000	730,000
Lewis Research Center	200,000	500,000	1,000,000
NASA Headquarters	4,503,000	3,894,000	8,940,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1966	1967	1968
Meteorology	$7,470,000	$5,865,000	$5,300,000
Communications	1,659,000	3,449,000	3,200,000
Navigation	360,000	475,000	900,000
Applications technology	1,350,000	1,171,000	1,300,000
Geodesy	---	670,000	900,000
Earth resources	---	---	5,000,000
Total	$10,839,000	$11,630,000	$16,600,000

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In meteorology, FY 1966 funds continued effort in such areas as an improved automatic picture transmission (APT) camera and storage system, and improved elements for the interrogation, recording, and location subsystem (IRLS) for processing meteorological data from remote instrumented platforms. Research has been continued into the relationship between the heat energy budget of the earth and large scale atmospheric phenomena, and the development of an interferometer, spectrometer, and other instruments to measure the structure and radiation of the atmosphere. Techniques are being developed to measure the intensity and location of sferics signals to determine the areas in which thunderstorms are occurring, and the refraction of starlight to determine the density of the atmosphere. Advanced simulated and scaled down systems are being completed for the optimization of satellite control and power components with emphasis on long life and reliable operation. FY 1967 funds are being utilized for design and development work on remote microwave radiation sensors to take advantage of recent break-throughs in frequency-multiplier components at experimental millimeter wavelengths in the electromagnetic spectrum. Prototypes of advanced new cameras on which work was initiated in prior years will be qualified for space flight. Advanced satellite control techniques, to replace present reaction wheels and associated gas-fed nozzles with passive gravity reacting masses and improved momentum damping techniques, will proceed beyond initial study stages. The design of a flexible automatic computerized telemetry system will begin in a two-year development period providing an extremely versatile method of collecting several types and rates of environmental data aboard the satellite for transmittal to the ground. Microminiaturized transmitters and receivers will be developed for various satellite needs, and will significantly advance the present capabilities for very low power, high reliability, and compactness in physical size. Solid state devices will be investigated. Advanced mission studies will be continued on future meteorological systems. FY 1968 funds are required for developing and evaluating components for potential meteorological satellite system applications; design and development of satellite sensors for the detection and controlled acquisition of meteorological data directly from the atmosphere; investigation of scientific techniques for the systematic observation, analysis, and subsequent interpretation of meteorological atmospheric phenomena; system analysis; and exploration of the atmosphere in the region of 20 to 60 miles altitude.

In communications no additional passive satellite launches are planned, however, a modest effort continued in FY 1966 and FY 1967 on materials, structures, and erection systems development for advanced passive satellites because such satellites have unlimited multiple access and frequency response capabilities, inherent long life, and high reliability. Investigations continued in FY 1967 on active satellite systems capable of linking terminals of greatly reduced size and cost, making possible communications with over-ocean aircraft, ships at sea, and small land stations. Investigations will continue on the effect of scattering electromagnetic waves by earth's atmosphere and space environment; results have and will make important contributions to the International Telecommunications Union Conference on Space Communications. Measurement techniques have been developed for measuring radio reflectivity characteristics of large inflatable structures on the ground so that their potential usefulness in space can be predicted. In FY 1967, these techniques

are being used to measure small segments of new and improved passive satellite materials and structures, and on advanced antenna designs to determine their characteristics. FY 1968 effort is primarily in the active satellite area. This effort consists of system comparison studies to determine the merits of advanced concepts and techniques applicable to small terminal multiple access communications and satellite aids to lunar and planetary communications; evaluation and development of components and subsystems required for broadcast applications; propagation studies and component development in the frequency region between 10 to 100 GHz where frequencies are more available for space communications, but much less understood; and interference analysis and prediction methods needed for developing sharing criteria. Data analysis consisting of reliability, spacecraft degradation, and lifetime data for ECHO-II, RELAY, and SYNCOM will continue in FY 1968.

Navigation and traffic coordination satellite system conceptual studies funded in FY 1966 and FY 1967 indicated that satellites could assist over-ocean aircraft and ships at sea to obtain more precise position information under all weather conditions, and could aid air-sea traffic control and coordination of emergency rescue operations. As a result, interagency review of existing and future agency needs is continuing. Various navigation and traffic coordination systems will be analyzed and compared (including those involving satellites) to determine the course of future research and development. In FY 1967, studies were conducted in the navigation-traffic control area to determine the feasibility of incorporating position-fixing experiments on future NASA satellites to establish the operational capabilities of the more promising techniques. In FY 1968, navigation and data collection effort will include studies and experiment development on data and voice transmission via satellite to ships, aircraft, and other mobile platforms; position determination techniques; studies of future navigation and traffic control satellite concepts; and the collection and retrieval of data from moving platforms such as balloons, ocean going buoys, ships and aircraft.

In applications technology FY 1966 and FY 1967 investigations of multiple beam forming, electronically steerable spacecraft antenna array techniques have yielded promising results. Laboratory models of promising arrays were developed for experimental purposes to determine their potential for space applications such as multiple access communications with small mobile terminals, and possibly direct broadcast satellites. Efforts in FY 1967 continued in the area of attitude measurement such as starfield readers, RF sensors, and non-RF sensors; and control devices such as gravity gradient components, momentum wheels and small thrusters were investigated. Effort continued on the design and preliminary development of a spaceborne millimeter propagation experiment for Applications Technology Satellites. Funds in FY 1968 are required for control systems studies directed at stabilization of spacecraft in orbit; spacecraft equipment developments to improve amplification and antenna system capabilities and increase the reliability and useful lifetime of satellite elements. Studies on long-lived, fully stabilized spacecraft having a large space erectable antenna which can be pointed precisely to selected geographic areas on earth will be continued. Active and hybrid gravity gradient stabilization control systems will be considered. A feasibility study will also be conducted to determine satellite system con-

cepts and approaches to provide wide band communications between interplanetary probes and earth terminals via satellite relays; provide aids to interplanetary navigation and tracking; and provide spacecraft-to-spacecraft communications and global navigation aids.

The FY 1966 and prior year Geodetic effort was included in the Physics and Astronomy program. The FY 1967 and FY 1968 geodesy effort will consist of (1) conceptual studies, feasibility analysis, and configuration definition of geodetic spacecraft, (2) analysis of geodetic requirements by various disciplines in terms of spacecraft mission and instrumentation configuration, (3) analysis of feasibility and effectiveness of geodetically optimized ground-based spacecraft observation systems, and of data analysis techniques for active and passive geodetic satellites, and (4) research into geodetic effectiveness and feasibility of advanced observations systems and techniques, to provide more precise and detailed measurement of geodetic data, and to calibrate geodetic observation methods intended for extraterrestrial use.

The FY 1966 and FY 1967 effort in Earth Resources Survey was funded under the Apollo Applications program and is included under this project effective with FY 1968. The FY 1966 and FY 1967 effort supported feasibility studies aimed at developing a research capability and at defining the potential for using remote sensing technology in detecting, measuring, and mapping earth resource phenomena from space. Studies have been conducted to determine the capability of remote sensing devices for obtaining data relevant to the fields of agriculture, forestry, geography, geology, hydrology, and oceanography. Two NASA aircraft equipped with experimental sensors gathered data over selected test sites in support of feasibility studies to assess potential space applications. The aircraft-acquired data, as well as data from such projects as Gemini, TIROS, and Nimbus, were distributed to the investigators for analysis. The Departments of Agriculture, Interior, and Navy are participating in this multidiscipline research. Studies to define the optimum earth resources sensing instrumentation configuration for space flights were also conducted. FY 1968 funds are required to continue the gathering of data from aerial overflight of test sites; for data interpretation; for application techniques; and to further study and improve remote sensing equipment.

TIROS/TOS Improvement

	1966	1967	1968
Spacecraft	$800,000	$2,100,000	$5,600,000
TOS improvements	1,700,000	1,000,000	1,900,000
Total Spacecraft and Support	$2,500,000	$3,100,000	$7,500,000
Delta (Launch Vehicle Procurement Program)	(1,584,000)	(---)	(---)
Total (including Launch Vehicles)	($4,084,000)	($3,100,000)	($7,500,000)

Ten TIROS spacecraft have been successfully launched including TIROS X funded by ESSA. The first eight TIROS spacecraft were spin stabilized and contained two vidicon camera systems and in some cases infrared radiometers; TIROS IX was a "Cartwheel" configuration carrying two wide-angle vidicon camera systems. In response to the requirements of ESSA for an early day-night capability in a single spacecraft, a development effort was initiated for a spacecraft designated TIROS M. The spacecraft design will be based on utilizing flight proven sensors for day and night coverage in a single spacecraft employing a gyromagnetic stabilization system and primarily flight proven components for the basic spacecraft subsystems. The spacecraft will also test a flat plate radiometer to map the earth's heat budget and a solar proton monitoring experiment. The TIROS M spacecraft scheduled for launch in 1968 from the Western Test Range (WTR) will contain two Advanced Vidicon Camera Systems (AVCS), two Automatic Picture Transmission (APT) systems, two High Resolution Infrared Radiometer (HRIR) systems, and secondary sensors. TIROS Operational Systems (TOS) Acquisition Stations at Wallops Island, Virginia, and Gilmore Creek, Alaska, will be utilized. Data will be utilized by the Goddard Space Flight Center (GSFC), ESSA, and cooperating government and non-government meteorological organizations.

The TOS improvements effort provides for the research and development of components and subsystems for meeting the evolutionary requirements of the TOS system which are: (1) increased reliability, (2) extended life, (3) expanded sensor capability, and (4) improved operational capability. Efforts currently being undertaken include development of improved vidicon cameras, automatic picture transmission (APT) location system, radiometers for higher resolution day-night coverage, and a multi-channeled narrow band radiometer.

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

The FY 1965 and prior years funds for this project, including launch vehicles, amounted to $50.0 million. FY 1966 funds were utilized for the design study of the TIROS M spacecraft and continued TOS improvements. FY 1967 funds are being used for initial hardware procurement for the TIROS M spacecraft and TOS improvement sensors development. FY 1968 funds are required to complete development and initiate qualification of the TIROS M spacecraft and to continue TOS improvement subsystem development on the two channel radiometer, high resolution cameras, and vertical profile radiometers. Subsequent funding requirements for completion of TIROS M are estimated to be $3.9 million. TOS improvement effort will continue.

Nimbus

	1966	1967	1968
Nimbus (A-D):			
Spacecraft	$15,300,000	$13,200,000	$14,100,000
Experiments	5,300,000	7,800,000	11,300,000
Ground operations and support	1,960,000	2,400,000	4,100,000
Sub-Total A-D	$22,560,000	$23,400,000	$29,500,000
Nimbus (E&F):			
Spacecraft	---	---	$3,500,000
Experiments	---	---	1,500,000
Sub-Total E&F	---	---	$5,000,000
Total Nimbus	$22,560,000	$23,400,000	$34,500,000
THORAD-Agena (Launch Vehicle Procurement Program)	(7,400,000)	(3,500,000)	(5,000,000)
Total (including Launch Vehicles)	($29,960,000)	($26,900,000)	($39,500,000)

The Nimbus project supports the development of improved meteorological satellites designed to provide data for use by meteorologists, flight test improved spacecraft instrumentation and sensors, and fulfill special data requirements of the atmospheric science research community.

The successful launches of Nimbus I on August 28, 1964 and Nimbus II on May 15, 1966 proved the basic spacecraft configuration and the usefulness of the meteorological sensors tested which included vidicon cameras for global daytime cloud cover data, high resolution infrared radiometer (HRIR) for global nighttime cloud cover, automatic picture transmission (APT) system for direct transmission of realtime daylight cloud cover pictures to small local weather stations and a medium resolution infrared radiometer (MRIR) for full global study of the earth's heat balance. The data from Nimbus II was made available to ESSA for meteorological research and operational use and is being utilized by other domestic users and foreign weather services.

Currently the major effort is being applied to Nimbus B scheduled for launch in 1968 and Nimbus D scheduled for launch in 1970. Significant spacecraft and meteorological sensor advances being developed for testing on these flights are (1) an infrared interferometer and a spectrometer for measurement of the vertical distribution of the atmospheric structure, (2) a solar ultraviolet photometer to extend meteorological observations to

regions of the terrestrial and solar spectrum, (3) an interrogation, recording, location system (IRLS) to collect meteorological data on a global scale, (4) a 50-watt radioisotope thermoelectric generator (RTG) to assess the applicability of this power source for operational meteorological satellites, (5) a sferics detector for location of global thunderstorms, (6) a cloudtop altitude spectrometer to measure cloudtop pressure altitudes during the day to an accuracy of a few hundred meters, (7) a filter wedge spectrometer to monitor water vapor content in the atmosphere and its vertical distribution, and (8) a high data rate storage system and a versatile information processor to collect, transmit and process the variety of meteorological data acquired. Improved versions of these initial test sensors as well as additional sensors for obtaining meteorological data will be tested on the subsequent Nimbus missions, in addition to advanced control and power supply systems.

Two subsequent missions, Nimbus E&F, are planned for initiation in 1968. These spacecraft will continue the evolution of the current series toward greater weight and power capability, providing the basis for further technological advances in meteorological satellites for scientific and operational purposes.

The Office of Space Science and Applications is responsible for the overall management of the Nimbus project. Responsibility for project management is assigned to Goddard Space Flight Center. The major contractors for the Nimbus A-D missions are General Electric for integration and test of the spacecraft and for the controls subsystems and the Radio Corporation of America for camera, power, and data storage subsystems. Selection of the contractors for the additional missions will be initiated in FY 1968.

Fiscal Year 1965 and prior years' funding including launch vehicles, amounted to $126.5 million. Fiscal Year 1966 funds were utilized to complete the spacecraft, integration, test and launch of Nimbus II, and provide ground operations and support; for incremental funding of the Nimbus B spacecraft and experiments and to initiate definition and design efforts on the Nimbus D spacecraft and experiments. Fiscal Year 1967 funds are being utilized for continued data handling on Nimbus II, continued development of Nimbus B spacecraft and experiments and initial procurement of Nimbus D spacecraft and experiments. Fiscal Year 1968 funds are required for evaluation and analysis of experiments and spacecraft data from Nimbus II, complete development of the Nimbus B spacecraft and experiments, continued development of spacecraft and experiments for Nimbus D and for definition and design studies and initiation of procurement for long lead experiments for Nimbus E&F. Subsequent funding requirements for completion, including launch vehicles, are estimated to be $102.3 million.

Meteorological Soundings

	1966	1967	1968
Large research sounding rockets....	$1,920,000	$1,920,000	$1,920,000
Sounding rocket system development.	630,000	630,000	630,000
Field experiment support.....	180,000	450,000	450,000
Total.....	$2,730,000	$3,000,000	$3,000,000

The large research sounding rockets effort is to explore atmospheric characteristics and develop and improve sensors and techniques for obtaining meteorological data on the composition, structure, and behavior of the atmosphere in the region 30 to 60 miles above the earth. The small sounding rocket system development effort is to develop a reliable, inexpensive, simplified system, for obtaining similar data in the region 20 to 40 miles above the earth. The field experiment support effort provides for the sounding rocket experiments in cooperation with other countries. NASA is cooperating with several foreign countries in assisting them to establish their meteorological rocketsonde capabilities. Through this support, useful data are obtained over the territories of cooperating foreign countries on a cost-sharing basis, involving no exchange of funds.

The Office of Space Science and Applications is responsible for the overall management of the project. Project management for large research rockets is assigned to Goddard Space Flight Center, for small developmental rockets to Langley Research Center, and for the field experiment support to Goddard Space Flight Center and Wallops Station.

Fiscal year 1965 and prior year funding amounted to $6.5 million of which $5.4 million was utilized for large research rockets and $1.1 million for small rocket development. Approximately 50 large research rockets and a number of small developmental sounding rockets are launched each year. Funds for FY 1966 were utilized for launch of large research and small developmental sounding rockets, flight test of various payload components, research for system improvements and for initiation of the international cooperative field experiment project with Argentina. Funds for FY 1967 are being utilized to launch large research rockets and small developmental sounding rockets; development and improvement of sounding rocket systems; initiation of design and development efforts on an advanced system; continuation, extension, and development of field experiment projects jointly with countries in South America, Europe, and Asia, to study and observe the upper atmosphere through the coordinated launches of small developmental sounding rockets.

FY 1968 funds are required to provide for the launch of approximately 50 large research rockets to continue study of the relationship of the arctic atmosphere structure to that in the sub-arctic, mid-latitudes, and the tropics during various seasons including the time of greatest frequency of noctilucent clouds; for launch of a number of small development sounding rockets; flight test of various payload components; research to improve rocket performance;

and the continuation and development of the field experiment projects with other cooperating countries.

French Satellite FR-2

	1966	1967	1968
Spacecraft and support.....	---	$100,000	$100,000

This project is to provide for U. S. cooperation with France in a space meteorology experiment involving free floating balloons and an earth orbiting satellite. This experiment will provide the in situ speed and direction of air masses at various altitudes. Data from the experiment will be used to assist in understanding the structure of the atmosphere and extending weather forecasts. A launch, with backup if required, is scheduled for 1969.

France will: (a) design, build, test, and launch balloons and balloon payloads which will be equipped to gather meteorological data in conjunction with an orbiting spacecraft; (b) demonstrate that the balloon position fixing technique developed is feasible; (c) design, build, test and deliver to the launch site two spacecraft; (d) perform satellite ground checkout and tracking, scientific data acquisition and analysis; and (e) provide to NASA the technical data acquired.

NASA will: (a) provide a Scout vehicle and a backup; (b) launch the satellite from either Wallops Island or the Western Test Range; (c) provide technical assistance to France during the spacecraft development and testing phases; (d) assist in data acquisition, as requested; (e) analyze, along with French scientists, the resulting scientific data obtained.

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

This project was initiated in FY 1967 and included in the Space Applications Program since it has meteorological applications. The FY 1967 funds are being utilized for spacecraft and balloon subsystems development support and studies. Fiscal Year 1968 funds are required to continue this effort including analysis of balloon and spacecraft antenna, electronics, balloon position fixing techniques, and general project support. Subsequent funding requirements for completion, including launch vehicle and backup, are estimated at $2.6 million.

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Applications Technology Satellites

	1966	1967	1968
Applications Technology Satellites:			
Spacecraft	$20,300,000	$14,500,000	$7,000,000
Experiments	12,800,000	11,500,000	9,100,000
Operational support	1,331,000	2,470,000	3,700,000
Sub-Total, A-E	$34,431,000	$28,470,000	$19,800,000
Applications Technology Satellites:			
Spacecraft	---	---	$12,000,000
Experiments	---	---	3,700,000
Sub-Total, F and G	---	---	$15,700,000
Total	$34,431,000	$28,470,000	$35,500,000
Atlas Agena and Atlas Centaur (Launch Vehicle Procurement Program)	(11,600,000)	(15,166,000)	(14,024,000)
Total (including Launch Vehicles)	$46,031,000	$43,636,000	$49,524,000

The objectives of the Applications Technology Satellite project are to design, develop, flight test, and evaluate spacecraft capable of performing communications, meteorological, gravity gradient stabilization, scientific and other technological experiments in medium and synchronous orbits. Five spacecraft (A-E) scheduled for launch in the 1966-69 period, will be developed; one spacecraft to be launched into a 6,500 mile circular orbit, primarily to evaluate the performance of a gravity gradient stabilization system; two spin stabilized spacecraft to be launched into synchronous orbit, one of which was successfully launched December 6, 1966; and two gravity gradient stabilized spacecraft to be launched into synchronous orbit.

Two additional ATS spacecraft (F&G) are planned for initiation of development in FY 1968. These are new spacecraft that are both larger and more complex than the initial A-E series. The objectives of these missions are to: (1) develop the technology for erecting and accurately pointing large antennas in space; (2) test multi-beam phased array antennas; (3) extend the accuracy of stabilization systems; and (4) perform a number of technological and scientific experiments. These spacecraft represent an extension of the ATS philosophy of combining the development of technology common to a number of space applications with the flight testing of several promising space applications concepts and associated instrumentation on each individual spacecraft. The additional missions will represent substantial technological advances over the initial ATS A-E series in the areas of

stabilization, antenna pointing, communication techniques and equipment; and in the number and capability of the technological and scientific experiments tested. Studies have indicated that these types of satellites weighing approximately 1,600 pounds can be placed in the synchronous orbit with Atlas Centaur launch vehicles and appropriate apogee kick motor, and the feasibility of developing the technology for erecting large antennas in space.

The Office of Space Science and Applications is responsible for overall management. Responsibility for project management is assigned to Goddard Space Flight Center. The major contractors for the first five ATS's are Hughes Aircraft Company for spacecraft development, and General Electric Corporation for gravity gradient stabilization system development.

FY 1965 and prior year funding for this project, including launch vehicles, amounted to $46.6 million. Funding through FY 1966 provided for the continuation of development including assembly of the first spin stabilized synchronous spacecraft, its experiments and their integration; parts fabrication and prototype model assembly of the second spacecraft and its experiments; and procurement of common components for the remaining spacecraft. Funding in FY 1967 provided for the first launch, completion of the second spacecraft and its experiments and preparation for its launch, fabrication of the third spacecraft and its experiments, and continuation of development on the fourth and fifth spacecraft. FY 1967 and prior years funding includes funds formerly budgeted under the Meteorological Flight Experiments. FY 1968 funds are required for the fabrication of the C-E spacecraft; launch of the A and C spacecraft; scientific and technological experiments including continuation of the meteorological experiment effort; operational support; and for systems studies, preliminary spacecraft design, and for definition and initial development effort of experiments in the communications, meteorological, navigation and geodetic areas for flight test on the new spacecraft that are being initiated to support the F and G missions. Subsequent funding for completion, including launch vehicles, is estimated to be $83.4 million.

Geodetic Satellites (A-E)

	1966	1967	1968
Spacecraft and support.....	$4,993,000	$1,600,000	$4,700,000
Thor Agena and Delta (Launch Vehicle Procurement Program).....	(4,200,000)	(200,000)	(3,000,000)
Total (including Launch Vehicles)	$9,193,000	$1,800,000	$7,700,000

This project was previously included in the Geodetic Explorers project under the Physics and Astronomy program but was transferred to the Space Applications program during FY 1966.

The objective of the Geodetic Satellites project is to conduct geodetic satellite measurements on a world-wide basis which, in combination with astrogeodetic, surface baseline and gravity data available from other sources, will result in: (1) the establishment of a unified world datum accurate to within ± 10 meters in a geocentric coordinate system to which the major world datums will be connected; (2) the definition of the

structure of the gravitational field of the earth and refinement of the locations and magnitudes of large gravity anomalies; (3) the improvement of the positioning accuracy of tracking sites and the location of isolated islands and areas; and (4) an evaluation and correlation of the results obtained from the geodetic instrumentation and techniques utilized.

The Geodetic Satellite Project consists of the PAGEOS I and GEOS A-E missions. PAGEOS I, a passive satellite of an ECHO I type balloon was successfully launched on June 23, 1966 into a near-circular orbit of 2400 nautical miles. GEOS I (Explorer XXIX) was successfully launched on November 6, 1965. All ground observational systems have successfully observed GEOS-I. Considerable data have been taken and are being transmitted to the Geodetic Satellites Data Service at Goddard Space Flight Center.

GEOS-B, like GEOS-I, will carry a full instrumentation complement; including flashing lights; minitrack beacon; doppler beacon transmitters; and C band transponders. Optical reflectors for laser tracking will be included and possibly passive radar reflectors.

GEOS C-E will be developed to contain the experiments required for fulfilling the scientific objectives of the National Geodetic Satellite Program (a joint NASA-DOC-DOD program). The spacecraft are scheduled for launch in the 1969-71 period at the inclinations and altitudes required for: (a) supplying the data for the improvement of the description of the earth's gravitational field, and (b) enabling the several observational networks to obtain data to complete a unified world datum and improve the location of the tracking stations. The three spacecraft will carry some basic GEOS-A and B geodetic instrumentation systems; in addition, other existing systems for an evaluation of their ability to provide precision geodetic data. The spacecraft will also enable the recently developed laser tracking systems to immediately realize their geodetic accuracy of $\pm$ 1 meter. Two spacecraft, GEOS D and E, will be launched from the Eastern Test Range; GEOS-C from Western Test Range.

The Office of Space Science and Applications is responsible for the overall project management. Responsibility for the PAGEOS project management was assigned to Langley Research Center and for GEOS to NASA Headquarters. The major contractor for the GEOS A and B spacecraft development is Applied Physics Laboratory, Johns Hopkins University.

FY 1965 and prior year funding, including launch vehicles, amounted to $14.3 million. FY 1966 funds were utilized to complete the GEOS I and PAGEOS I spacecraft and experiments, and for integration, launch and data acquisition. FY 1967 funds are being utilized to continue development of the GEOS B spacecraft with modification based on experience gained from GEOS I and for continued data acquisition and analysis from the GEOS I

and PAGEOS I missions. Funds in FY 1968 are required to complete the GEOS B spacecraft and provide systems engineering and ground support for its launch in 1968, for continued data acquisition and analysis of GEOS I and PAGEOS I and for initial hardware procurement of the spacecraft and experiments for the GEOS C-E missions. Subsequent funding requirements for completion, including launch vehicles, are estimated to be $25.8 million.

Voice Broadcast Satellite

	1966	1967	1968
Spacecraft.....	---	---	$2,300,000

The objectives of this project are to develop the capability and demonstrate the feasibility of broadcasting aural program material directly to conventional FM and/or shortwave AM radios. The spacecraft transponder could be made wideband to make possible an alternative mode permitting the transmission of wideband program material to specifically designed receivers for experimental purposes.

Two flights are planned for launch in the 1971-72 period on Atlas Centaur vehicles which will carry the necessary equipment aboard a large spacecraft structure to demonstrate the capability for transmission of aural program material via satellites to radios on earth. An active spacecraft stabilization system is planned, but passive control system augmentation is still being considered. A large aperture spacecraft antenna and a high power transmitter are required to provide signals of sufficient magnitude to be received by the receiving systems identified in the project objectives. In addition, antenna pointing and orientation systems are required to direct and provide efficient transmission of aural program material to specified areas. The amount of primary space power required is dependent upon the extent of the capability to direct broadcast signals toward the earth, the quality of reception desired by the users, and the ability of ground receiving systems to receive the signals. Since the power required for aural broadcasting will be several kilowatts, both large sun oriented solar cell arrays and body mounted solar converters are being considered. NASA is currently studying voice broadcast satellites in various orbits. The results of these efforts will be used in selecting the orbit for this project.

The Office of Space Science and Applications is responsible for the overall management of this project. Responsibility for project management will be assigned to a NASA field center.

The FY 1968 activity is to be concentrated on spacecraft design and definition. The FY 1968 funds are required for detailed spacecraft definition studies and analysis to be performed by contractors to be selected. Funding requirements from initiation of development in FY 1969 to completion including launch vehicles are estimated to be $117.7 million.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — BASIC RESEARCH PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Basic Research program supports fundamental research in the physical and mathematical sciences. It is aimed at providing an understanding of the physical phenomena pertinent to other NASA programs concerned with current and future aircraft and space activities. This basic research is carried out principally in NASA's Research and Flight Centers with some contract assistance by universities, industrial research laboratories, and other Government research centers. Since fundamental understanding of physical phenomena in many fields of science is required to develop the technology for NASA's programs, basic research in NASA encompasses a wide spectrum of disciplines. It ranges from very fundamental studies into the nature and properties of atoms and molecules to the more applied research areas of determining the best materials for the supersonic transport airplane. Although much of the Basic Research program cannot be identified with current NASA projects, it increases our knowledge of those scientific areas related to NASA's missions.

The Basic Research program is divided into four broad disciplines: Fluid Physics, Electrophysics, Materials, and Applied Mathematics.

Fluid physics phenomena of significance to aircraft and spacecraft propulsion and power generation, as well as to atmospheric entry dynamics, communication and simulation in laboratory tests, are being investigated in the disciplines of fluid mechanics, aerodynamics, and gaseous physics.

Electrophysics is a research program to gain a better understanding of the interaction of acoustic, magnetic, electric, nuclear and gravitational forces with the electrons and ions of the atomic and molecular constituents of solids, liquids, and gases. This new information is the basis for advancing the state of knowledge of various technologies, especially electronics, space power systems, and propulsion.

The broad goal of our materials research is to understand the behavior of materials under the diverse environmental conditions encountered in aerospace missions. With such an understanding, materials can be rationally designed to cope with high vacuum, high temperature, ionizing radiation, micrometeorite impact, corrosive fluids and electromagnetic fields.

The basic research program in applied mathematics is concerned with the investigation and development of mathematical techniques necessary for applications to the many problems of science and technology which arise in

connection with the aerospace missions of NASA. Mathematical research is extremely valuable in that firm bases for continued research in the other disciplines of science and engineering are provided and, in many instances, significant economies are achieved through the elimination of costly non-mathematical experimentation.

SUMMARY OF RESOURCES REQUIREMENTS:

	1966	1967	1968
Supporting research and technology.....	$22,000,000	$21,465,000	$23,500,000
Total.....	$22,000,000	$21,465,000	$23,500,000

Distribution of Program Amount by Installation:

	1966	1967	1968
Marshall Space Flight Center	$815,000	$888,000	$992,000
Goddard Space Flight Center.	117,000	145,000	175,000
Jet Propulsion Laboratory...	5,056,000	4,757,000	5,125,000
Ames Research Center.....	2,070,000	2,106,000	2,313,000
Electronics Research Center.	1,035,000	1,126,000	1,695,000
Flight Research Center.....	30,000	---	---
Langley Research Center.....	2,144,000	2,360,000	2,420,000
Lewis Research Center.....	2,731,000	2,775,000	2,960,000
NASA Headquarters.....	7,351,000	6,698,000	7,170,000
Western Support Office.....	651,000	610,000	650,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1966	1967	1968
Fluid physics.....	$7,538,000	$7,710,000	$8,615,000
Electrophysics.....	4,726,000	4,335,000	4,740,000
Materials.....	8,438,000	8,038,000	8,655,000
Applied mathematics.....	1,298,000	1,382,000	1,490,000
Total.....	$22,000,000	$21,465,000	$23,500,000

Fluid Physics

Major emphasis in the Fluid Physics program will concern the radiant heat generated by the high temperature gas cap in front of re-entry vehicles at entry velocities in the 40,000 to 70,000 feet per second range. At these

velocities, radiation cooling and large self absorption and precursor effects will require intensive study. The blocking of the radiation by ablation vapors which are added to the flow field by large rates of ablation will also be studied.

During FY 1968, the Langley Hot Gas Radiation Research Facilities will become operational and begin to contribute to the research program in superorbital re-entry radiation. Other facilities will be investigated, such as the explosively driven shock tube, because of its potential for producing the extremely hot gas and high velocity required for laboratory simulation of superorbital flight conditions.

In the study of the radiation properties of gases the emphasis is very much on the basic physics of atoms and molecules and their interactions. Such knowledge contributes to the study of nonequilibrium gas dynamics, chemical kinetics, transport properties and a number of other areas of fluid physics such as the fluid-mechanical laser. Efforts will be made to accelerate research on fluid mechancial lasers because they offer the possibility of generating continuous beams of high power and efficiency and have potential promise for direct conversion of heat to radiation. If such potentials are realized, new possibilities arise for space communication and even for space power transmission.

Re-entry into the earth's atmosphere at superorbital speeds introduces other heating problems besides thermal radiant heating. The trend in vehicle configurations is expected to depart from the blunt shapes in favor of somewhat slenderized shapes where the radiation is less severe in the heating of the vehicle. However, more slender shapes are prone to have turbulent boundary layer flow connected with higher friction and, therefore, higher convective heating rates. Careful investigations have to be made of the onset of turbulent flow to determine at what speed laminar flow can be maintained. Only in the latter case will the more slender shapes with the reduced radiant heating be fully advantageous. The Fluid Physics program will concentrate substantially on this position.

Another important role of boundary layer research is connected with hypersonic aircraft performance; specifically with the large fuel penalty incurred at the expense of payload for any increase in drag. Therefore, research in the field of turbulent boundary layers will expand significantly.

Related to the high speed turbulent boundary layer work is research on flow in advanced rocket nozzles. In such flows, the cumbustion gases accelerate rapidly in the throat region which also is the region of highest heat transfer. The behavior of the turbulent boundary layer and particularly the heat transfer characteristics under those conditions is not well understood. Programs under way are expected to contribute significantly to the design of high performance nozzles having optimum performance and cooling.

In interplanetary flight, the payload fraction increases with specific impulse, and the duration of the mission reduces with increasing thrust to engine weight ratios. Both of these desirable factors require working fluids at high energy densities. High energy density fluids, which exist in the plasma state, are not yet well enough understood, however, to be utilized for relevant system design. Therefore, emphasis is being put on research on the stability, the transport properties, and on the interactions of such plasmas with electromagnetic radiation over the whole spectrum.

Electrophysics

The Electrophysics program consists of in-house and contractual research investigations in the areas of nuclear, atomic, molecular, solid state, and theoretical physics. Concerned with the interactions of various force fields with the fundamental constituents of solids, liquids, and gases, the results contribute to the advancement of technology programs such as electronic communications, space power, and propulsion.

The following are four examples of research presently underway in the Electrophysics program. The first is concerned with the movement of electrons through a thin film of titanium dioxide (TiO_2) placed between aluminum films. The TiO_2 film is an electrical insulator so that electrons normally do not pass freely through the film. To date, this work has been able to explain the electron passage from one aluminum film through the TiO_2 film to the other aluminum film. This understanding shows promise of a device being developed which is a very sensitive detector of long wavelength infrared radiation such as emanates from the planets. The investigation of the various parameters involved will be continued.

The second example is a determination of the attenuation of high frequency acoustic waves by dislocations in the lattice structure of sapphire (Al_2O_3). The dislocations are introduced into the crystal and their density altered by irradiating the Al_2O_3 with fast neutrons, whereby the attenuation is changed. Data are being obtained and analyzed in order to clearly understand the mechanism responsible for the attenuation. Such information should be helpful in achieving new type solid state amplifiers in electronic systems.

The third example is that of self-confinement of a laser light beam. It has been found that when a very intense laser light beam is passed through a liquid-carbon-disulfide cell, the diameter of the light beam is reduced along the cell length. This beam narrowing effect may be applicable in such advanced uses as optical communications and computer readout where very small diameter optical beams are needed. This work will continue to find the explanation of this mechanism by considering the interactions between the laser light and the molecular structure of the liquid.

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An investigation of the growth and formation of tornadoes is the fourth example. The reason for the tornado formation is traced back to the circulation of electrically charged water droplets in the atmosphere. The usual explanation for tornado growth is that the violent atmospheric motion is due to temperature and pressure differences. If the investigation is successful in proving that tornado formation is an electric phenomenon, it may be possible to prevent tornado growth by short-circuiting the charges prior to the circulation build up. A properly constructed laboratory model will be installed and experiments will be conducted to simulate the formation of tornadoes and to investigate in detail the electrical mechanism responsible for their growth.

Nuclear physics research will be intensified using the 600 million electron volt proton accelerator at the NASA Space Radiation Effects Laboratory. The data from the experiments should contribute to our understanding of the effects of impacts of solar protons on the structure of the spacecraft and its equipment. The data may be useful in improving the design of shielding material needed to prevent radiation damage to the spacecraft. Additional attention will be given to obtaining a better understanding of electron oscillations in solid state plasmas. Such research may lead to the generation of coherent radiation at the far ultraviolet and X-ray wavelength regions by techniques not now available. This will extend the spectra of frequencies available for space communications.

Materials

The Materials program ranges from the academic study of submicroscopic phenomena in solids through the more pragmatic development of new materials to the research aimed at producing permanent solutions to such operational difficulties as stress corrosion and fatigue. The kinds of materials within the scope of the program cover a spectrum which includes polymers, ceramics, metals, lubricants, minerals and the composites which take advantage of the mechanical interactions between diverse constituents.

Fundamental research in electronic properties of materials will continue as the Electronics Research Center approaches full operation. Controlled excitation of the vibrations of the electrons in materials produces electromagnetic radiation, as in the laser. Transport of the electrons by way of crystalline defects characterizes such materials as thermistors, superconductors and thermoelectric energy converters. Control of electron spins produces new families of magnetic materials. All of this work will require the highest level of cooperation between the physicist and the materials scientist if continuing advances are to be made.

New discoveries have explained the friction and wear of completely unlubricated solids in terms of the arrangement of the atoms in their crystals. This work will be extended in several directions to include studies of single crystals and of non-metallic materials and development of heat treatments

to change friction and wear characteristics. This effort will assist greatly in obtaining simple and trouble free lubrication systems for advanced space vehicles.

High temperature materials continue to draw attention. The strength of tungsten and tantalum, for example, has been further increased by new techniques for alloying these metals. Development of a slurry process for application of oxidation-resistant coatings increases their reliability for re-entry structures. On the theoretical side, studies of diffusional behavior and of strengthening mechanisms are guiding further improvements. The mechanical working of ceramic materials at high temperatures will also be emphasized in order to develop optimum microstructures which in turn should improve the properties of these brittle materials. Through such techniques as extrusion or swaging the strength of oxides and carbides may be doubled. In a slightly lower temperature regime renewed effort is making dispersion-strengthened nickel-chromium alloys leading contenders for high performance gas turbines.

New temperature-resistant and radiation-resistant polymers such as the pyrrones extend the capabilities of organic materials to approximately 1000°F. Intensified effort will be devoted to their development in sufficient quantity and form for such uses as adhesives and dielectric films. Modifications in chemical structure will be made to optimize useful properties.

Applied Mathematics

The Applied Mathematics program is concerned with mathematical investigations the results of which have applications to the many problems of science and technology relevant to the aerospace missions of NASA. The program consists of both in-house and external research activities and basic mathematical investigations in such areas as ordinary and partial differential equations, numerical analysis, celestial mechanics, and statistics. As the research efforts in the other disciplines of science and engineering within NASA advance, new mathematical problems, requiring new methods and techniques, are continually being raised. Thus, the necessity for a continuing program of research in applied mathematics is clearly demonstrated.

The area of gravitational and orbital mathematics will continue to receive heavy emphasis. This area includes the complex theories necessary for predicting or planning the motion of any object moving under gravitational and other possible forces. The precise mathematical representation, at all times, of any mass moving under the forces of gravitational attraction centered on one or more other moving bodies is a particularly important and difficult problem. Investigations in celestial mechanics and differential equations, including the development of methods of solution and studies of the properties of solutions, are major phases of research in this area. Also, since the differential equations involved in the problems of orbit determination

and prediction are usually so complicated that no exact analytic solution may be known, investigations concerned with approximation techniques and the development of sophisticated numerical procedures will be important problems in this area.

Research will continue in aerodynamic mathematics for investigations of the flow field around or within a body moving at hypersonic speeds, and to improve the mathematical techniques for describing and solving problems in lift and drag theory for various shaped bodies in the gases of planetary atmospheres from high to near vacuum pressures. In addition, studies will also continue in the theory of plates and shells of various shapes and at various temperatures in order to provide the mathematical basis for safe and efficient design of advanced or proposed aircraft and spacecraft structures.

Investigations in propulsion and control mathematics will include in-house research on the applications of modern functional analysis and the calculus of variations to problems concerning the optimization of space flight trajectories. Grants and contracts in this area will be concerned with research in partial or ordinary differential equations, variational methods, and numerical analysis with special emphasis on the development of techniques which have applications to the problems of optimal control theory.

Finally, increased effort will be made in the area of tracking and data processing mathematics. This area is concerned with the development of abstract numerical analysis and computing principles for the purpose of allowing more effective exploitation and efficient use of computation facilities. The mathematical problems include numerical error analysis of tracking accuracy, as related to orbit determination, methods for obtaining the fastest as well as the most precise and convenient handling of large amounts of data, and techniques which allow the reduction of data to simple but scientifically sound summaries.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY SPACE VEHICLE SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objectives of this program are to identify and solve critical technical problems of spacecraft and launch vehicle design. The program is concerned with the more immediate problems of vehicles in actual use or under active development by NASA and the Military Services, as well as the more advanced problems related to the next generation vehicles required for new missions. Although the objectives remain much the same from year to year, the program is continually refocused on new problems as required by the National Space Program and by advancing technology.

The program encompasses the technical areas of Aerothermodynamics, Structures, Space Environmental Factors, Design Criteria, and Flight Experiments. It deals with launch and exit through the atmosphere of the integrated spacecraft and launch vehicle, flight of the spacecraft through space, entry into the atmosphere of the earth and other planets, and landing. Research in all these aspects is accomplished in a complex of advanced ground-based facilities which include high-speed, high-temperature wind tunnels and arc jets, vacuum chambers, high-energy charged particle accelerators, and other equipment. Carefully selected critical flight experiments are carried out in close association with the ground-based research to verify and extend the laboratory results.

Special emphasis in the Space Vehicle Systems Program will be placed in FY 1968 on the continuing M-2 and HL-10 lifting-body flight research program, developing the technology of parachutes and other decelerators for entry and terminal flight in the atmosphere of Mars, and on an aggressive effort to develop the technology of maneuverable gliding descent techniques and systems for the recovery on land of current types of manned spacecraft.

SUMMARY OF RESOURCES REQUIREMENTS:

	1966	1967	1968
Supporting research and technology.....	$26,450,000	$26,635,000	$29,000,000
Lifting-body flight and landing tests.....	1,000,000	1,000,000	1,000,000
Scout re-entry project.....	3,000,000	4,050,000	4,500,000
Small space vehicle flight experiments.....	3,000,000	2,250,000	2,500,000
Project Fire.....	50,000	---	---

	1966	1967	1968
Project Pegasus (Saturn-Launched meteoroid experiment).....	1,500,000	---	---
Total.....	$35,000,000	$33,935,000	$37,000,000

Distribution of Program Amount by Installation:

	1966	1967	1968
Manned Spacecraft Center.....	$456,000	$560,000	$485,000
Marshall Space Flight Center....	4,617,000	3,682,000	4,260,000
Goddard Space Flight Center.....	1,624,000	1,905,000	2,100,000
Jet Propulsion Laboratory.....	3,718,000	2,426,000	1,575,000
Ames Research Center.....	3,126,000	2,825,000	3,015,000
Electronics Research Center.....	250,000	320,000	470,000
Flight Research Center.....	1,010,000	1,010,000	1,200,000
Langley Research Center.....	13,442,000	15,963,000	18,535,000
Lewis Research Center.....	3,199,000	2,288,000	2,425,000
NASA Headquarters.....	3,062,000	2,665,000	2,935,000
Western Support Office.....	496,000	291,000	---

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1966	1967	1968
Spacecraft aerothermodynamics...	$ 6,033,000	$ 4,813,000	$ 5,420,000
Spacecraft structures.....	6,260,000	6,661,000	6,935,000
Launch vehicle aerothermodynamics	735,000	1,118,000	1,230,000
Launch vehicle structures.....	2,523,000	2,909,000	3,040,000
Space vehicle environmental factors.....	8,544,000	10,181,000	10,795,000
Space vehicle design criteria...	1,725,000	953,000	1,580,000
Advanced space vehicle concepts.	630,000	---	---
Total.....	$26,450,000	$26,635,000	$29,000,000

Spacecraft Aerothermodynamics

Spacecraft aerothermodynamics deals with the problems of heating, motions, and control of manned and unmanned spacecraft in hypervelocity entry into the atmosphere of the earth and other planets, and with terminal atmospheric flight and landing of spacecraft.

The FY 1967 program to investigate recovery of manned spacecraft on land has resulted in the testing of several promising steerable-parachute and flexible-wing systems to investigate aerodynamic and structural problems associated with deployment and controlled flight. This program will continue during FY 1968. It will include tests of two full-scale systems appropriate for future Apollo applications.

Continued progress has also been made in research programs on several advanced manned spacecraft concepts including the M-2 and HL-10 lifting-body types. The higher maneuvering potential of these configurations, compared to the Apollo type of spacecraft, permits greater flexibility of return from orbit. The M-2 and HL-10 manned flight research vehicles, constructed to investigate the special problems involved in transonic and terminal flight, have been flown successfully. Flight characteristics of these vehicles in the transonic speed regime will receive emphasis in FY 1968.

During FY 1967 research was intensified on spacecraft configurations for landing instrumented capsules on Mars. This research included the initiation of flight tests of parachutes at very high altitudes in the earth's atmosphere where the air density is comparable to that near the surface of Mars. (See Small Space Vehicle Flight Experiments.) Research on Mars probe entry and landing will continue in FY 1968.

Progress has been made toward better understanding of re-entry heating of spacecraft, including accomplishment during the past year of an important Scout-launched flight experiment of a promising heat shield material that had been extensively tested in ground facilities. Uncertainties still exist, however, regarding the heating environment, ablation processes, and the heating-ablation interactions which are important in tailoring ablation heat shields to particular vehicle configurations and flight conditions. These problems will receive greater emphasis in FY 1968 with the objective of decreasing spacecraft weight and enchancing reuse.

Re-entry heating flight and ground-based experiments in FY 1968 will investigate the heating associated with turbulent boundary layers at high Mach numbers. Ground-based research during FY 1968 will also include studies of re-entry heating problems associated with planetary return at speeds of 50,000 feet per second.

Spacecraft Structures

Major elements of this program are advanced structural concepts and materials applications, protection against entry heating and space environmental hazards, determination of critical loads and structural response, protection against vibration environments and landing impact, and prolonged storage of cryogenic liquids in space.

An important objective is to provide the structures technology necessary to permit expensive spacecraft to be reused. A critical component of current spacecraft is the entry heat protection system which cannot be used more than once nor conveniently repaired. Research is being conducted on concepts for heat shields which could be readily and economically refurbished for repeated flight operations. One promising configuration consists of a number of individual ablative heat shield panels which are insulated from the basic structure and can be easily replaced. The behavior of the joints between such panels under entry heating conditions is, however, a potential problem which requires new testing techniques. Research in FY 1968 will be directed to requisite testing methods as well as to a variety of advanced materials and heat shield concepts.

For long-term space missions such as manned orbiting laboratories, research is being directed toward new concepts for protection against meteoroids to minimize weight penalties. Double-wall structures with thinner walls but with greater wall-spacing than previously considered appear promising. Experimental research to determine the potential weight savings will be undertaken.

Preliminary studies of a large orbiting 120-inch-diameter optical telescope have identified important structural problems related to the high optical quality requirements of the mirror. The mirror must either withstand the severe loads and vibrations of launch and exit flight or be isolated and protected from these forces by suitable mounting systems to prevent damage. The mirror must also be rigid and lightweight. Research will be conducted in FY 1968 to develop solutions to these conflicting requirements.

Another potential mission requiring advanced structures technology is a large radio-telescope antenna. Consideration is being given to the possible use of a very long expandable lattice column that might be used as the central mast for the antenna. Such a mast could be of the order of one-half a mile long and only ten feet wide.

Other areas of research in FY 1968 include structures for landing of manned spacecraft and the problems associated with long-term cryogenic storage in space.

Launch Vehicle Aerothermodynamics

This program deals primarily with aerodynamic characteristics, base heating problems, and the acoustic environment associated with the rocket exhaust. The program also seeks to devise advanced launch vehicle concepts.

Base heating arises from three primary sources: jet-flame radiation, which is complicated by the interaction of multiple jets; convective heating from the rocket exhaust; and after-burning of vented gases in the rocket exhaust. Base heating investigations in these problem areas will be continued in FY 1968.

Studies of the acoustic environment of launch vehicles during flight and ground testing and research to develop more accurate methods of predicting sound propagation over large distances will be continued.

Aerodynamic research in FY 1968 will be focused on improvements to existing launch vehicles and on performance of advanced configurations, including reusable launch vehicle concepts.

Launch Vehicle Structures

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

In 1966, development of a generalized computer program for space vehicle structural analysis was initiated. This program will provide a much improved NASA-wide capability for solving various static, dynamic, and thermal structural problems of space vehicles. One portion of the program will be available in FY 1967, and during FY 1968 the dynamics and thermal sections will be completed.

Another method of determining structural behavior is to test the actual vehicles. In the past, dynamic testing was required either on the full-scale launch vehicle, or on a specially contructed full-scale model. It would be simpler and less costly if tests on small-scale models could be conducted with confidence. Research at Langley during the last three years has been directed to advancement of dynamic modeling technology. Results using models of the Saturn I, Saturn V, and Titan III, indicate that full-scale tests may not be necessary in most cases for launch vehicles of these types. Efforts to improve the technology for simulation of certain vibration characteristics will continue in FY 1968.

Effort will also continue on the more important structural design considerations which affect the weight and cost of launch vehicles. New applications of materials and improved structural configurations will be emphasized.

Space Vehicle Environmental Factors

The objective of this program is to determine the effects of space environment on space vehicle design and operation and to develop the technology for controlling and minimizing these effects. High-energy radiation effects and shielding, the meteoroid environment and impact hazard, low-gravity fluid behavior, thermal radiation and temperature control, and high-vacuum technology are the principal research areas.

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Effort is continuing to resolve problems resulting from charged-particle radiation in space. Research is required on the more critical radiation-sensitive materials and components. Emphasis will be placed on applying knowledge of basic damage mechanisms for pure materials to actual operating devices for the purpose of improving the radiation resistance of spacecraft.

Research is continuing to develop improved shielding materials and methods. Techniques developed have been applied to Gemini and Apollo spacecraft. An advanced shielding concept which uses magnetic and electrostatic forces to deflect space radiation was investigated in FY 1967. This promising work will continue.

The three Pegasus meteoroid detection satellites continue to furnish significant data which together with those obtained by the smaller Explorer meteoroid satellites, have resulted in a revision of the meteoroid design guidelines for the Apollo program, and are being used to formulate definitive generalized space vehicle design criteria.

To obtain information on large meteoroids, natural meteors entering the earth's atmosphere are being studied using radio reflection and optical techniques. Increased emphasis has been placed on this area.

Research will continue in FY 1968 on the behavior of fluids under near-zero gravity conditions. Low-gravity research using drop towers at the Lewis Research Center has led to improved propellant management systems for the Centaur and Saturn S-IVB stages. The effectiveness of these systems was demonstrated in a successful rocket flight experiment in mid-1966. The new 500-foot drop facility at Lewis Research Center has greatly extended our capability for ground testing.

The investigation of thermal equilibrium of space vehicles will continue in FY 1968. In space, ultraviolet solar radiation impinges directly upon the spacecraft and affects the ability of the surface coatings to reflect sunlight, complicating the heat control problem. Research on thermal-vacuum problems in FY 1968 will emphasize development of improved surface coatings and means of simulating the solar/vacuum environment of space as well as investigation of such physical quantities as the thermal radiative properties of solids.

Space Vehicle Design Criteria

The objective of this program is to develop, document, and issue space vehicle design criteria or guides to design to promote the development of more reliable and efficient space vehicles. This object requires the identification of design problems, evaluation of existing information bearing on these problems, and formulation of the required authoritative criteria.

The criteria program encompasses the areas of structures, chemical rocket propulsion, stability, guidance and control, and environment. This work is carried out in the various NASA centers and industry.

This program, which aids in developing more reliable and efficient space vehicles, will continue in 1968.

Lifting-Body Flight and Landing Tests

	1966	1967	1968
Flight vehicle and support services.....	$1,000,000	$1,000,000	$1,000,000

Flight research will be continued on the M-2 and HL-10 lifting-body test vehicles during FY 1968. These vehicles are representative of a class of lifting-re-entry configurations that offer possibilities of substantial improvement in maneuverability over current types, together with a capability for horizontal landing at prepared sites.

The objective of the flight program is to determine the performance and handling characteristics of these vehicles at transonic speeds and during terminal flight and landing. The M-2 configuration has been successfully flown in gliding flight by Air Force and NASA test pilots. The HL-10 is now in flight status. During FY 1968, both vehicles will be flown under rocket power through the transonic and low supersonic speed range.

In FY 1968 it is anticipated that the Air Force will provide a third test vehicle of different design, designated SV-5, to be flown at the Flight Research Center. Funding in FY 1968 will support the continuing flight test program.

Scout Re-entry Project

	1966	1967	1968
Spacecraft and support.....	$3,000,000	$4,050,000	$4,500,000
Scout (Launch Vehicle Procurement Program).....	(---)	(200,000)	(3,800,000)
Total (including Launch Vehicles).....	($3,000,000)	($4,250,000)	($8,300,000)

This project supports atmosphere entry technology by performing critical anchor-point experiments in hypervelocity re-entry flight. Scout vehicles are used. Emphasis is on the technologies of aerothermodynamics and high-temperature structures and thermal protection systems with the aim of correlating, verifying, and extending research results obtained in laboratory facilities.

Two flight experiments will be flown in calendar year 1968 to provide data which cannot be acquired in ground facilities on the aerodynamic heating associated with a turbulent boundary layer at high Mach number. These data are required in the prediction of heating rates and skin friction on a variety of advanced vehicles including lifting-re-entry vehicles, ballistic missiles, hypersonic-cruise aircraft, and certain classes of reusable launch vehicles. Data will also be obtained on the conditions under which transition from laminar to turbulent flow in the boundary layer takes place on a clean, non-ablating surface.

Flight experiments are being studied to determine heat shield performance and to determine aerodynamic-ablating surface interactions at speeds in excess of 50,000 feet per second. Valuable data can be obtained in precursor experiments at intermediate speeds using Scout launch vehicles before proceeding to a much larger and more expensive 50,000-feet-per-second experiment. Development of the intermediate experiments will proceed during FY 1968.

Small Space Vehicle Flight Experiments

	1966	1967	1968
Spacecraft and support.....	$3,000,000	$2,250,000	$2,500,000

Planetary Entry Technology - Small-scale and full-scale parachute testing will be continued in FY 1968 in an effort to evaluate promising parachute concepts for terminal descent of unmanned Mars instrument capsules. Since ground testing cannot duplicate expected Mars descent conditions, small-scale test vehicles and parachutes are carried by a two-stage Nike rocket to test altitudes above the earth which simulate closely the expected Mars atmospheric conditions. Testing will also continue with near full-scale parachutes which are deployed behind a representative Mars entry spacecraft under realistic deployment conditions. These test vehicles are carried aloft by large balloons built especially for these high-altitude tests. In both the full-scale and small-scale tests, the primary objective is to study parachute opening characteristics, structural loading, stability, and the effects of parachute size. Results from these flight tests will provide a basis for later selection and development of the most reliable parachute for a soft landing on the Mars surface.

Further improvement in the size and weight of payload to be landed on the Mars surface can be attained by drag augmentation devices deployed at supersonic or hypersonic speeds before terminal parachutes are deployed. Exploratory flight tests of devices such as extendable skirts and trailing ballutes will be initiated in FY 1968.

Heat Shield Materials Technology - The NASA ground-based program on heat shield materials requires complementary flight tests using Scout launch vehicles (see the Scout Re-entry Heating Project) and also smaller launch vehicles such as the Pacemaker. The small vehicle flight program

provides a needed link between the ground-based results and the larger Scout-launched tests. An important part of the heat shield materials program is test vehicle recovery to permit inspection and analysis of the material after flight.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1968 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — ELECTRONICS SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATIONS:

The Electronics Systems Program has the basic objective of deriving the knowledge and technology through which the requirements of future space and aeronautical systems can be satisfied most effectively. The program encompasses all aspects of electronics and control functions from conceptual system studies to the development and evaluation of new or improved components techniques, and hardware subsystems. Specific examples of program goals are: (1) Long-life attitude control systems, (2) Terminal guidance capability for unmanned planetary spacecraft, (3) Optical technology for space applications, (4) Technology to support direct broadcast of radio and TV from space, and (5) Improved avionics systems for all types of aircraft from light planes to advanced supersonic transports. Complementary to these efforts are the general research in new or advanced techniques for instrumentation, data processing, communications, guidance, control, and component technology. Analytical and experimental studies, performed in industrial, university, and government laboratories are used to achieve program goals. Flight experiments validate research results, collect data, and obtain verification of predicted performances in those areas which cannot be simulated in earth-bound laboratories.

SUMMARY OF RESOURCES REQUIREMENTS:

	1966	1967	1968
Supporting research and technology	$29,848,000	$31,797,000	$39,200,000
Flight projects	2,452,000	1,800,000	1,000,000
Total	$32,300,000	$33,597,000	$40,200,000

Distribution of Program Amount by Installation:

	1966	1967	1968
Manned Spacecraft Center	$500,000	$340,000	$340,000
Marshall Space Flight Center	4,408,000	4,019,000	4,090,000
Goddard Space Flight Center	3,090,000	2,990,000	2,990,000
Jet Propulsion Laboratory	3,591,000	2,182,000	3,040,000
Ames Research Center	3,893,000	3,635,000	3,710,000
Electronics Research Center	5,407,000	9,651,000	15,710,000
Flight Research Center	683,000	810,000	890,000
Langley Research Center	7,442,000	7,024,000	5,915,000
Lewis Research Center	539,000	450,000	460,000
NASA Headquarters	2,747,000	2,496,000	3,055,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1966	1967	1968
Guidance systems.....	$5,940,000	$5,868,000	$6,660,000
Control systems.....	6,073,000	6,365,000	6,755,000
Communications.....	4,725,000	5,027,000	6,445,000
Tracking and data acquisition...	3,372,000	3,100,000	4,380,000
Data handling and processing....	3,532,000	3,821,000	4,755,000
Instrumentation.....	3,981,000	3,816,000	4,760,000
Electronic techniques and components.....	2,225,000	3,800,000	5,445,000
Total.....	$29,848,000	$31,797,000	$39,200,000

Guidance Systems

Guidance systems research and technology efforts are directed toward identifying requirements and characteristics of future space guidance and navigation systems, and developing sensors, components, and subsystems capable of attaining advanced performance goals. Systems and trajectory analyses provide a basis for determining the optimum integration of advanced sensor technology with implementation methods derived from guidance theory studies. Research to develop more powerful tools for analyzing guidance system requirements and performance will be continued in FY 1968.

During the coming year, the development of the first strapdown inertial guidance system using electrostatic gyros will be completed, and laboratory testing will be initiated, in preparation for aircraft flight demonstration in calendar year 1968. Research will continue on fundamental problems limiting the performance of gas bearing, laser and electrostatic gyros, and on advanced strapdown system concepts.

Optical and electromagnetic sensor research and technology will be increased. In the area of simple manual navigation, the excellent accuracy attained in a Gemini star-to-star navigation sighting experiment in FY 1967 will be applied to the development of an Apollo experiment incorporating lunar limb and lunar landmark sightings to be performed in calendar year 1968.

Results of simulator and aircraft flight evaluation of a first generation laser rendezvous guidance system will be applied to extending the technology to wide-angle gimballess optical guidance system development.

Control Systems

Control and stabilization research efforts develop technology for space and aeronautical control systems. Emphasized are precise pointing for astronomical or applications optical systems, increased lifetime of satellite

attitude control for earth orbital missions, aeronautical flight control, display and avionic subsystems and synthesis techniques.

As reported last year, the Langley Research Center placed strong emphasis on controlling and stabilizing space telescopes on manned spacecraft to within 0.1 arc seconds. The control moment gyro subsystem was developed, and consequently incorporated by the Apollo Telescope Mount (ATM) project. Space station application of control moment gyros will be developed.

Gravity-gradient stabilization is typical of the efforts to increase lifetime of satellite attitude control. Concepts developed at the Ames Research Center are being used on the Applications Technology Satellite and the Department of Defense DODGE satellite. Sensors and actuators for long life economical control must be developed.

Both the aircraft flight control and display areas are centers of concentration in a program intended to improve the utility of general aviation. Analytical studies, simulation, and flight test will be used to develop flight control and display systems providing improved navigation and approach capabilities. Fluidic technology is being applied to a 3-axis multimode flight control system recently flight tested. Further cost reduction must be obtained for economical application to light aircraft.

Communications and Tracking and Data Acquisition

Research is directed towards understanding the environment in which communication processes take place, and developing the technology required to optimize the speed, capacity and accuracy of communications and tracking systems. To accomplish these ends, efforts are pursued in the microwave, millimeter, submillimeter, and optical frequency domains.

Space qualified transmitter tube technology has progressed, in the recent years, from tens to several hundreds of watts of transmitted power. Tubes in the 500-watt to 20,000-watt power range are required for earth orbital applications and future deep space missions. Solutions to major environmental problems and long life times must be found. The Electronics Research Center will seek these solutions in the vacuum tube research facility currently being acquired. This equipment will be initially installed in the temporary facilities and moved to the permanent Microwave Laboratory at that Center upon completion.

Larger spacecraft and ground antennas will provide technological support to radio astronomy and direct broadcast missions as well as significantly increase data rate capabilities. A 9-foot deployable spacecraft antenna, described last year, has been successfully tested and is being used as a laboratory instrument to further refine deployment techniques. Research is needed to provide the capability to erect and employ antennas with apertures larger than 30-feet for earth orbital applications, radio astronomy, and deep space missions. Large mechanically-steered antennas present pointing problems. Research on electronically steered arrays now under way should ultimately

result in simplifying these problems.

Information theory is a powerful tool that is being used to increase communication efficiency. For example, coding improvements, recently developed under a university grant, will provide the advanced Pioneer spacecraft with a significant communication efficiency gain without the need for increasing power sources, or introducing expensive spacecraft antenna and structural changes.

There is a critical need for high resolution space telescopes of 60 to 120 inches diameter for optical astronomy and communications. These instruments will provide the capability to study celestial objects which cannot be viewed from the ground because of atmospheric attenuation and will provide vastly improved resolution over that attainable through the earth's atmosphere. The environmental, structural, and control problems associated with such large mirrors in space are almost insurmountable using conventional fabrication and alignment techniques, and unique approaches must be developed. One concept employing a 24-inch diameter, 3-segment mirror feasibility model is now being tested. Initial results have been promising and this will be continued. Successful development of this concept will provide a significant technological breakthrough in space applications of optical astronomy and communications.

Data Handling and Processing

The expanding base of new aerospace knowledge and increasingly more complex experiments require continuing research in data processing techniques and devices to keep pace with our basic capabilities for scientific advancements.

One development to advance technology for high capacity, low power computer memories capable of long life in the space environment employs laminated ferrites as the storage medium. Significant reductions achieved in weight, power, volume, and cost will contribute to enhanced capability for future spacecraft. Efforts will be continued in Fy 1968 to develop circuitry for programming and communications with the memory elements.

A longer range effort to develop optical techniques for spacecraft computer memories with potential advantages of minimum interconnections, greater storage density and ultra-reliability will be continued. The technique uses the magnetic and optical properties of the memory material to store data in binary form. Access to the memory involves a beam of light and a photo-cell sensor, thus eliminating mechanical interconnections to the memory and resulting in higher reliability.

A feasibility study of an automated flight failure warning system for advanced experimental aircraft has been completed. The system employs a computer to monitor many sensors at high rates and provide identification to the pilot/engineer of potentially dangerous conditions in the aircraft. Computers in many future missions, will be required to program and control a wide variety of operations ranging from scientific measurements, guidance,

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navigation, control, system testing, and performance monitoring to control of life support systems. To provide the necessary computer capability, research is being directed toward application of time-sharing and multiprocessing concepts to spacecraft use. This work will continue in FY 1968.

Computer techniques, originally developed for enchancement of pictures such as those transmitted from Mars by Mariner IV, have been applied to other pictures such as medical X-ray photographs, and have indicated the possibility of obtaining information not otherwise available. Exploitation of these techniques for other applications will continue.

Instrumentation

Expansion of scientific and engineering knowledge requires continuous advancement in instrument technology. Aerospace instrument research is needed to increase accuracy and resolution, to extend the measurement range and to improve signal conversion capabilities.

The advent of the laser has made it possible to advance along several measurement frontiers. Examples to illustrate its wide range of application are:

1. The measurement of atmospheric density to altitudes higher than 40 kilometers by recording the backscatter of a ground based pulsed laser has been accomplished. Clouds and aerosol concentrations observed in the lower atmosphere up to 12 km, show promise for successful studies of meteorological phenomena at higher altitudes. Further efforts are required to expand the method for day-light operations and to perform tests at different laser wavelengths.

2. The visualization of flow phenomena around models in wind tunnels at hypersonic speeds becomes increasingly difficult because of the reduced gas density under higher altitude conditions. The introduction of laser light sources permit better optical adjustments since the laser beam is essentially a point source and filters can be used to block the self-luminescent lighting. An overall improvement of a factor of 10 is expected in such systems.

3. Remote measurement of vibrating surfaces has been accomplished by utilizing the doppler shift of a laser beam. This technique, developed for vibration mapping of large structures such as launch vehicles, is also applicable to the calibration of microphone membranes where any attached sensors would grossly distort the vibration characteristics.

4. The measurement of the velocity of a gas stream having variable pressure and density has been difficult in the past because of the disturbing effect of sensing devices placed in the gas stream. Using the doppler frequency difference between undisturbed laser light and light scattered by the flow, a direct measure of the flow speed can be obtained. This method can be used over a wide range of velocities from 1 cm/sec up to 300 meter/sec. Research is planned to extend the technique to higher speeds and to multi-dimensional velocity measurements.

Gamma backscatter techniques are being studied for measuring the density of the Martian atmosphere. Proven feasible for measurement of Earth atmospheric density from rockets, the techniques appear well suited to probing the atmosphere of other planets. Research is needed to provide compensation for the effects of heat shield ablation during planetary approach.

In the field of bio-electronics, a miniature telemetry transmitter and biopotential sensors have been developed and incorporated into a conventional flight helmet to obtain electro-encephalograms with minimum inconvenience to the subject.

Successful tests have been conducted in the Ames Research Center centrifuge and on aircraft training flights. Future efforts are planned to include additional channels for pulse and respiration data and communications.

Electronic Techniques and Components

This project covers the development of electronic components having the performance and reliability required for future space and aeronautical missions, and techniques to improve the quality of procured parts, and extend their useful lifetime.

The usage by NASA of microelectronics is rapidly increasing, largely because they reduce the size, weight, and power consumed, while at the same time increasing reliability. Because of this, the technology of micro-electronics is being given major attention. Materials and processes of manufacture, inspection techniques, increased functionality, and lifetimes of microelectronics are being given special emphasis. Recent advances include development of techniques for vacuum-depositing thin film active devices, and for silk-screen deposition of thick film active elements. These, and related efforts will continue.

The problem of component reliability falls in two major areas: assurance of the quality of procured components, and determination of expected operational lifetime under stressed environments. Improved criteria and test methods for inspecting parts, and more precise methods for analyzing failures and determining their effects on performance and lifetime are needed. The advantages to be realized from increased commonality of procurement and inspection will be studied on an inter-Center basis. The effects of process variation upon quality will be studied by the Electronics Research Center in

recently acquired laboratory equipment in which each of the manufacturing steps can be varied at will, to ascertain the type and degree of process control required for quality parts.

Since the lifetime of the spacecraft ultimately depends on the lifetime of its parts, research to extend the reliable lifetime of parts, and short-term means for ascertaining long-life characteristics are important segments of this subprogram. Techniques for optimizing the design of circuitry; for improving soldering, welding, and packaging; and for detecting errors in assembly, are under development and will continue in Fiscal Year 1968.

Many factors, external to a part itself, have an influence upon its performance and lifetime. Parts that will endure environmental hazards, such as shock and vibrations of launch, high-voltage arc-over and space radiations; and as an alternative, methods for protecting the parts and circuits from such hazards will be developed. As future space missions reach destinations near the sun or far out from the sun, extreme temperatures will be experienced that are beyond the capability of current part-types. Efforts to develop parts that will operate in extreme temperatures will be expanded in Fiscal Year 1968.

SST Avionics

A new segment of the Electronic Systems Program is the effort to develop an integrated avionics system for high speed aircraft of the future typified by the current supersonic transport development program. During FY 1967, the Electronics Research Center initiated a concerted systems analysis program to delineate the avionics requirements of such advanced aircraft. In FY 1968, system requirements resulting from this study will be used to direct research programs to provide the technology for all elements of an integrated avionics system. The system will include the functions of navigation, guidance, control, communications, instrumentation and on-board data processing.

Flight Projects

	1966	1967	1968
Radio Attenuation Measurements (RAM-C).....	$1,300,000	$1,300,000	$400,000
Small Flight Project (SCANNER).....	1,152,000	500,000	---
Earth Coverage Horizon Measurement.....	---	---	600,000
Total Flight Projects.....	$2,452,000	$1,800,000	$1,000,000
Scout (Launch Vehicle Procurement Program).....	(1,400,000)	(900,000)	(1,900,000)
Total (including Launch Vehicles).....	($3,852,000)	($2,700,000)	($2,900,000)

Flight projects serve to substantiate experimental results obtained in laboratory investigations and to measure natural phenomena required in the development of advanced sensors and systems. Brief descriptions of these projects are provided in the following paragraphs.

Radio Attenuation Measurement (RAM)

Project RAM is directed towards understanding the phenomena of plasma formation and its interactions with the spacecraft antenna during atmospheric reentry. This understanding should lead to the development of means of overcoming the signal attenuation and communication blackout present during reentry.

RAM A and B experiments demonstrated the relative merits of using water injection, aerodynamic shaping, and higher radio frequencies as methods of overcoming the blackout problem in the lower reentry velocity ranges.

RAM C will obtain reentry communications measurements in the 28,000 feet per second velocity region. At these velocities, as yet undetermined ionization and recombination phenomena occur which are not present at lower velocities and which cannot now be simulated in ground facilities.

A launch is scheduled in calendar year 1967 for RAM C-A, RAM C-B is scheduled for 1968. Provisions are made for an additional launch during 1968, if the results from the first or second launch make it advisable.

Horizon Definition Research (SCANNER)

The objective of the SCANNER project was to make detailed measurements of the earth's horizon radiation profile and to determine the existence of relatively stable gradients in the profile which could be used to design precise horizon sensors. The project was undertaken as an extension of laboratory research on horizon characteristics to verify theoretical predictions of the existence and nature of radiation gradients. Two ballistic flights were performed by Langley Research Center in FY 1967. The flights provided excellent correlation between the theoretical predictions and experimental results. Continuation of efforts on this problem are now centered in the Earth Coverage Horizon Measurement program.

Earth Coverage Horizon Measurement

This project will extend limited measurements attained through Project SCANNER and supporting X-15 flights to a comprehensive measurement of the earth's horizon radiance profile over a broad range of seasonal and latitude variations. Advanced studies have been initiated in FY 1966 to identify suitable flight experiments and techniques. The preliminary results of these studies and Scanner rocket flights carried out in FY 1967, indicate that an order of magnitude improvement in the definition of the earth's horizon is feasible, and that obtaining comprehensive measurements will require polar orbit satellite measurements over a complete cycle of seasonal

variations. In FY 1967, these feasibility studies will be completed.

The funding requested in FY 1968 will provide for the initiation of project definition studies.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1968 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY HUMAN FACTOR SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

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

The success and the spectrum of missions-of-choice available to future aeronautical and manned space missions are dependent upon the timely solutions to identified technology problem areas. These technology problem areas in the Human Factor Systems program are: physiological effects, human engineering, extravehicular technology, personal protective systems, and life support. The understanding of the physiological effects of man as he responds to long-term manned space flight and future aeronautical flight regimes is necessary for effective integration of man as a functional part of the total system. Human engineering is essential to human factors in aviation, maintainability in space, and for the appropriate design for man in the man-machine complex. Extravehicular technology will provide the astronaut with work aids, translation devices and other astronaut augmentation systems for use in free space as well as on extravehicular surface environments. The technology area of personal protective systems is being pursued to provide the astronaut with protection from all environmental factors noxious to him and to maintain him with personal life support systems. Life support is one of the most difficult technology areas because of the many subsystems capabilities that must be integrated as a functional system.

The Human Factor Systems program is accomplished through a multi-disciplined approach including researchers in nearly every field of medicine, biology, psychology, engineering, physics, and electronics located in NASA Centers, Department of Defense aerospace medical facilities, universities and industry.

SUMMARY OF RESOURCES REQUIREMENTS:

	1966	1967	1968
Supporting research and technology.....	$13,000,000	$14,675,000	$19,500,000
Small biotechnology flight projects.....	1,900,000	1,500,000	1,500,000
Total.....	$14,900,000	$16,175,000	$21,000,000

Distribution of Program Amount by Installation:

	1966	1967	1968
Manned Spacecraft Center....	$ 795,000	$1,160,000	$2,300,000
Marshall Space Flight Center	310,000	300,000	300,000
Goddard Space Flight Center.	25,000	---	---
Jet Propulsion Laboratory...	100,000	---	---
Ames Research Center.....	5,260,000	5,690,000	5,500,000
Electronics Research Center.	359,000	650,000	850,000
Flight Research Center.....	1,500,000	1,000,000	1,000,000
Langley Research Center.....	4,286,000	4,354,000	6,850,000
Lewis Research Center.....	14,000	100,000	150,000
NASA Headquarters.....	2,171,000	2,921,000	4,050,000
Western Support Office.....	80,000	---	---

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1966	1967	1968
Human research and performance	$5,102,000	$6,312,000	$6,500,000
Life support and protective systems.....	4,496,000	5,236,000	8,500,000
Man-systems integration.....	2,902,000	2,702,000	4,000,000
Advanced concepts.....	500,000	425,000	500,000
Total.....	$13,000,000	$14,675,000	$19,500,000

Human Research and Performance

During long term manned space flight missions, man will be exposed to environmental conditions not previously encountered. The technology problem area which refers to man's response to these conditions is physiological effects. Within physiological effects, consideration must be given to the effects on man brought about by altered gravity, spacecraft atmospheres, stress measurements, radiation, and noise.

An example in the altered gravity area is the research on cardiovascular effects being conducted by Mayo Associates for NASA of the acceleration profiles of launch and re-entry. In this research effort the cardiovascular and respiratory dynamics of dogs are investigated during 6-g runs on a centrifuge.

Another problem of altered gravity is its effect on the vestibular system. Under study are the components of the vestibular system in the ear, brain, and spinal cord, along with other related sensors such as the eye.

Using biological information, an engineering model of the vestibular system is being derived to study its non-linear behavior. Human studies include tests with normal and defective vestibular subjects.

The second problem area of physiological effects is the spacecraft atmospheric requirements. For example, the variables under investigation concerning oxygen toxicity are neurological changes, subcellular chemistry, pulmonary pathology, pulmonary mechanics, pulmonary surface characteristics, and microcontaminants of closed systems.

A third problem area of physiological effects is the measurement of stress--the detection and quantification of physiological change in man in space as well as his everyday pursuits. The Flight Research Center is using flight qualified bioinstrumentation to quantify the physiological response of man under stress in high performance aircraft.

The fourth problem area in physiological effects is radiation. For instance, radiological studies are being performed on primates to study the effects of various discrete proton energies as found in solar flares. Other investigations include the study of cataract formation from protracted low level proton radiation on the lens of a rabbit's eye.

The fifth problem area of physiological effects is noise. One of the studies is an effort to quantify the audibility of the N-wave from the sonic boom with its different characteristics. Other studies are measuring the effects of sonic boom on sleeping persons through monitoring the electronencephalogram.

Life Support and Protective Systems

The most critical technology problem area is life support. For extended missions, life support systems which can recycle water and oxygen are most desirable. For example, on a 500 day-mission, recycling water and oxygen will save thousands of pounds per man.

In support of advanced manned space flight missions a two gas sensing system, miniaturized and ruggedized for actual space use, is being developed for atmosphere control. This development followed design studies of two different approaches for the Langley Research Center.

An integrated recycling life support system is under test at Langley Research Center. It is being utilized for ground based tests and an evaluation of systems integration. Subsystem problem areas have been identified and integration interfaces more clearly defined.

Another recycling life support concept is under study which could operate under partial g environments such as the 1/6 g lunar environment. This concept uses a molten electrolyte which permits the continuous removal of carbon dioxide and recovery of oxygen. A solid electrolyte is being studied at the Ames Research Center. Oxides of zirconium, cerium, and calcium are

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being investigated as electrolytes.

The next technology problem area, protective systems, is concerned with new space suits, personal life support systems, and restraining systems. During the past year, two anthropomorphic or form-fitting hard space suits concepts studies have been conducted. These are the RX-4 hard suit, the most advanced development, being developed for the Manned Spacecraft Center, and another hard suit which utilizes no soft elements being developed by the Ames Research Center.

Man-System Integration

Within the scope of the man-system integration subprogram research and technological studies are being supported to solve the programs in the pacing technologies of human engineering and extravehicular technology. In human engineering during the past year, visual information requirements for aircraft handling have been studied for the Langley Research Center. The pattern of instrument scanning by the pilot for a particular mission was determined by computer analysis of the dominant eye movement. This permitted the detailed study of the time and sequence of instrument viewing requirements.

For formulation of space maintenance requirements, data on manned performance capabilities in space suits utilizing maintenance procedures was obtained at the Manned Spacecraft Center.

To provide for adequate design integration of man in man-machine complexes, Marshall Space Flight Center completed a study on the minimum habitability requirements of a two-man lunar scientific vehicle for 18 days.

In the technology area of extravehicular technology, studies are being conducted to evaluate the energy costs and biomechanics of extravehicular operations. Neutral buoyancy techniques in water immersion, simulating in part free space conditions, are exploited. These facilities and techniques were utilized by the astronauts in the last Gemini flights.

Advanced Concepts

Research on advanced concepts in any field is essential to solving the next generation of problems in a particular field.

A representative study at the Applied Physics Laboratory of John Hopkins University is exploring the potential feasibility of an inflatable, non-anthropomorphic space suit concept. In this system, man can extract his arms from the suit arms and perform bodily functions inside, as well as work on intricate equipment with his bare hands.

Small Biotechnology Flight Projects

	1966	1967	1968
Small biotechnology flight projects.....	$1,900,000	$1,500,000	$1,500,000

In addition to ground-based studies, flight validation of concepts is often necessary to verify a concept as a potential useable system. An example is the measurement in the spacecraft of aerosol particles which will not settle with the absence of gravity. These data are necessary for life support system design. Tiny particles of micron size can be harmful to man's respiratory system. This flight instrument will be of use in ground air pollution studies. This experiment is scheduled for the first manned Apollo flight.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY

SPACE POWER AND ELECTRIC PROPULSION SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

Current solar cell, battery and fuel cell power system technologies have permitted the development of useful power systems for a variety of manned and unmanned missions. Nuclear systems are in the early stages of development with several low power isotope systems and one low power reactor system having been placed in earth orbit. However, these current power system technologies are not yet satisfactory for more ambitious missions such as high power, direct broadcast satellites, science probes and orbiters to the distant planets and long duration, manned earth orbital, lunar and planetary missions. The space power program is aimed at providing the research and technology necessary for the improvement and/or development of a limited number of solar, chemical and nuclear systems at a rate consistent with the estimated mission requirements. These potential power requirements range from watts to kilowatts in the early 1970's for unmanned planetary landers and manned orbital missions to megawatts in the 1980's and 90's for manned interplanetary electric propulsion systems.

The electric propulsion part of this program is aimed at providing the research and technology leading to the early application of small solar powered, electric thrustor systems for spacecraft position control; and to the development of both solar (kilowatt class) and nuclear (kilowatt and megawatt class) powered primary propulsion systems. The unique capability of some kinds of electric thrustors to develop very low thrust levels (10^{-5} to 10^{-6} pounds) for attitude and position control, and the high specific impulses obtainable from all electric thrustors offer promise of significant improvements in spacecraft operational simplicity, weight, trip time and payload.

SUMMARY OF RESOURCES REQUIREMENTS:

	1966	1967	1968
Supporting research and technology.....	$38,200,000	$34,940,000	$34,200,000
SNAP-8 development.....	4,000,000	5,500,000	9,700,000
Space electric rocket test (SERT)	3,000,000	---	1,100,000
Total.....	$45,200,000	$40,440,000	$45,000,000

Distribution of Program Amount by Installation:

	1966	1967	1968
Manned Spacecraft Center.....	$635,000	$1,430,000	$800,000
Marshall Space Flight Center.	1,685,000	1,731,000	1,400,000
Goddard Space Flight Center..	4,270,000	4,676,000	4,400,000
Jet Propulsion Laboratory....	4,812,000	5,641,000	7,500,000
Ames Research Center.....	110,000	295,000	250,000
Electronics Research Center..	84,000	853,000	1,500,000
Langley Research Center.....	1,322,000	1,370,000	700,000
Lewis Research Center.....	28,194,000	20,569,000	25,650,000
NASA Headquarters.....	2,586,000	2,862,000	2,500,000
Western Support Office.....	1,502,000	1,013,000	300,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1966	1967	1968
Nuclear-electric power.....	$14,000,000	$12,820,000	$13,200,000
Solar power generation.....	9,050,000	7,450,000	8,300,000
Chemical power generation.....	5,150,000	5,580,000	5,000,000
Electric propulsion.....	10,000,000	9,090,000	7,700,000
Total.....	$38,200,000	$34,940,000	$34,200,000

Nuclear-Electric Power

The purpose of the nuclear electric power generation technology program is to provide a broad option and design basis for the selection and evaluation of energy conversion equipment to be used in advanced nuclear electric power generation systems for future space missions. These systems will utilize nuclear energy generated by isotope or reactor heat sources and, therefore, close cooperation and coordination is maintained with the AEC isotope and reactor programs. The program covers the power range from watts to megawatts with system endurance goals of 1 to 5 years.

The spectrum of electric system technology covers research on several selected and promising concepts including: (1) the Brayton cycle gas turbo-electric system, (2) the Rankine cycle alkali metal turboelectric system, (3) thermionic direct conversion system, and (4) magnetohydrodynamic (MHD) systems. The Rankine cycle and thermionic conversion systems in combination with reactor heat sources offer the potential of achieving the lightest power system weights at high power levels for auxiliary electric power and electric propulsion systems. Both, however, require the establishment of a sound technology base relating to the use of new materials and working

fluids at temperatures never before used in power systems. The Brayton system, with its inherent high cycle efficiency, offers an attractive power source in the 2-10 KW range for manned orbital laboratories especially if coupled with isotope heat sources. MHD systems constitute a longer range research goal of interest primarily because they do not require the use of a rotating turbogenerator, but, instead, generate power by forcing liquid metal fluid through a magnetic field.

The Rankine cycle turbogenerator program in FY 1967 significantly advanced the technology of refractory metals and of such major components as the turbine, boiler and radiator and test instrumentation.

A broad program of property determinations was performed for tantalum, niobium and molybdenum refractory alloys which may be used in eventual development of flight systems. Important properties of these alloys such as strength, resistance to attack by potassium working fluids, resistance to contamination by gases, weldability and fabricability were determined. Design and fabrication were started on an experimental two-phase pumped potassium corrosion loop fabricated from a tantalum alloy. This test loop will be completed in FY 1968 and tests to determine the long term resistance of the tantalum alloy to corrosion by boiling and condensing potassium at temperatures up to 2150°F will be started.

A two-stage potassium vapor turbine successfully completed a 5000-hour endurance test without significant mechanical or erosive damage. Design was completed on a three-stage test turbine which will provide operating data under erosive conditions similar to those predicted to occur in an actual system. Fabrication of this test turbine using a molybdenum bucket alloy will be completed in FY 1968.

During FY 1968 work will be continued on the development of high temperature (~1600°F)-high strength magnetic and electrical insulating materials for use in turboalternators. Mechanical design studies of complete turbogenerator packages were started in FY 1967 and will continue in FY 1968.

During FY 1967 design was completed and fabrication started on a tantalum alloy, 2200°F lithium-to-potassium single tube boiler, intended as a prototype element for later multitube segments and complete boilers. Tests of this boiler are scheduled to start in the latter half of FY 1968. In addition, boiler stability studies were performed in FY 1967 and will continue in FY 1968.

During FY 1968 research and development will be continued on radiators which are required to reject unused heat energy to space. Since the radiators may constitute one-third or more of the entire weight of a space power system, it is important to fully understand the factors which lead to efficient radiator designs. During FY 1968 work is planned on promising radiator concepts such as the vapor chamber (heat pipe) and the effort on structural and mechanical problems of solid fin radiators will be continued.

During FY 1967 fabrication and tests were completed on rapid-response pressure transducers for measurement of absolute and differential pressures of alkali metal systems at temperatures to 2000°F. Design and fabrication were started on flow metering and on-off valves composed of refractory metal alloys in alkali metal streams; testing of these valves is scheduled to start early in FY 1968.

The reactor-thermionic concept of major interest has been the "in-core" reactor approach. In this design the thermionic converters are an integral part of the reactor fuel elements with the fuel cladding serving as the emitter electrode. The major problems presently associated with the "in-core" system include: the high temperature (1700-1900°C) reactor fuels that are required; the achievement of stable, long-lived converter operation; the improvement of converter performance; attainment of a satisfactory integral cesium reservoir design, electrical insulators and seals, and certain reactor design considerations that affect overall system stability.

FY 1968 funds will continue research on these major problems. During FY 1967 converter operating life continued to improve and considerable reactor fuel test data, from both in- and out-of-pile tests, are being obtained. In FY 1968 reactor fuel tests will continue and tests of single-cell fueled-converters will begin at the NASA Plum Brook Test Reactor and irradiations of thermionic electrical insulators will be continued at the University of Arizona Research Reactor. Various promising approaches aimed at improving the performance of thermionic converters will also continue to be investigated at various contractor facilities.

The feasibility of the liquid metal magnetohydrodynamic electric power system concept is being investigated at the Jet Propulsion Laboratory. During FY 1967 data were obtained on many of the critical components which would be used in this system. It was determined that the two-phase supersonic nozzle, the liquid-vapor separator, the liquid diffuser and the MHD generator itself all functioned essentially as designed. During FY 1968 feasibility investigations will be continued and a 50 KW MHD power generator component will be tested.

The work on space isotope power is concerned with the evaluation of low power thermoelectric and thermionic concepts for various missions and with determining the feasibility of the more efficient Brayton conversion cycle for use with isotope heat sources. This work is conducted in cooperation with the AEC which is developing isotope thermoelectric generator systems for NASA's NIMBUS and Apollo programs and is responsible for providing suitable isotope fuel forms and heat sources. During FY 1967 progress was made in understanding the mechanisms of thermoelectric performance degradation. During FY 1967 a simple heat pipe was operated for over 5300 hours at temperatures of interest for thermionic converters, and a heat pipe-thermionic converter combination has operated with good performance for more than 300 hours. These results are promising and testing will be continued in FY 1968.

Technology work on the Brayton cycle power conversion system is continuing with the major emphasis on the design, fabrication and test of a system which will eventually be integrated with a radioisotope heat source to be developed by the AEC. A radioisotope Brayton power system, with a power output in the 2-10 KW range and a cycle efficiency of 25%, is of particular interest for manned space stations. In this power range, where the quantity of isotope required is large, the attainment of high overall conversion efficiency Brayton equipment minimizes the amount of scarce and expensive plutonium-238 isotope required.

During FY 1968 a breadboarded Brayton cycle system will be assembled and testing started in a closed-loop facility where components (turbocompressor, turboalternator, heat exchangers) and control interactions will be studied. The high temperatureisotope heat source program for the power system is being conducted by the AEC and coordination between these programs is being maintained.

Solar Power Generation

Solar Cell Power Systems

Despite the significant success of solar cell power systems, their technological base must be broadened and scaled up to meet the needs of space exploration that may be undertaken in the next decade (1970-79). The largest solar cell power systems developed thus far are those for NIMBUS, Mariner, and the Geophysical and Astronomical Observatories. The peak solar cell array output ranges between 500 to 1000 watts on these spacecraft, while the average power delivered to the loads is between 200 and 500 watts. Power levels in the tens of kilowatts are proposed for such applications as direct broadcast satellites. At present, average spacecraft life is between one and two years. There is a need to acquire the technology to extend the useful life of solar cell power systems to five years by the early 1970's. As space exploration reaches out from the earth to Mars and beyond to Jupiter, and to Venus, and Mercury and even to within five million miles of the Sun, new environments and environmental extremes will be encountered. Present solar electric power technology is not adequate to cope with these new requirements.

A dramatic improvement in radiation resistance of solar cells was achieved with the discovery of the superior characteristics of the reverse structure N/P silicon solar cell in 1960. Even though these cells afforded about 10 times greater resistance to damage than the earlier devices, there is still a need for further radiation hardening of solar cells. In FY 1967 laboratory tests of lithium diffused solar cells have indicated a further gain of 50-100 times may be possible. During FY 1968 work will be conducted to determine long time stability of these new cells and whether such cells will be a satisfactory replacement for the currently used solar cells.

An examination of the space mission possibilities being considered indicates that we should plan on potential requirements for solar power systems delivering up to 50 kilowatts output. Noteworthy examples include direct broadcast satellites, planetary probes using solar-electric propulsion and manned space stations. Starting in FY 1966 NASA began a three-phase program to acquire the technology needed for lightweight (50 lbs/kw), large area (up to 5000 square feet) deployable (folded for launch) solar cell arrays. Work in the second phase was initiated in FY 1967. During FY 1968 the third phase will be initiated and will consist of the experimental fabrication and test of a deployment model of one wing (1250 square feet) of a four wing, 50 kilowatt array.

In addition to the need for lightweight, large area solar cell arrays, there is a need for lightweight, compact arrays to satisfy the increased power requirements of satellites launched on vehicles with limited payload volume. For such cases it appears possible to mount conventional solid or thin film solar cells on flexible plastic substrates which can be rolled up in window shade fashion for compact storage during launch. These arrays could be unrolled in space by actuating self-erecting booms or electric drive motors. During FY 1968 work will continue on compact roll-up and folding arrays.

As solar cell systems increase in size it will be necessary to discover new, low-cost methods of array assembly. More extensive automation of the assembly process than is currently used is one approach for such cost reductions. During FY 1968 studies will be conducted aimed at identifying those processes in array assembly that can be adapted to machine operations.

Power Conditioning

Spacecraft power conditioning requirements to date have been generally limited to a few hundred watts. In FY 1967 work has been started on the problems of scaling up existing solid state converter and inverter technology. Improvements in efficiency are being sought so that temperature control requirements can be reduced to a manageable level. A modularized or building block approach is being studied. Work on high power converters and inverters will be given increased emphasis in FY 1968 and subsequent years.

In FY 1967 work has been initiated on other critical power conditioning problems aimed at extending the life and increasing the power level of solar cell/battery and fuel cell power systems. Methods for failure sensing and isolation will be investigated in FY 1968 and components and circuits for more efficient and reliable distribution and utilization of the raw generated power must be devised. The use of large area solar cell arrays will require suitable methods for orienting such arrays and for transfer of electric power from the turning array to the spacecraft.

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Solar Thermal Systems

Work on solar thermal power systems utilizing thermoelectric, thermionic, and the Brayton gas turbine conversion systems has been decreasing since FY 1964. This decrease has been due in part to the transferal of the solar power program portion of the Brayton effort to the nuclear electric power program where it is being continued for potential use with large isotope heat sources and, in part, due to the relatively lower priority assigned to solar thermal systems. It is expected that this effort will continue to decrease in FY 1968.

Chemical Power Generation

There is a need at this time to obtain the technology for secondary (rechargeable) batteries with 3 to 5 year cycling capability for such applications as communications and meteorology satellites. Cycle tests performed on nickel-cadmium and other alkaline batteries have identified such critical problems as internal shorts, separator deterioration and seal rupture from gas pressure buildup. High failure rates have been experienced and substantial improvements are required if reliable operating lifetimes of 3 to 5 years are to be obtained.

The problem of acquiring the technology for extended cycle life will be time consuming since non-destructive methods for determining the cycle capability do not exist. At the present time, verification of a 5 year life requires testing representative cells for the full 5 years. Work on non-destructive test methods (i.e., methods for determining life capability from limited testing) will be continued. As the size of solar cell arrays is increased, battery size must also be increased in order to avoid the weight and cost penalties that are normally associated with using large numbers of the current small capacity cells. Work has been initiated on large capacity (100 ampere-hours) nickel-cadmium cells and experimental tests on thermal models of full size batteries are underway.

The sealed batteries that are being used in the space program today cannot withstand the high temperature (105-145°C) required for the sterilization of spacecraft components to be landed on planetary surfaces such as Mars. Nickel-cadmium, silver-cadmium and silver-zinc batteries using a mixture of water and potassium hydroxide electrolyte are being investigated and evaluated for landing capsule battery applications. The organic separators used in present batteries tend to disintegrate under sterilization temperatures. Work is underway on new separator materials and will need to be continued in FY 1968. In addition to sterilization conditions, landing capsule batteries will need to withstand high-G loads during atmospheric entry and at impact. Development is required to achieve mechanical ruggedness.

The hybrid metal/gas battery, which is made possible by the development of high-performance fuel-cell electrodes, has been shown to yield at least

a 50% increase in energy density over the best conventional primary battery system. These preliminary indications must now be followed up to obtain the engineering data required in assessing the suitability of the technology for future mission possibilities.

Whereas batteries have been maintained at or near room temperature in space thus far, future mission requirements indicate that batteries operating at extreme temperatures may be needed. These may be extremely low or extremely high temperatures. The problem of coping with long-term battery operation at extreme temperatures will require substantial work over the next several years.

Fuel cells are used in conjunction with primary batteries to provide all the electric power for the Gemini and Apollo spacecraft. However, these systems, although adequate for mission durations of a few weeks, possess drawbacks which discourage their use on advanced manned missions requiring from 30 to 90 days reliable operation. These drawbacks include membrane degradation, electrode corrosion, and narrow operating limits. Preliminary experimental data have been obtained on a two kilowatt breadboarded fuel cell of improved design that operated for about 75 days. Engineering models are being assembled for stack testing at off-optimum conditions to determine the fuel cells' sensitivity to variations in reactant pressure and temperature, to electrode, electrolyte and catalyst temperature and to variations in the water content of the electrolyte. Start-up, shut-down, and re-start characteristics need to be studied. Work is also needed to obtain cathode catalysts with improved stability and more efficient oxygen dissociation.

Early lunar shelters will make extensive use of fuel cell powerplants. In conjunction with solar or nuclear powerplants, fuel cells will be used to power roving vehicles, large portable tools and the lunar shelter during the two week lunar night or during emergency repairs of the primary power systems. The high cost of transporting reactants (hydrogen and oxygen) to the moon will make it desirable to recover the fuel cell product water for drinking and especially for regeneration into hydrogen and oxygen fuel for re-use in the fuel cell. During FY 1968 work will be undertaken to obtain the data needed to assess the feasibility and performance capability of water electrolysis and reactant processing and storage plants suitable for installation on the lunar surface.

There is a general need to provide for research on the properties of electrolytes and on the mechanisms of reactions occurring at electrode-electrolyte interfaces. A better understanding of the mechanisms that govern electrochemical reactions is needed to guide rational choices of new electrolytes and improved structures of electrodes.

Electric Propulsion

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

Electrostatic thrustor systems in which the propellant atoms (or heavy particles) are electrically charged and then accelerated by an electrostatic field, will continue to receive the major emphasis in FY 1968. Two types, the electron-bombardment and contact ion engines which differ basically in the propellant charging or ionization technique, have made the most progress.

One of the most important life limiting components in an electron-bombardment engine is the cathode that produces the electrons necessary for propellant ionization. In FY 1967 endurance tests of several thrustors utilizing cesium and mercury as the propellant, and including several types of cathode design, were successfully conducted with a maximum of 8200 hours being obtained by a cesium thrustor. These data lead to the conclusion that the cathode life problem has been resolved and that it is feasible to build 1-2 kilowatt thrustors with the required operating lifetime. In addition, during FY 1967 a full system test, including thrustor, power conditioning and propellant feed system, was carried out for about 500 hours. The above results provided the level of confidence necessary to proceed in the planning of a second space flight in the SERT series utilizing a mercury thrustor. In FY 1968 attention will shift from life testing toward further performance improvements such as efficiency at lower specific impulses. Also, the effect of a varying power profile such as may be encountered in missions deriving power from photovoltaic arrays on engine performance and control systems will be evaluated. During FY 1967, study on interactions between the propulsion system and the spacecraft were initiated. Effects such as plasma beam impingement on structure, radio frequency interference (RFI), and interaction with the space environment will continue to be investigated during FY 1968. Some of these effects, such as

radio frequency interference, will be evaluated during the SERT flight. The studies of solar-powered mid-course propulsion for planetary missions continue to show promise and these efforts will continue in FY 1968.

In the contact ion engine the propellant atoms are ionized by coming in contact with a hot material, ordinarily porous tungsten. Although the difficulties in obtaining suitable ionizer materials have caused a de-emphasis in research on this type of engine for prime propulsion, the level of technology required for useful auxiliary thrustor development appears to be available. This progress has led to the start of development of a very low thrust (10^{-5} lbs) version for flight test and eventual possible use in the Applications Technology Satellite (ATS) series.

A resistojet system is being flown on the ATS-1 spacecraft as an experiment during FY 1967. This is one version of an electrothermal engine which accelerates propellant by heating and subsequently expanding through a conventional converging-diverging nozzle system. The system on ATS-1 is being evaluated for later applications in an auxiliary propulsion role on the ATS-D and ATS-E synchronous satellites. System studies have also shown the resistojet to be of interest for cancelling aerodynamic drag of large orbiting spacecraft such as orbiting laboratories. Life testing of resistojet thrustors with an initial goal of 2100 hours was initiated in FY 1967. This work will continue in FY 1968. In addition, the possible replacement of the resistojet electrical heater with radioisotope heat sources is being evaluated.

Electromagnetic thrustors, which employ the interaction between high currents and magnetic fields to develop thrust, could offer performance and design advantages in comparison with the much more highly developed electron-bombardment ion engine due to their potential simplicity and smaller size. Consequently, they will continue to receive attention in FY 1968. The verification of performance continues to be an important problem. Improved testing environment and diagnostic instrumentation will be employed during FY 1968 in attempts to eliminate present measurement uncertainties.

SNAP-8 Development

	1966	1967	1968
Development.....	$4,000,000	$5,500,000	$9,700,000

The objective of this project is to obtain the technology leading to the eventual development of a 10,000 hour, 35 electrical kilowatt nuclear electric generating system suitable for space applications in the mid-1970's and beyond. Principal applications proposed for SNAP-8 are large earth orbiting space stations, lunar exploration, direct TV broadcast satellites and manned planetary missions. During FY 1968 SNAP-8 development will emphasize component and power conversion system technology.

SNAP-8 is a joint NASA-AEC development with the AEC responsible for reactor development and NASA responsible for the power conversion system and for full system integration. SNAP-8 utilizes a mercury-Rankine turboelectric conversion loop to convert thermal power developed by a compact reactor into electrical power. The design approach places priority on maximum use of current state-of-the-art and provides flexibility to adapt to a range of potential missions with a minimum of changes in the system.

Under the direction of the Lewis Research Center SNAP-8 components have now been tested in the first power conversion system breadboard and the electrical output, at reference conditions, has been measured at 33 KW. Also, stable operation and control have been demonstrated under simulated space vehicle load conditions. Over 23,000 hours of component testing have been accomplished. Test results indicate that the system pumps, alternator, and condenser are generally satisfactory. Endurance achieved to date for these components ranges from 830 hours to in excess of 4500 hours. Technical problems requiring correction have been identified in the present turbine mechanical design and a life problem has been found to exist in the boiler tubes. Also, testing of the complete power conversion system has indicated the need to improve turbine aerodynamic performance. Progress has been made in improving boiler performance but additional improvement is required.

In FY 1967 the endurance testing of components and the correction of deficiencies noted from tests were continued. This effort will continue through FY 1968. An improved turbine has been designed and will be tested beginning in late FY 1967 and continuing in FY 1968. Experiments in heat transfer and corrosion are continuing in order to provide solutions to the boiler tube life problem. Also, operations of the first power conversion system which began operation in FY 1966 are continuing and in the remainder of FY 1967 NASA expects to complete the investigation and characterization of automatic startup procedures for the power conversion system under simulated space conditions. The first power conversion system will be used to test and verify turbine design corrections.

Funds requested for FY 1968 provide for the continuation of the component and system technology program and supporting investigations as required. It is expected that a 2500 hour performance and endurance qualification test will be run on the improved SNAP-8 turbine. It is intended that the supporting investigations, which are underway and will be continued in FY 1968, will lead to the design and start of fabrication of an improved prototype boiler in FY 1968. Testing of other major components will be continued to further advance the demonstrated endurance capabilities. Testing will be continued to assess the capability of the components to survive and function following shock and vibration associated with launch into space. Component and system technology development will continue to be supported by testing at the Lewis Research Center.

Operation of the first power conversion system will be continued in FY 1968 with the aim of providing performance and endurance data on the turbine alternator under system design conditions as well as providing additional endurance data on other system components.

Space Electric Rocket Test (SERT)

	1966	1967	1968
Spacecraft and Experiments Development	$3,000,000	---	$1,100,000
Agena (Launch Vehicle Procurement Program)	(---)	($500,000)	($5,300,000)
Total (including Launch Vehicle	($3,000,000)	($500,000)	($6,400,000)

The overall objective of the SERT flight program is to provide information on the operation of electric thrustor systems in the space environment. The first flight in the series, SERT I, was successfully concluded in July 1964. This suborbital flight demonstrated that an ion beam could be neutralized in space, and hence removed a basic uncertainty as to the feasibility of ion engines.

During FY 1967 plans were defined for a second flight in the SERT series and initial work toward such a goal was started using FY 1966 funds. The objective of this test is to provide a long term evaluation (minimum of six months) of the performance and reliability of an ion thrustor system in the space environment and to study such other ion engine effects as radio frequency interference, propellant deposition on spacecraft and spacecraft potential. This information is required for the further assessment of ion propulsion for use in prime propulsion applications.

The technical plan for the SERT II development calls for a single launch of a THORAD-Agena from Western Test Range to inject the Agena, together with the attached SERT experiment package, into a near-polar sunlight orbit. Two complete 1 KW ion thrustor systems will provide redundancy. The Agena system, which has been previously employed extensively, will provide the necessary electrical power from a solar array, control system and telemetry system. Present planning calls for the launch to take place during the first half of calendar year 1969.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1968 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — NUCLEAR ROCKETS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objective of the nuclear rockets program is to develop the necessary research, design and engineering data, test hardware and general technology of nuclear engine systems utilizing graphite solid-core reactors for possible advanced space missions and to investigate and evaluate advanced reactor concepts which may offer improvements in nuclear rocket propulsion technology.

The use of nuclear rocket propulsion would provide significant performance advantages for many possible advanced space missions such as high energy earth orbital operations, lunar logistics operations, deep space probes with heavy spacecraft, and manned exploration of the planets. Payload increases of 25 to 100 percent or more are possible through use of nuclear rocket stages in connection with Saturn V. For manned planetary landing missions, spacecraft weight in earth orbit is substantially less with nuclear rocket propulsion than with chemical propulsion, the weight differences ranging from 1 to 2 million pounds for favorable mission modes and times, to many millions of pounds for less favorable mission opportunities.

The nuclear rocket program is a joint AEC-NASA effort, managed by a single office, the Space Nuclear Propulsion Office which was established by interagency agreement between AEC and NASA. Research and technology development work is conducted both in AEC laboratories (e.g., the Los Alamos Scientific Laboratory) and NASA centers (e.g., Lewis Research Center) although the major portion of the work is conducted by industry.

This program supports the objective of continued development of nuclear rocket technology for possible future use. However, if a decision is reached to proceed with the development of a nuclear rocket engine, an activity carried under "allowance for contingencies" in the overall national budget, the program described herein will provide the logical nuclear rocket technology support.

SUMMARY OF RESOURCES REQUIREMENTS:

	1966	1967	1968
Supporting research and technology	$20,644,000	$16,506,000	$16,500,000
NERVA	35,356,000	33,494,000	26,000,000
NRDS operations	2,000,000	3,000,000	4,000,000
Total	$58,000,000	$53,000,000	$46,500,000
Distribution of Program Amount by Installation:			
Marshall Space Flight Center	$1,125,000	$1,500,000	$2,950,000
Lewis Research Center	6,444,000	3,515,000	4,200,000
Space Nuclear Propulsion Office	50,431,000	47,985,000	39,350,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1966	1967	1968
Rocket reactor research.....	$14,901,000	$10,786,000	$ 8,500,000
Nuclear rocket engine systems	4,393,000	3,970,000	4,700,000
Safety.....	250,000	250,000	500,000
Vehicle technology.....	1,100,000	1,500,000	2,800,000
Total.....	$20,644,000	$16,506,000	$16,500,000

The supporting research and technology effort (SR&T) supplies three basic needs: (1) general SR&T data for current projects; (2) basic technology for the development of future generations of nuclear rocket engines and vehicles; and (3) feasibility analyses of advanced nuclear propulsion concepts.

Rocket Reactor Research

NASA conducts two major activities within the scope of rocket reactor research including: (1) research into the problems determining feasibility and performance potential of advanced nuclear reactor propulsion concepts and (2) the development and purchase of jet nozzles and liquid hydrogen feed systems, turbopump systems, to support the reactor tests at the Nuclear Rocket Development Station (NRDS), and the provision of liquid hydrogen to conduct these developments and the reactor tests.

Advanced concept work is concentrated on various types of cavity reactors, in which the fissionable materials are in gaseous or liquid form. In-house capability and research is centered at the Lewis Research Center. Also, the capabilities of industry and universities are applied through contracts and research grants. At the present level of development, emphasis is on laboratory research, to provide the basic research data. During FY 1968, effort must be expended to provide new research tools and methods to extend our knowledge concerning heretofore unattainable pressures and temperatures that would exist in cavity reactors.

NASA has funded the development of a liquid hydrogen turbopump feed system to be used to test the high-power Phoebus-2 and NERVA reactors. These turbopumps are an advancement in the technology established in the feed systems used for KIWI and NRX reactors. Two of these units have been delivered and utilized in qualification and facility tests conducted at NRDS. Additional feed system hardware will be procured during FY 1968 to assure availability of pumping systems to conduct the reactor tests.

The development of liquid hydrogen regeneratively cooled, exhaust nozzles required to meet the Phoebus-2 reactor requirements has been underway since FY 1965. This nozzle development will be completed during FY 1968 with the

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delivery of the nozzles for the Phoebus reactor tests.

Nuclear Rocket Engine Systems

This research provides the necessary advanced component technology for nuclear rocket engines. It seeks to 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. This in-house effort is conducted by the Lewis Research Center with other work being accomplished under industrial and university contracts principally under Lewis Research Center's direction.

The work on turbomachinery 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 combustion rocket technology.

Nuclear rocket engine system research also includes research and development of pneumatic transducers and control components which are less sensitive to radiation damage than normal electromechanical devices.

Engine dynamics are under investigation using the Nuclear Rocket Dynamics and Control Facility at Lewis. In this facility, the first nuclear cold flow rocket engine systems tests were conducted with more than 26 runs having been made on a cold flow nuclear rocket engine to investigate the start-up dynamics of the engine. These runs have included the first bootstrap starts of the nuclear rocket engines, and start-up tests in which the turbopump was deliberately run into stall to determine the start-up performance of a nuclear rocket engine under such conditions. This information supported analysis and power tests of the breadboard engine in FY 1966.

The radiation effects effort conducted as part of the engine systems research work, is directed toward defining the behavior of materials in combined radiation, cryogenic, and vacuum environments. Work in this area is continuing in the Plum Brook Reactor.

Very high bearing speeds and space environmental conditions create difficult development problems in regard to bearings, seals and lubrication. An in-pile bearing test loop is in operation at Plum Brook for research on high speed bearing configurations in a combined radiation and cryogenic environment.

Research on novel designs and materials for fabrication of higher performance nozzles will continue in FY 1968. Efforts will be made to extend the current technology beyond the initial limits needed to provide nozzles for the NERVA engine.

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 primarily from the nuclear rocket program, the research has benefited all programs that use liquid hydrogen by supplying basic property data and cryogenic engineering support. This program will be continued in FY 1968.

Safety

Safety work is an integral part of the overall nuclear rocket program. It includes effort on hydrogen safety by the Bureau of Mines aimed at unique safety problems associated with handling large quantities of liquid hydrogen in ground test facilities and the evaluation of countermeasure systems to assure safe disposal of nuclear engines in-flight. Of special interest are studies and research into means for rapid, controlled venting of liquid hydrogen to reduce weight and provide an additional velocity increment following a premature loss of thrust during flight.

Vehicle Technology

This portion of the program provides basic design information which will assist the development of nuclear rocket vehicles for flight mission applications.

Studies of modular vehicle concepts were initiated in FY 1965. The modular concept has particular attraction since one basic tank/engine system (referred to as a propulsion module) could satisfy a variety of missions. The modular studies have defined a configuration in sufficient detail to determine the feasiblity of such a concept and to point out areas requiring advanced technology effort.

General flight system technology activities underway in prior years continues. Design of a ground test module was initiated in FY 1967 and will be continued during FY 1968. Most of the ground test module work will be conducted in-house at Marshall Space Flight Center to take advantage of the available experience at that Center.

NERVA

	1966	1967	1968
Engine system development.....	$ 5,975,000	$ 5,042,000	$ 5,160,000
Component and subsystem development.....	11,657,000	13,748,000	8,040,000
Ground test and operations support.....	14,803,000	12,654,000	10,300,000
Propellants.....	2,921,000	2,050,000	2,500,000
Total.....	$35,356,000	$33,494,000	$26,000,000

During FY 1968 effort will be directed towards the test activities required to satisfy the remaining objectives of the NERVA technology program. Efforts will support fabrication of the remaining 1,100 mega-watts thermal test articles and the test activities conducted at the Nuclear Rocket Development Station.

The remaining test activities of the NERVA program include two reactor assemblies to investigate corrosion effects up to approximately 60 minutes test duration, and a series of ground experimental engines which will demonstrate engine operation in a downward firing engine test stand. These ground experimental engines will have provisions for remote maintenance and replacement of major subassemblies. In early FY 1968, the NRX-A6 reactor will be tested at rated power in Test Cell "C" at NRDS. In 1968 the final NERVA technology test reactor, NRX-A7, will be tested.

Activation of Engine Test Stand-1 and the Engine Maintenance Assembly and Disassembly Facility will be completed in late FY 1967. A series of cold flow tests using an unfueled experimental engine assembly will be conducted in ETS-1 to demonstrate readiness of the test stand and the capability of the engine to bootstrap in conjunction with the facility exhaust system. Two experimental engine assemblies will be tested. The objectives of these tests include determination of the most desirable techniques for starting and controlling a nuclear rocket engine, demonstration of shutdown techniques using liquid hydrogen for cooling (as in space) and demonstration of the capabilities of the downward firing test stand. The capabilities of these engines for remote maintenance will also be tested.

In FY 1969, the final work in the technology phase of the NERVA program is expected to be performed.

Nuclear Rocket Development Station - Operations

	1966	1967	1968
General site support.....	$1,800,000	$2,600,000	$3,600,000
Capital equipment.....	200,000	400,000	400,000
Total.....	$2,000,000	$3,000,000	$4,000,000

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

Maintenance, housekeeping and management functions must be provided at the site. These functions taken together constitute general site support. They include routine maintenance and operation of the facilities; for example, custodial services, maintenance of roads, grounds, and utility systems and furnishing of utilities, building operating supplies, fire protection, and cafeteria services. Included also are the services of a support contractor to maintain and operate plumbing, electrical, carpenter, welding and machine shops as well as support facilities and equipment.

The amounts shown in this section provide for NASA's share of the general site operations, the major part of which is now funded by the AEC. NASA's share of the NRDS Operation cost will increase from $3,000,000 in FY 1967 to $4,000,000 in FY 1968, to cover the additional support required for the E-MAD and ETS-1 facilities which will become operational at the end of FY 1967 and the increasing effort associated with engine testing.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1968 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — CHEMICAL PROPULSION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The purpose of the chemical propulsion program is to establish a foundation in technology on which to develop and improve propulsion capabilities for the nation's future space missions. The program also supports current mission endeavors by examining the fundamental aspects of problems that arise. The program covers research in propulsion disciplines, engineering data, new cycle and design concept evaluation, design, fabrication and experimental testing; and for the advancement of propulsion to meet requirements for extended orbital and lunar operations, and for planetary observation and landing missions.

Our present space mission capabilities, for both launch vehicles and spacecraft, are heavily dependent on chemical propulsion. Chemical propulsion systems are used for launch vehicles, escape stages, lunar and planetary landing modules, in orbit and de-orbit maneuvers, midcourse correction, attitude control, rendezvous, propellant settling, as well as personnel transport devices. Basic and experimental studies of chemical propulsion systems must extend through the rocket thrust range from micro ounces to millions of pounds. A concentrated effort to realize the full potential of chemical propulsion in systems that can be developed at relatively low cost is a principal purpose of this work. Chemical propulsion work covers liquid and solid propellant systems and hybrid systems, which are a combination of the two main propellant types. Increased knowledge of propulsion processes, design techniques, properties of materials, and fabrication techniques provide the basis for advanced system development. The studies also cover measurement of physical properties of propellants, combustion phenomena, ignition, non-equilibrium and classical thermodynamic processes, development of new materials, understanding and controlling the processes of fluid mechanics, gas dynamics, heat transfer at extremely high rates and solid mechanics.

New propulsion system problems and identification of future requirements are also part of the program. Efforts are made to match propulsion system capability to performance needs of spacecraft and where necessary, to concentrate effort to improve propulsion system efficiency and increase performance of the vehicle. Such analysis leads to assessment of new methods and design concepts. Basic scientific and disciplinary examinations of the propulsion technology are complemented by an experimental demonstration program to disclose the problems of design methods, fabrication and test procedures, and practical operating limits. Information on necessary funding and facilities of a contemplated advanced engine system result from this work. The collation of disciplinary research investigation and advanced engineering technology development provide the base for advancement of chemical rocket propulsion capabilities.

NASA field centers provide direction and support of chemical propulsion activity and are sufficiently diversified to cover the vast array of components and systems involved. Work is done in-house using unique government facilities and by contract with industrial and academic organizations where appropriate.

SUMMARY OF RESOURCES REQUIREMENTS:

	1966	1967	1968
Supporting research and technology	$32,950,000	$30,138,000	$38,000,000
M-1 engine project	2,000,000	---	---
Large solid motor project	4,750,000	3,500,000	---
Total	$39,700,000	$33,638,000	$38,000,000

Distribution of Program Amount by Installation:

John F. Kennedy Space Center, NASA	$193,000	---	$100,000
Manned Spacecraft Center	625,000	$550,000	1,000,000
Marshall Space Flight Center	7,050,000	3,790,000	7,950,000
Goddard Space Flight Center	550,000	450,000	450,000
Jet Propulsion Laboratory	3,511,000	3,338,000	4,600,000
Langley Research Center	2,869,000	2,516,000	2,775,000
Lewis Research Center	17,186,000	11,890,000	9,725,000
NASA Headquarters	2,451,000	5,279,000	7,650,000
Western Support Office	5,265,000	5,825,000	3,750,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1966	1967	1968
Liquid Rocket Research and Advanced Technology	$12,295,000	$11,690,000	$12,450,000
Solid Rocket Propulsion Research and Technology	5,045,000	4,507,000	5,050,000
Liquid Rocket Experimental Engineering	12,660,000	10,984,000	17,000,000
Solid Rocket Experimental Engineering	2,950,000	2,957,000	3,500,000
Total	$32,950,000	$30,138,000	$38,000,000

Liquid Rocket Research and Advanced Technology

The liquid rocket research and advanced technology project provides research in the disciplines associated with liquid rockets. It also studies advanced propulsion concepts to select future mission related programs for further examination in the experimental engineering effort. 200 tasks are now included in this effort. Half are in broadly based applied research applicable to all liquid engines; a third are aimed at spacecraft engine requirements specifically; the remainder at launch vehicle engine problems. 45% of the work is in-house, 45% is contracted with industry and 10% is contracted with universities.

Research includes future requirements analysis, combustion and combustion instability research, studies of ignition, catalysis, and propellant injection, the hydraulic and hydrodynamic behavior of pumps, total system dynamics, examination of promising high performance propellants, including monopropellants, new materials of construction, fabrication processes and techniques, and design data of engineering handbook type.

The high energy space storable propellant effort has made significant progress recently. High performance with difficult-to-handle propellant systems, such as oxygen difluoride-diborane, has now been demonstrated. The oxygen difluoride-diborance (OF_2-B_2H_6) combination provides about 20 specific impulse units over the next best space storable competitor. Further research on chamber construction and cooling will be conducted.

The launch vehicle work includes in-depth analysis and experiments to determine the optimum configuration of multiple chambers expanding on a plug nozzle to examine high pressure combustion, to characterize flow problems in large ducts, to provide data for cool-down and thermal design of large components, to study transient behavior of multiple engine systems, to advance injector design concepts, and to develop methods for more economical fabrication of engine components. The turbopump is being critically analyzed to determine how best to design a pump for rapid cool-down, and to determine how much vapor a pump can actually ingest as a function of its speed. This work will provide defined margins for start and restart conditions. Effort to identify and exploit substantially cheaper ways of constructing rocket engines, while maintaining high performance, light weight, and reliability will be expanded. This effort will capitalize on combining improvements of design techniques with new ways of fabricating materials.

Solid Rocket Propulsion Research and Technology

The solid propulsion research and technology project develops the basic solid propulsion science and technology.

Solid and hybrid systems have certain areas of performance superiority for space missions due to improved reliability, simplicity, logistic and ground support characteristics, as well as potential development and operational economy. In addition to boosters for launch vehicles, solid motors are used extensively in upper stage and accessory applications such as separation, spin, propellant settling, gas generation, and abort.

New demands on solid propellant motors, such as precise propulsion outputs, accurate command cut-off, and a limited number of stop-restart cycles, necessitate a better understanding of the fundamentals of ignition and combustion. Recent advances in steady-state and transient combustion theory have lead to successful demonstration of solid motors capable of interrupted combustion and limited stop-restart cycles. A more profound scientific background is needed. Command stop-restart and thrust variation in solid propellant space motors will receive continued attention in FY 1968.

Hybrid systems offer advantages for some missions, but technology problems must be resolved. High performance propellants which are becoming available need assessment of their kinetics of decomposition, chemical erosivity, instability characteristics, physical properties, sensitivity, and processing characteristics.

Liquid Rocket Experimental Engineering

The experimental engineering effort, in both liquid and solid propellant rocket engines, develops data and experience on engine components and systems, generally in breadboard form, through experimental demonstration tests. These tests verify engineering design concepts and generate sound design and material specifications for new equipment based on test results, define best operating conditions, and lead to good estimates of development procedures, funding and test equipment requirements.

Launch Vehicle Systems - NASA has been engaged for several years in examination of the technology for advanced high performance rocket engines using cryogenic (hydrogen and oxygen) propellants. The NASA effort and complementary work supported by the Department of Defense in the development of technology for engines using cryogenic propellants have proceeded through design studies and are now engaged in testing critical components of such advanced engines. Two approaches have evolved; one operates at high combustion chamber pressures, the other involves a toroidal combustion chamber with a truncated plug nozzle. In the latter concept, chamber pressures are lower; high performance is achieved by greater expansion of gases in a given length.

The diverse technologies of these concepts will be explored with scale model hardware, with particular attention to anticipated trouble areas in future larger applications. In FY 1968 emphasis will be placed on testing of subsystems and components such as turbomachinery, injectors, combustion chambers, valves and controls, and the assembly of these components to examine their dynamic interaction. System integration tests and design integration of an advanced engine will follow in future years. This work will provide the necessary background for advanced engine developments of the 1970's.

Work on these engine technologies has been coordinated with the DoD through joint working groups, ad hoc committees, and subpanel reporting to the Support Space Research and Technology Panel of the Aeronautics and Astronautics Coordinating Board.

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Space Propulsion Systems - The space propulsion experimental work covers three areas: (1) advanced systems utilizing conventional earth-storable propellants; (2) deep-cryogenic systems utilizing liquid hydrogen in conjunction with either liquid oxygen or liquid fluorine; and (3) the space-storable high-energy systems. The storable propellant systems appear most suitable for maneuvering spacecraft into orbit around the planets and onto their surfaces; the normally liquid earth-storables for the near term missions and the high performance semi-cryogenic space-storables for the more ambitious missions of the future. The deep cryogenics are adaptable to missions where the limited storability of liquid hydrogen presents no problem.

Activity in the earth-storable propellant area is diminishing, although improvements must be made in systems to be used for the Voyager mission. Technology work on earth storable systems will continue until the Voyager flight configurations are final. The areas to be studied in FY 1968 are thrust chamber design, positive expulsion, fluid flow regulation, valves and tank pressurization.

Oxygen-hydrogen systems are now operational for short term missions. The technology needed to extend liquid hydrogen storage time is being advanced. A high-performance fluorine-hydrogen engine is being demonstrated. This work will be continued to provide criteria for the design, fabrication, inspection and servicing of flight weight liquid fluorine propulsion systems.

The principal efforts in FY 1968 will be in the space-storable propellant area, with focus on two propellant combinations: oxygen difluoride and diborane (OF_2-B_2H_6) and oxygen difluoride and a representative liquified petroleum gas fuel.

The Lewis Research Center and the Jet Propulsion Laboratory are establishing the performance attainable with these high energy propellants over a wide range of operating conditions, including chamber pressures, thrust levels and mixture ratios. FY 1968 efforts will concentrate heavily on the system aspects of using these propellant combinations. This work will lead to the preparation of preliminary model specifications for high performance spacecraft engines.

Attention will also be directed to extending the space storability of these mildly cryogenic propellants. Experimental data are needed to determine the requirements for insulation, thermal isolation and equipment orientation that will maintain the space storable propellants in equilibrium indefinitely so that no tank venting will be required.

Auxiliary Propulsion Systems - Auxiliary propulsion systems are important for vehicle retro, mid-course and rendezvous maneuvers and to maintain vehicle attitude in flight. Because of repeated use, these small systems must be developed to extremely high reliability. Operational difficulties with current systems indicate a need for further work in this area.

Monopropellant auxiliary systems have the lowest specific impulse, but show adequate system performance for many auxiliary applications. Earth-storable propellant systems are used in many current programs such as the Apollo. High energy propellant auxiliary systems are being examined for use in advanced launch vehicles and spacecraft.

The major effort in the monopropellant area has been with hydrazine, (N_2H_4). Several flight development programs have been committed to use of hydrazine auxiliary systems. Continuing work with monopropellant hydrazine will cover design improvements to the catalyst, evaluation of blended propellants for low temperature storability, use for propellant tank pressurization and power generation applications.

Support of earth-storable propellant systems is directed to elimination of ignition problems which have been the apparent cause of several space system failures.

The high energy oxygen-hydrogen propellant combination has been under investigation for auxiliary propulsion use. The use of oxygen and hydrogen from the stage main tanks of high performance stages such as Centaur and Saturn is being investigated.

Work on space storable propellant auxiliary propulsion systems is just getting under way. Due to the high combustion temperatures associated with the fluorine family of oxidizers used in space storable systems, a primary problem is thrust chamber design. Novel approaches to uncooled designs will be investigated.

Solid Rocket Experimental Engineering

Activity in this area is divided into launch vehicle, spacecraft, and auxiliary propulsion motors.

Launch Vehicle Propulsion - Solid launch vehicle motors are applicable for the first or boost stages of launch vehicles. The main effort in this project is to develop technology to support the large solid-propellant class of motors.

The evaluation of advanced materials for large motor cases is being undertaken. Maraging steel has been satisfactory for the 260" class of motor, but exacting inspection and weld repair standards must be maintained. Since a small flaw could cause motor case failure during hydrotest, investigations of steels that resist such failure are underway. These steel technology developments are finding many uses outside the space program.

Less costly nozzle materials and methods for refurbishing fired nozzles are under study. The materials which are currently used for nozzle ablative sections will be replaced by cheaper materials as they are proven successful in small motor tests.

Thrust vector control is being investigated. The best system for future motor application will be selected on the basis of small-motor demonstrations.

Spacecraft Propulsion - Solid propellant motors are used on small spacecraft, such as Surveyor, for major propulsion maneuvers, such as decelerating to land on the moon. High specific impulse, low inert weight space storability, and in some cases a degree of controllability, are important design features.

An experimental project was started to demonstrate solid-propellant motors which meet the impulse, thrust, control, and structure requirements for space missions. A motor with a high performance beryllium-containing propellant and with thrust restart capability will be demonstrated.

Auxiliary Propulsion - Solid propellant motors are extensively used for retro, ullage, escape, and attitude control applications. Thrust levels of these motors vary from a fraction of a pound to thousands of pounds. One of our goals is to establish consistent criteria for such propulsion systems.

Large Solid Motor Project

	1966	1967	1968
Large solid motor project.....	$4,750,000	$3,500,000	---

The 260-inch diameter solid motor demonstration program is being completed with funds appropriated for FY 1967. The objective of this program has been to establish the technologies of large solid motors to the point where design and development could be undertaken with confidence at the time when a need for flight hardware emerges.

Major progress has been made toward accomplishing these objectives through the construction and firing of two 260-inch diameter rockets. The completion and firing of a third and final rocket of this size in June, 1967, is expected to fulfill the major objectives of the large solid demonstration program. Specifically, the technologies that will have been demonstrated are the selection of motor case material and establishment of fabrication techniques; the design and selection of material for the ablative nozzle; the design of igniters; and the establishment of other incidental but pertinent processes and techniques.

Supporting research and technology activity relating to large solid rockets will continue in FY 1968. This work will be concentrated on motor case materials research and on methods of obtaining high reliability with a view toward enhancing the position of the large solid rocket as a low cost, highly reliable system of the future.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY AERONAUTICS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The role of the Aeronautics program is to provide through research the technology to improve the efficiency, utility, and safety of aircraft. The program encompasses work in aerodynamics, structures, materials, air breathing propulsion, operational aspects, including safety, noise, and sonic boom, and pilot and aircraft integration. Studies in these areas point to the most profitable paths for technological advances in the future. For example, the XV-5A fan-in-wing aircraft, the tilt-wing XC-142A V/STOL transport, and the variable-sweep wing for the F-111 all appeared several years ago as research concepts. In the years between the first indication of the value of the concept and the first flights of the vehicles, NASA aided in the detailed formulation of the concepts and in substantiating through research the over-all capabilities of practical vehicles based on these concepts.

During development of these new aircraft NASA conducts extensive wind tunnel tests, simulator programs, and flight investigations using appropriate testbed aircraft to verify predicted performance and operational characteristics of these vehicles and to aid in the solution of problems of a developmental nature. This advanced technical development in support of military and civil aircraft procurement is performed at the request of the cognizant government agencies and in cooperation with the requesting agency's contractor.

Research in Aeronautics in FY 1968 will include studies directed toward improvement of subsonic aircraft; studies of new materials and structural design concepts required to fabricate reliable lightweight structures suitable for a long life under high temperature conditions for supersonic and hypersonic aircraft; studies of air-breathing propulsion cycles and engine components to increase efficiency and permit the design of efficient lightweight engines for V/STOL aircraft, supersonic transport, and hypersonic aircraft; and studies directed toward improving flight safety and increasing operational flexibility especially under adverse or all-weather flight conditions including general business and private airplanes of present and proposed aircraft.

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:

	1966	1967	1968
Supporting research and technology	$10,186,000	$9,582,000	$18,600,000
X-15 research aircraft	883,000	878,000	4,000,000
Supersonic transport	12,331,000	11,090,000	11,100,000
V/STOL aircraft	3,200,000	5,550,000	7,100,000
Hypersonic ramjet engine	5,000,000	2,000,000	7,000,000
XB-70 flight research program	9,896,000	2,000,000	10,000,000
Aircraft noise reduction	---	4,800,000	3,500,000
Quiet engine development	---	---	2,000,000
Delta X-15 aircraft	---	---	1,000,000
F-111 aircraft	---	---	500,000
F-106 aircraft	---	---	2,000,000
Total	$41,496,000	$35,900,000	$66,800,000

Distribution of Program Amount by Installation:

	1966	1967	1968
Ames Research Center	$4,995,000	$5,980,000	$11,000,000
Electronics Research Center	190,000	94,000	150,000
Flight Research Center	12,605,000	5,191,000	20,500,000
Langley Research Center	11,926,000	12,873,000	18,900,000
Lewis Research Center	9,716,000	10,359,000	14,200,000
NASA Headquarters	2,064,000	1,403,000	2,050,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1966	1967	1968
Aircraft aerodynamics	$2,032,000	$1,625,000	$2,500,000
Aircraft loads and structures	1,915,000	2,252,000	2,800,000
Air breathing propulsion	2,250,000	2,500,000	3,500,000
Aircraft operating environment	3,989,000	3,205,000	3,100,000
Systems dynamics	*	*	6,700,000
Total	$10,186,000	$9,582,000	$18,600,000

* Prior to FY 1968 Aircraft operating environment and Systems dynamics were called Operating Problems.

Aircraft Aerodynamics

Research in aerodynamics is a continuing effort on aircraft components and their combinations, the flow field and boundary layer phenomena associated with them, and the prediction of their aerodynamic characteristics at low and high speeds. This area of activity involves the formulation and refinement of applicable theory and calculative methods, the improvement of wind-tunnel capabilities and experimental techniques, and the application of these tools to the improvement of aircraft technology.

Wind-tunnel and analytical investigations aimed at improving stability and control of general aviation aircraft will be conducted. The first objective in this area will be to devise stability and control concepts which tend to increase the forgiveness of the aircraft in adverse weather operation and in critical maneuvers such as landing. A second objective will be to extend the existing speed, range, and payload capabilities of the class without increasing size or cost.

Improved aerodynamics for subsonic and transonic aircraft will continue to be sought for attainment of higher cruise speeds and flight efficiencies, lower speeds and power requirements during approach and landing (for increased safety and reduced noise), and wider stability and control margins to ease the pilot's workload. While the primary target for this research will be the next generation of subsonic jet transports, any fundamental advances in the technology obtained should also be of benefit to other aircraft types.

Theoretical and experimental studies aimed at determining efficient aerodynamic configurations for volumetrically efficient hypersonic cruise vehicles are being performed and will be continued as part of a systematic program to provide aerodynamic principles for developing highly efficient hypersonic aircraft.

Although lift-drag ratio is an important aerodynamic efficiency parameter in obtaining extended cruise flight, it is not the sole determining factor in the selection of an efficient hypersonic vehicle. Assessment of other fundamental aerodynamic phenomena, such as, shock impingement, boundary layer transition, interference effects, heat loads as they affect skin friction, will be made in detail and included in the design principles for aerodynamic configurations. Intensive efforts will be directed at developing improved methods of predicting the magnitude and distribution of aerodynamic heating on complex configurations representative of hypersonic aircraft. Through these configurational studies the degree of agreement between experimentally determined aerodynamic characteristics and those predicted by available analytic techniques will be assessed. The establishment of this methodology will be somewhat similar to the computer programs of supersonic aircraft technology but modified and extended to the hypersonic speed regime through the use of appropriate theory.

The funds requested are for both small and large-scale models, wind tunnel model support systems, special instrumentation, and support services contracts.

The technology resulting from the research as discussed above will be integrated, through the NASA/Air Force Systems Command Steering Group for joint program planning, into the Hypersonic Aircraft Technology program.

Aircraft Loads and Structures

A structural design problem common to all aircraft is failure due to fatigue, the weakening and cracking which occurs under repeated stressing for all structural materials. Research on fatigue extends from studies directed towards a more accurate definition of the aircraft loads important to fatigue, to cyclic loading tests of components, representative of airframe structures. Increased emphasis is being placed on studies of rates of crack growth under repeated loads and the strength characteristics remaining in a structure containing a fatigue crack.

The prevention of flutter of skin panels in transonic and supersonic flight is a difficult problem. This flutter arises from the complex interaction of numerous aerodynamics and structural effects. A continuing experimental effort involving wind tunnel studies is being maintained to evaluate the relative effects of various parameters including assessment of flutter characteristics of new proposed designs. Complementary analytical studies are being conducted to improve flutter prediction methods for use in design.

Research is being directed toward the development of analytical and experimental techniques to obtain more accurate methods of prediction of the dynamic response of an airplane to atmospheric turbulence. A particularly promising technique, in which the airplane gust response can be determined by means of model tests in a wind tunnel, is being evaluated. Also being sought are improved techniques for predicting structural response to engine and boundary layer noise.

Hypersonic flight presents a formidable task in structural design and materials utilization to obtain light-weight structures for the severe heating environment. Three structural design problem areas are the cryogenic hydrogen tankage, the hot wing and the cooled engine inlets. Laboratory and wind tunnel tests under combined loading and high temperatures and complementary theoretical studies are being initiated and expanded.

Air Breathing Propulsion

The primary goals of the air breathing propulsion research program are to increase the performance, reliability, safety, and economics of

operation in current and future subsonic and transonic aircraft for commercial and military supersonic applications, and to explore the potential of hypersonic propulsion systems. The extensive propulsion research effort directed toward advanced supersonic transport aircraft is described under the heading "Supersonic Transport."

Research is being initiated to determine analytically and experimentally noise generation and transmission processes in fan blade rows and associated ducting. Fan blade row modifications as well as tip speed and loading changes will be studied to determine effective means of reducing noise at the source.

Research will be conducted on inlets, exits, and afterbodies typical of high bypass ratio propulsion systems anticipated for very large subsonic aircraft.

In the hypersonic area, research will continue on representative hypersonic inlets and inlet control systems. Basic studies of supersonic mixing and diffusion, minimum combustion length, catalytic ignition, fuel injection, and ignition optimization will continue. The advanced synthetic air facility authorized last year is to be completed.

Aircraft Operating Environment

Research in this area is directed toward improving flight safety and increasing the operational flexibility of current and advanced design aircraft. Research on aircraft noise is also included.

Aircraft noise alleviation research will continue at the increased level of effort established during the previous fiscal year with emphasis on full-scale hardware and flight tests. Control of fan compressor noise, the greatest source of annoyance during approach to landing, will be studied using acoustically treated fan inlet and discharge ducts on a four-engine jet transport to determine the noise alleviation potential. In addition the economic and performance penalities that would ensue if such systems were to be retro-fitted to present jet transports will be determined. Research on steep approach techniques for minimizing the noise under the flight path by increasing the distance of the aircraft from the ground has indicated the need for new, more positive methods of rapidly controlling the flight path of transport aircraft in climbout and landing approach. Flight tests of the direct lift control concepts developed through analysis and wind tunnel tests will be carried out using a four-engine jet transport prototype modified to incorporate a direct lift control system.

Research will continue on methods to improve control of aircraft during the landing roll out. A program has been initiated to evaluate the effectiveness of grooved runways as a means to improve control on wet runways. Laboratory tests will be made to arrive at optimum runway groove spacing and

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configuration. Based on these results the NASA's Wallops Island runway is to be grooved properly and various aircraft operated therefrom to evaluate operational aspects encountered in full-scale situations.

Aircraft control difficulties while in rough air and operating under instrument flight rules have been carefully documented in the recent past. The research will continue using a variable stability aircraft to change control characteristics to determine favorable aircraft/pilot coupling for rough air flight. The results of the program will be applicable also to the allied problem of flight path control during conditions of clear air turbulence (CAT). Means to detect clear air tubulence in advance of the aircraft to permit the pilot to take adequate penetration precautions or evasive maneuvers are also under study as part of a coordinated governmental effort.

Based upon previously-funded studies, refinement of computer simulations of seat/passenger restraint systems will make available for the first time meaningful design criteria on which the seat designer can rely in providing greater safety and survivability to the passenger involved in an airplane crash.

Basic research studies on fuel ignition sources and mechanisms of fuel ignition in tanks and vents, investigations of the behavior of aircraft metals when struck by lightning, the effect of lightning strikes on fuel systems, and investigations of cold flame phenomena in the SST environment should provide a greater measure of safety against in-flight fires as well as an understanding of factors affecting post crash fire prevention.

Empirical and analytical investigations of turbine disk burst containment/deflection schemes will be continued.

Other research programs are concerned with: artificial precipitation of moisture to prevent generation of warm fog; sampling the velocity-acceleration-altitude experiences of commercial aircraft during routine operations; and relating radar reflectivity to areas of intense lightning, winds, and hail intensity to improve operational procedures near severe storms.

Aircraft System Dynamics

Research in this area is directed toward obtaining a better understanding of the interrelationship between the pilot and the vehicle he controls. This includes improving methods for aircraft control, the measure of pilot acceptance of vehicle handling characteristics and improvement in the capability of ground and flight piloted simulators for handling qualities investigations of all classes of aircraft. In addition to continued ground-base simulator and variable-stability airplane studies of particular handling qualities problems of existing aircraft, criteria will be formulated for new classes of aircraft.

Improved methods for control of future, huge jet transport aircraft to provide satisfactory handling qualities during low ceiling-low visibility approach and landing will be investigated using existing ground-based simulators and by flight tests with a current jet transport. Of particular concern are the slow pitch and maneuvering responses of such aircraft at low speeds. An increased effort in general aviation will be directed at wind tunnel, simulator, and flight studies to determine stability derivatives and other handling qualities data pertinent to easing the flight control problem for non-professional pilots.

X-15 Research Aircraft

	1966	1967	1968
Aerodynamics.....	$267,000	$160,000	$40,000
Loads and structures.....	10,000	215,000	230,000
Propulsion.....	---	---	---
Operating environment.....	606,000	503,000	30,000
Systems dynamics.....	*	*	3,700,000
Total.....	$883,000	$878,000	$4,000,000

* Prior to FY 1968 Operating Environment and System Dynamics were called Operating Problems.

The X-15 Research program provides data on manned, maneuverable hypersonic flight. The X-15 provides the only means in the world for studying hypersonic flight in its true environment. Experimental results to date have given basic insight into problems of aerodynamics, structures, propulsion and operations. The X-15 results provide confidence and guidance to research in ground-based hypersonic research facilities enabling exploration in depth of many hypersonic flight problems. Major programs which will use this X-15 capability in the future are the Hypersonic Ramjet Experiment and the advanced technology delta wing designed to investigate the programs of hypersonic cruise aircraft propulsion systems and configurations, respectively.

In addition to a continuing program in basic hypersonic flight research, the operational success of the X-15 program has opened its use to space sciences as a carrier vehicle for certain experiments requiring its unique performance capabilities. For example, research on horizon seekers for satellites; high-speed high-altitude photography and stellar ultraviolet radiation has been performed using the X-15 as a carrier vehicle. This type of research will be continued during FY 1968.

Total funding responsibility for the operational support of the X-15 research program, conducted in cooperation with the Department of Defense since its inception, will be transferred to the NASA on January 1, 1968,

for the remainder of FY 1968 and all subsequent years, in accordance with the decision of the NASA-DOD Aeronautics and Astronautics Coordinating Board. This support has cost approximately $8,000,000 per year. Therefore, operational support of the program for one-half of fiscal year 1968 is $4,000,000.

Supersonic Transport

	1966	1967	1968
Aerodynamics.....	$585,000	$700,000	$800,000
Loads and structures.....	385,000	800,000	700,000
Propulsion.....	9,260,000	8,790,000	7,000,000
Operating environment.....	2,101,000	800,000	800,000
System dynamics.....	*	*	1,800,000
Total.....	$12,331,000	$11,090,000	$11,100,000

* Prior to FY 1968 Operating Environment and System Dynamics were called Operating Problems.

By inter-agency agreement, NASA will continue to provide technical support and assistance to the Federal Aviation Agency* (FAA) in the evolution of the U. S. prototype supersonic transport. In addition NASA, by virtue of its statutory responsibility, will conduct a continuing research program to provide the technology for improved and advanced airframes, propulsion systems, and operational concepts applicable to this type of aircraft.

Aerodynamic research will be directed to extend the technological state-of-the-art to higher cruise speeds, increase aerodynamic efficiency throughout the speed range, and improve supersonic flow field patterns to minimize generation of sonic boom. These objectives, of prime importance to the ultimate usefulness of supersonic transportation, will be pursued by continued analytical and experimental effort in wind tunnels on shape optiminzation, minimization of performance penalties for adequate stability and control, development of techniques for dealing with aeroelastic deflections of the structure, and reduction of design contraints imposed by sonic boom considerations.

The effects of low-density fuels such as liquid methane and hydrogen on the characteristics of the aerodynamic configuration will be determined. Particular attention will be given to the transonic and low-speed as well as the supersonic characteristics of promising advanced concepts. Feasibility and preliminary design studies will be performed concurrently as needed to guide and focus the activity.

Wind tunnel tests and associated direct technical support will be provided for the National Supersonic Transport Development Program as required. This support will include necessary use of NASA facilities and key personnel by the FAA* and its contractors in the course of prototype development.

*Currently the Department of Transportation.

Design problems associated with gust loads will continue to receive increasing attention. The supersonic transport, (SST) because of large size and high speed, will exhibit a greater response than current subsonic transports to the large size or long wavelength disturbances of the atmosphere. Special airborne instrumentation currently being developed will be utilized in flight to obtain a definition of atmospheric turbulence for these conditions. If the long slender fuselage of the SST has a sizeable dynamic bending response to turbulence a problem of passenger and crew comfort arises. Analytical and experimental wind tunnel studies will be continued aimed at minimizing the structural response to atmospheric disturbances.

The NASA-FAA-USAF have initiated a joint program to measure the cosmic and solar radiation environment at SST altitudes. Measurements will be made with NASA instruments carried aloft in balloons, launched at the Churchill Research Range, and in RB57F aircraft, supplied by the USAF. The objective of the NASA measurements will be to map the components of radiation as protons, neutrons, stars and heavy primaries. Interaction between these particles and the atmosphere cannot be precisely defined at present.

FAA instrument packages (containing a tissue equivalent dosimeter, a linear energy transfer spectrometer, and a geiger counter) will also be installed in the USAF RB57F aircraft to measure radiation intensities to complement the NASA component measurements.

Measurements will be made over a three year period of increasing solar sunspot activity and at different geographical locations. Establishment of the radiation environment will permit an analysis to be made of the biological significance of the radiation and indicate what precautions, if any, need be taken during high altitude flight.

Operational research on sonic boom will be concentrated upon further exploration of various atmospheric effects on boom signatures such as temperature, turbulence, wind shears and humidity. In addition, laboratory studies of structural response to booms and field tests of boom seismic effects will be expanded following the initiation of these programs in the later part of the present fiscal year.

The General Purpose Airborne Simulator (modified Jet-Star aircraft) and the new six-degree-of-freedom motion Advanced Aircraft Simulator will be used to investigate handling qualities problems unique to supersonic transport operations and to simulate a complete SST mission profile. In addition, take-off and landing certification criteria for SST's will be evaluated.

An increasingly larger in-house propulsion research effort is being conducted to provide the advanced technology required for second generation supersonic transport engines. In general, the work will be a continuation of the effort instituted during FY 1965, 1966, and 1967, and will be focused on advanced engine components and materials.

Some of the promising compressor and turbine blade element designs will be incorporated into single stage and multistage wheels for further research. Advanced cooling techniques and the use of advanced materials will also receive consideration and study during this period. Combustor and augmentor research will continue to follow the trend of advancing the initial combustion research from small scale models and segment rig work to larger scale model studies. The work on lubrication systems, bearings and seals will be directed to increasing the reliability and life of these critical elements.

V/STOL Aircraft

	1966	1967	1968
Aerodynamics.....	$1,055,000	$1,000,000	$1,900,000
Loads and structures.....	40,000	200,000	100,000
Propulsion.....	280,000	2,000,000	2,100,000
Operating environment.....	1,825,000	2,350,000	100,000
System dynamics.....	*	*	2,900,000
Total.....	$3,200,000	$5,550,000	$7,100,000

* Prior to FY 1968 Operating Environment and System Dynamics were called Operating Problems.

Research on V/STOL aircraft will be directed at improving the performance of the more promising types and at easing the difficult flight control problem existing during the transition from conventional flight to hover, particularly during poor or zero visibility conditions.

Wind tunnel and flight research will be continued on the hingeless and jet flap rotor principles offering the potential of increasing the cruise performance of helicopters, reducing the rotor generated vibration and improving the control power. Studies will continue on the use of small wings and auxiliary thrusting devices to reduce the rotor thrust and lift requirements in cruise, and hence increase efficiency. Much of this activity will be a cooperative effort with the U. S. Army in view of the great importance of helicopters to that organization.

Two promising techniques for improving short take-off or landing (STOL) aircraft performance will be given major attention. The first, a flap containing a rotating cylinder has been shown by wind tunnel tests to be very effective in converting propeller thrust to lift, enabling very low speed flight. An effort is being made to arrange for release to NASA, from the Navy, one of the COIN aircraft in order that it can be modified to contain the rotating cylinder flap and enable carrying this research to flight. The second is a wing flap arrangement which effectively utilizes air bled from the jet engine compressor to provide a substantial augmentation in wing aerodynamic lift. This technique evolved from a joint program between the NASA, the Canadian

Defense Board, and De Havilland of Canada who are undertaking preliminary wind tunnel study. The joint wind-tunnel program will continue with a more sophisticated model and, if the initial promise remains, plans will be developed to carry the technique to flight research.

Wind-tunnel research will continue to be directed at improving hover performance of vertical take off on landing (VTOL) aircraft. Detailed studies will be made of advanced propellers, ducted fans, lift fans, lift-cruise fans, and direct-lift engines, and of the installation and noise problems of these propulsion types in various designs in order to improve hovering, efficiency and reduced adverse interference effects. Studies of these designs will also continue to find arrangements providing good levels of control and stability throughout transition from conventional flight to hover.

As noted earlier, the most difficult problem in V/STOL operation is that of flight path control during transition, particularly under poor visibility conditions. The problem contains two major elements; providing the proper airplane handling qualities, and providing the pilot proper information in a readily understandable form.

Studies of V/STOL handling qualities follow two lines: First an establishment of desirable handling qualities in general, and second, techniques for obtaining these in given V/STOL concepts. The first, which also has an important input to the FAA's certification problem, is being studied through use of variable stability aircraft and ground based simulators. Continued use will be made of the X-14 airplane, the CH-46 helicopter, and the 6-degree-of-freedom simulator. Increasing refinement of these studies will lead to a clearer definition of criteria that V/STOL aircraft must meet if it is to be operationally successful.

Studies of the way in which the various promising concepts can meet these criteria will continue with wind-tunnel models particularly aided when the new V/STOL facility comes into operation and in flight research. Flight programs using the P-1127 fighter and the XC-142A transport will be active in 1968. Through the NASA/Air Force V/STOL Technology Panel, plans are being made for a jet-fighter VTOL research airplane program now in the feasibility study stage by NASA and AFSC.

All of the problems related to flight control during transition are amplified when operation under poor visibility conditions is considered. All of the handling qualities programs are conducted with this constraint in view. Two programs will continue which are relating handling qualities requirements to the information a pilot requires to perform the task and to provide information enabling a rational division of effort between the pilot and automatic guidance and control systems. Studies providing this information for helicopters and VTOL aircraft are underway using a Bell 204B helicopter; for STOL aircraft the system studies are being carried out in a Convair 340 aircraft. As solutions to the problems become evident from this research, the work will be

transferred to more appropriate VTOL and STOL aircraft. The VTOL research airplane referred to earlier is expected to be an important tool in completion of this research.

The growing air breathing propulsion research program will expand to include research on propulsion systems appropriate for V/STOL aircraft. Lift fan types and light weight turbojets of small volume will receive special attention. Noise control will form a major constraint in this research.

Hypersonic Research Engine

	1966	1967	1968
Propulsion.....	$5,000,000	$2,000,000	$7,000,000

This project was initiated to accelerate the technological advancement of air breathing propulsion for hypersonic atmospheric flight by: (1) providing a focus for application and integration of fundamental and engine component research; (2) generating factual engine data as a basis for future decisions; (3) guiding and stimulating future hypersonic air breathing propulsion research; and (4) establishing the validity of existing hypersonic engine research and development methods and facilities, and establishing future requirements.

Three contractors participated in parallel feasibility and preliminary design studies of a liquid hydrogen fueled research engine capable of operating at speeds between Mach 3 and 8 with combustion occurring in both a subsonic and supersonic air stream. The Garrett Corporation was selected to conduct the detailed design, experimental wind tunnel verification, fabrication, and proof test of its proposed concept. This engine must be capable of withstanding the severe environment of hypersonic flight, and regeneratively cooled surfaces will be used within the engine to maintain structural integrity.

Upon delivery of the research engine, a test program will be initiated to determine the performance levels and operational problems associated with this hypersonic propulsion system. This will be accomplished by using the X-15 aircraft as a test vehicle to obtain the necessary test environment.

XB-70/SST Flight Research Project

	1966	1967	1968
Aerodynamics.....	$5,146,000	---	---
Loads and structures.....	600,000	---	---
Propulsion.....	850,000	---	---
Operating environment.....	3,300,000	*	---
System dynamics.....	*	$2,000,000	$10,000,000
Total.....	$9,896,000	$2,000,000	$10,000,000

* Prior to FY 1968 Operating Environment and System Dynamics were called Operating Problems.

The potential of the Air Force XB-70 aircraft as a research tool to obtain research information and advanced technology for design, development, construction, and flight test of the prototype supersonic transport has been recognized for several years. The NASA research portion of the XB-70 program began in FY 1963 with installation of instrumentation in the two XB-70A aircraft during manufacture and the subsequent acquisition of certain data during the preliminary USAF flight test program. The second phase, beginning early November 1966 consists of continuation and expansion of the initial program plus the start of research which could not be done during the USAF flight program.

In the second phase basic theories and the results of small-scale tests performed in ground-based facilities will be evaluated. Efforts will be directed toward analysis of the effects of vehicle size and weight; the effects of inertia combined with low aerodynamic damping at the higher operating altitudes of the SST; and the effects of structural elasticity and deformation on the basic aerodynamics of the vehicle. The highest priority tests during this second phase are directed toward a better understanding of sonic boom phenomena and their effect on persons on the ground. These problems have and will continue to be the subject of major research efforts in analysis and ground based facilities; the XB-70 program will provide vital guidance and assessment of the initial planning of these programs, assuring that major programs such as the supersonic transport will proceed on a sound basis.

During the first phase, the instrumentation and data acquisition was funded for those measurements of interest to NASA and the FAA. The cost of operating the aircraft was funded by the Department of the Air Force. In the second phase (the present NASA-USAF XB-70 Flight Research Program authorized by a NASA-DOD Memorandum of Understanding signed on May 28, 1965) the total cost of the program is shared equally by the Department of the Air Force and the NASA.

The FAA participates in the overall planning of the program, including determination of the specific program objectives and priority of the objectives and is kept informed on the progress of the program.

Aircraft Noise Reduction

	1966	1967	1968
Operating environment.....	---	$4,800,000	$3,500,000

Two important aspects of aircraft noise alleviation are covered by the research to be carried out in this program area (1) the research and development necessary to provide means for minimizing the noise radiated from the compressor and fan discharge ducts of turbofan engines such as are installed in presently operating commercial jet aircraft, and (2) research directed toward developing a more positive means for accurate flight path control which

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would be required in order to make use of steeper approach paths for landing thus increasing the distance of the aircraft from the ground in the vicinity of the airport and lowering the noise level.

Both project elements were initiated in FY 1967 and will continue in FY 1968 and will involve wind tunnel testing, simulation, design, ground testing and flight testing to produce flight proven hardware which may then be utilized by the aircraft industry as the economics of the situation warrants.

In FY 1968 the study and development of means of minimizing the noise radiated from turbofan engines will be in a phase of construction and ground run up testing of selected turbofan engine nacelle combinations utilizing acoustic treatment and choked inlet approaches. In the same period the research related to more positive means of flight path control will enter the construction and modification phase for the installation of direct lift control devices on a suitable four-engine commercial jet transport as a preliminary to planned flight tests.

Quiet Engine Development

	1966	1967	1968
Propulsion.....	---	---	$2,000,000

Basic research has shown that the elements of a turbojet engine can each be modified in design to permit substantial noise reduction with small penalty in performance. Information on the successful operation of such a propulsion system is completely unavailable. The interaction of the various components will differ substantially from any turbojet propulsion system now in use. The objective of the Quiet Engine project is to combine all of the low noise elements into a single operating system having approximately 20,000 pounds of thrust, and designed to operate at high subsonic flight speeds.

Based on theoretical and basic laboratory research, compressors, including both fixed and rotating components, burners, turbines, and nozzles, will be designed to permit maximum noise reduction with a minimum performance penalty. These elements will be constructed in operational form and size appropriate to 20,000 pounds of thrust. They will be combined into complete propulsion system(s) and research conducted in the Propulsion System Laboratory at the Lewis Research Center. In addition to establishing the performance of the individual elements of the system, particular attention must be paid to the interaction between elements to assure satisfactory system operation over a wide range of conditions.

Delta X-15 Aircraft

	1966	1967	1968
Aerodynamics.....	---	---	$550,000
Loads and structures.....	---	---	450,000
Total.....	---	---	$1,000,000

The NASA and the USAF have been engaged in formulating a joint long-range program planning effort on hypersonic aircraft technology. Ground and flight programs have evolved after considerable study and numerous interagency discussions to provide the pertinent hypersonic research. The flight program includes only high priority projects in which both agencies are participating jointly. A part of the flight research program is the delta X-15 project which is being conducted by the NASA.

An existing X-15 aircraft will be modified by substituting a highly instrumented, slender delta-wing for the present wing and horizontal tail surfaces. The basic objectives are to obtain unique in-flight aerodynamic, structural and materials research information on an aircraft with a representative wing designed for flight in the hypersonic speed range up to Mach number 8. Current wind tunnels capable of operating above Mach number 5 do not fully duplicate the hypersonic flight environment. Detailed flight measurements will be obtained for comparison with ground facility results and, at the same time, will provide the basis for evaluating and upgrading ground facility test techniques.

In FY 1966 and FY 1967 wind tunnel tests necessary to define and designate a structural wing configuration including the development and selection of pertinent instrumentation were initiated. This ground based research will continue in FY 1968.

A minimal contractual study was initiated in FY 1967 which is concerned with an analysis of the feasibility of converting an X-15 to a delta-wing configuration and the generation of preliminary and limited design data. FY 1968 funds are requested for an overall engineering design prerequisite to the fabrication and assembly of this delta-wing X-15 airplane.

F-111 Aircraft

	1966	1967	1968
Propulsion.....	---	---	$250,000
System dynamics.....	---	---	250,000
Total.....	---	---	$500,000

The objectives of this program are to obtain in-flight verification and validation of wind tunnel and theoretical prediction of aerodynamic characteristics and performance of variable geometry aircraft to define areas in which more research is needed and to provide confidence for the design of future vehicles. The F-111 is the first production variable-sweep aircraft to reach flight status. The program todate has accumulated a large amount of wind tunnel test data that is available for comparison with data to be obtained in flight. A number of problems can be investigated only in flight research such as the combined and inter-related effects of aerodynamics; structures; systems; inlets and exits; and the pilot-in-the-loop.

This program will be carried out using an F-111 loaned to NASA by the Department of the Air Force under a reimbursable support agreement; NASA funds the maintenance and spare parts and operational support of the aircraft.

F-106 Aircraft

	1966	1967	1968
Propulsion.....	---	---	$2,000,000

The supersonic transport, in addition to attaining high efficiency while in the cruise condition, must also maintain a high level of performance at the lower speeds associated with take off, holding traffic patterns, subsonic cruise, and transonic acceleration. To provide this high level of performance over a broad range of flight speeds, the inlet and exhaust systems will be required to undergo a considerable change in geometry. The performance and operation of these systems are sensitive to the manner in which they are integrated into the airframe design, with the interactions between airframe and propulsion system exerting a strong influence on total performance.

To study these problems a small jet engine will be installed in a nacelle typical of that proposed for the supersonic transport, and mounted on the lower wing of an F-106 airplane similar to that proposed in the SST installation. Methods of controlling the interaction between inlet, nozzle and airframe to maintain high efficiency under all conditions will be studied in true flight environment.

OFFICE OF TRACKING AND DATA ACQUISITION

TRACKING AND DATA ACQUISITION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The purpose of this program is to provide responsive and efficient tracking and data acquisition support to meet the requirements of all NASA flight projects. In addition, support is provided, as mutually agreed, for projects of the Department of Defense, other Government agencies, and other countries engaged in space research endeavors.

Support is provided for manned and unmanned flights; for spacecraft, sounding rockets, and research aircraft; and for earth orbital and suborbital missions, lunar and planetary missions, and space probes.

Types of support provided include: (a) tracking to determine the position and trajectory of vehicles in space, (b) acquisition of data from scientific experiments and on the performance of spacecraft and launch vehicle systems, (c) transmission of commands from ground stations to spacecraft, (d) communication with astronauts and acquisition of medical data on their physical condition, (e) communication of information between various ground facilities and mission control centers, and (f) processing of data acquired from the space vehicles. Such support is essential for the critical decisions which must be made to assure the success of all flight missions, and, in the case of manned missions, to insure the safety of the astronauts.

Tracking and data acquisition support is provided by a world-wide network of NASA ground stations and control centers supplemented by instrumentation ships, aircraft, and selected ground stations of the Department of Defense. These facilities are interconnected by a network of ground communications lines, undersea cables, high frequency radio links, and communication satellite circuits, which provide the capability for instantaneous transmission of data and critical commands between spacecraft and control centers. Facilities also are provided to process into meaningful form the large amounts of data which are collected from flight projects. In addition, instrumentation facilities are provided for support of sounding rocket launchings and flight testing of research aircraft.

The Research and Development appropriation provides funds for: (a) the operation and maintenance of the world-wide facilities, (b) the procurement of equipment and modifications to adapt the facilities for new and changing

flight project requirements, and (c) the investigation and development of advanced tracking and data acquisition equipment and techniques. The subsequent sections describe plans and related funding requirements to continue the Tracking and Data Acquisition program in each of these areas during FY 1968.

SUMMARY OF RESOURCES REQUIREMENTS:

	1966	1967	1968
Operations	$127,510,000	$197,400,000	$228,800,000
Equipment	89,755,000	59,650,000	55,100,000
Supporting research and technology	13,800,000	13,800,000	13,800,000
Total	$231,065,000	$270,850,000	$297,700,000

Distribution of Program Amount by Installation:

	1966	1967	1968
Manned Spacecraft Center	$1,271,000	---	---
Marshall Space Flight Center	1,627,000	$800,000	$800,000
Goddard Space Flight Center	155,425,000	191,400,000	213,100,000
Jet Propulsion Laboratory	52,629,000	55,800,000	60,400,000
Wallops Station	5,300,000	6,600,000	7,100,000
Flight Research Center	1,900,000	1,900,000	2,000,000
Langley Research Center	1,800,000	2,450,000	2,000,000
NASA Headquarters	11,113,000	11,900,000	12,300,000

BASIS OF FUND REQUIREMENTS:

Operations

	1966	1967	1968
Manned space flight network	$37,909,000	$65,200,000	$78,000,000
Satellite network	27,640,000	35,000,000	38,500,000
Deep space network	25,350,000	35,900,000	39,800,000
Other instrumentation	6,620,000	7,000,000	7,300,000
Communications	23,890,000	44,300,000	52,700,000
Data processing	6,101,000	10,000,000	12,500,000
Total	$127,510,000	$197,400,000	$228,800,000

Manned Space Flight Network Operations

The primary function of the Manned Space Flight Network is to provide tracking, data acquisition, communications, and command support for NASA's manned space flight programs. The Network: (a) provides spacecraft tracking data which are used to initiate and verify orbital maneuvers, (b) receives telemetered information concerning the condition of the astronauts and the performance of the spacecraft, (c) communicates information to control centers in real time for critical decisions, (d) transmits commands to the spacecraft, and (e) records the engineering data from the spacecraft. In addition to support provided for manned missions, selected stations of the Network provide support to unmanned deep space and earth orbital projects of NASA and the Department of Defense.

The Manned Space Flight Network, having completed support of the Gemini program, has successfully supported three Apollo Uprated Saturn I missions and is being prepared to support additional Apollo Uprated Saturn I missions and the upcoming Apollo Saturn V missions. The Network, when completed for Apollo, will consist of: (a) ten 30-foot diameter antenna stations located at Cape Kennedy; Bermuda; Antigua; Ascension; Canary Island; Carnarvon, Australia; Guam; Kauai, Hawaii; Guaymas, Mexico; and Corpus Christi, Texas; (b) three 85-foot diameter antenna stations located at Madrid, Spain; Canberra, Australia; and Goldstone, California; and (c) one transportable 30-foot diameter antenna station at Grand Bahama Island. In addition, five instrumentation ships and eight aircraft, operated by the Department of Defense, and three 85-foot diameter antenna stations of the Deep Space Network will provide support for Apollo. Secondary support will be provided by NASA stations at Tananarive, Madagascar, and Canton Island; and by Department of Defense stations at Point Arguello, California, and White Sands, New Mexico, using existing equipment.

The station at Kano, Nigeria, was closed upon completion of the Gemini program, and support from the Department of Defense station at Eglin Air Force Base, Florida, was terminated. In addition, support by two ships, the Rose Knot Victor and the Coastal Sentry Quebec, will be phased out early in the Apollo program.

During FY 1967, facility and equipment additions for Apollo support are being completed at eight Manned Space Flight Network stations. In FY 1968, six more Manned Space Flight Network stations, the three Deep Space Network stations, and the five instrumentation ships will be completed for Apollo support.

There has been a correspondingly rapid buildup of personnel to staff the stations and to perform necessary computer programming, network engineering, and logistics support which will continue into FY 1968. The FY 1968 operations budget reflects a significant increase to cover both a full year

of costs for those augmentations which are being effected in FY 1967 and initial costs for those augmentations which will be effected in FY 1968.

Also during FY 1968, the eight Apollo/Range Instrumentation Aircraft (A/RIA), which are being modified under the management of the Department of Defense, will become operational. About 30% of the total Manned Space Flight Network operations increase from FY 1967 reflects Department of Defense estimates for operating these aircraft.

Satellite Network Operations

The primary function of the Satellite Network is to support NASA's unmanned scientific and applications satellite programs. The Network includes the electronic stations of the Space Tracking and Data Acquisition Network (STADAN) operated by the Goddard Space Flight Center, supplemented by the optical camera tracking stations operated by the Smithsonian Astrophysical Observatory. The STADAN stations provide a ground system which: (a) tracks each satellite, (b) determines the status of on board systems, (c) commands the satellite functions, and (d) acquires stored or real-time data from the satellite. The optical camera tracking stations provide specialized services in precision orbital tracking as well as backup support to STADAN during launch and early orbit tracking of satellites.

STADAN stations are located at Fort Myers, Florida; Mojave, California; Quito, Ecuador; Lima, Peru; Santiago, Chile; Johannesburg, South Africa; Tananarive, Madagascar; Canberra, Australia; Fairbanks, Alaska; St. John's, Newfoundland; Winkfield, England; Rosman, North Carolina; and Toowoomba, Australia. In addition, a Range and Range Rate tracking system is located at Carnarvon, Australia, for specialized support. During the past year, stations at East Grand Forks, Minnesota, and Blossom Point, Maryland, were closed, and a station at Woomera, Australia, was consolidated with the Canberra station.

In early FY 1967, the modifications at the Mojave and Rosman stations for support of the successful Applications Technology Satellite were completed along with the required staffing. Also completed and staffed was the new station at Toowoomba, Australia, for support of the Applications Technology Satellite.

As part of a general cost reduction program in FY 1967, action has been taken to reduce the staffing levels at Quito, Ecuador; Winkfield, England; and Mojave, California. As a result of these staffing reductions, there will be an approximate decrease of 10% in the amount of data obtained from Explorer class satellites. Additional reductions in logistics levels and calibration services have been made; however, these latter reductions are of a one-time nature and these items will have to be restored to normal levels in FY 1968.

For FY 1968, the budget request includes funds for a 24-hour day, seven-days per week operation of the network at most locations. Estimates for FY 1968 are based on operating the Mojave, Winkfield, Quito, and Tananarive stations at the reduced levels. Increases from FY 1967 are related to budgeting for a full year's costs for support of the Applications Technology Satellite in FY 1968, and restoring logistics and calibration services to normal levels.

Deep Space Network Operations

The primary function of the Deep Space Network is to support unmanned lunar and planetary space flight missions. The Network: (a) provides tracking data which are used to determine and make mid-course corrections to spacecraft trajectories, (b) acquires engineering telemetry data concerning performance of the spacecraft, (c) transmits commands to the spacecraft to execute the above functions, and (d) receives and records the scientific data which are acquired from the spacecraft. The Network consists of stations located at Goldstone, California; Woomera and Canberra, Australia; Madrid, Spain; Johannesburg, South Africa; Ascension Island; and Cape Kennedy, Florida.

The control center for the Deep Space Network is the Space Flight Operations Facility (SFOF) located at the Jet Propulsion Laboratory in Pasadena, California. The SFOF: (a) receives information transmitted via ground communications from stations of the Deep Space Network; (b) processes the data; (c) displays the resulting information so that mission directors and associated project personnel can analyze mission performance and make critical decisions in near real time concerning functions to be executed by the spacecraft; and (d) transmits instructions to the stations for commands that must be sent to the spacecraft.

The flight missions of the Lunar Orbiter, Surveyor and Pioneer projects will continue through FY 1968. A Venus fly-by mission is scheduled for launch in late FY 1967 and the flight mission continues well into FY 1968. Increased support is required for the Mariner IV mission late in FY 1967 and early FY 1968. In addition, three stations in the Network (one each in Australia, Spain, and California) will provide full joint support for the Apollo manned lunar missions. To meet this flight schedule, the Deep Space Network and the SFOF must support three or more flight missions simultaneously.

With the Network reaching a record workload in FY 1968, some increases are included in the FY 1968 budget request for additional station staffing and network engineering support. In addition, the SFOF computer capacity is being increased in late FY 1967 to handle the projected workload requiring additional staffing for computer programming and operation. The FY 1968

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budget also reflects costs for a full year to operate two major facilities, the 210-foot diameter advanced antenna facility at Goldstone, and the second 85-foot diameter antenna facility at Madrid, which became operational during FY 1967.

Other Instrumentation Operations

Instrumentation systems are operated in support of sounding rocket programs conducted at Wallops Station, Virginia, and the Churchill Research Range, Canada; and for flight research programs at the Flight Research Center, California. General purpose tracking, telemetry, data handling, recording, timing, plotting, and communication systems are provided as well as special purpose fixed and mobile optical and sound ranging (acoustical) equipment.

The instrumentation at Wallops Station is operated by NASA contractors and by other Government agencies such as the Environmental Science Services Administration, the National Bureau of Standards, the U. S. Navy, the U. S. Air Force, and the Military Sea Transportation Service. Funds required for FY 1968 will permit approximately the same level of effort as in prior years. The slight increase is attributed to a full year's costs for the engineering effort required to support existing programs.

The Langley Research Center funds for the partial operation of two aircraft in support of rocket programs at Wallops Station and the Planetary Entry Parachute program conducted at White Sands in support of Voyager. In addition, mobile telemetry and optical equipment are maintained and operated at various sites along the eastern seaboard to support rocket flights from Wallops Station.

Instrumentation at the Churchill Research Range consists of general purpose tracking, telemetry, command and control, and associated systems required to conduct sounding rocket experiments at high altitudes. The Range is contractor operated under the management of the National Research Council of Canada which shares the costs with NASA as a cooperative effort.

The Flight Research Center operates the Aerodynamics Test Range consisting of facilities at the Edwards Air Force Base and two up-range sites at Ely and Beatty, Nevada. Instrumentation at Edwards is NASA operated with contractor logistic support, whereas the up-range stations are entirely contractor operated. Programs supported include the X-15, XB-70, Re-entry Lifting Bodies, and various small aircraft research projects.

Communications Operations

NASA's tracking stations and control centers are linked together by a single operational communications system operated by the Goddard Space Flight Center. Communications switching centers have been established

at major locations, such as Goddard, London, Honolulu, and Canberra, Australia, to maximize circuit sharing. Requirements in most cases are being met by providing alternate voice/data circuits instead of separate voice and data circuits, thereby reducing the total number of circuits needed.

In the early Mercury missions, considerable reliance was placed on high frequency radio communications. As a result, network communications were limited and not of satisfactory reliability. Although this situation improved with Gemini, it was still not possible to transmit sufficient voice, telemetry, and tracking data from remote stations to the Mission Control Center or to provide sufficient and reliable voice up-data and commands from the Control Center to the spacecraft in real time.

In the Apollo Program, the increased complexity of the missions and the number of vehicles to be supported require real-time centralized mission control. To achieve the required centralized control, it is essential that there be highly reliable and large capacity communication links between a central facility and the remote stations.

For Apollo, these communication links are being provided by satellite as well as conventional means. Communications satellites will provide alternate voice/data and teletype circuits to the Apollo ground stations at Canary Island, Ascension Island, and Carnarvon, Australia, and to the three Apollo insertion/injection ships located in the Atlantic, Pacific, and Indian Oceans.

More than one half of the increase in communications costs from FY 1967 to FY 1968 is related to communications satellite services. Although partial year funding for these services has been budgeted in FY 1967, the first full year of service and costs will occur in FY 1968. This includes not only the cost of providing overseas communications via satellite from the stations and ships to the communication satellite ground terminals located in the United States, but also the domestic cost of transmitting the data from the ground terminals to the Goddard Space Flight Center.

The FY 1968 budget also reflects the first full year of operations costs for providing real-time television coverage from the Apollo spacecraft to the Mission Control Center at Houston. Most of the remainder of the increased budget request in FY 1968 is for providing communications for the new stations becoming operational for Apollo.

Data Processing Operations

Information received in the form of tracking and telemetry data from satellites and space probes must be processed into a form that can be used by both those performing the real-time control of the space vehicle and those responsible for analyzing the scientific data acquired by the spacecraft.

Tracking data are processed to provide orbital elements which are used to supply stations with predictions on future passes of the spacecraft, and to provide position information that can be used by the scientific experimenters to determine where in the trajectory the scientific measurements were made.

Telemetry data must be processed to: (a) separate the information from the various scientific experiments aboard the spacecraft, (b) consolidate information from each experiment, (c) apply the necessary scaling factors and calibrations of the measuring instruments, and (d) correlate these measurements with the position data mentioned above. Processed data is the primary product of the spacecraft missions, and it is through analysis of this data by the experimenters that a better understanding of space is achieved.

Several projects, particularly those in the Observatory class, require extensive pre-mission orbit studies, including spacecraft position predictions and mutual visibility analyses. Studies are also required to work out operational methods and procedures to be used during the actual mission operation.

Support must be given to a wide variety of programs which vary from the small University Explorer satellites to the large Solar, Geophysical, and Astronomical Observatories, and the Applications satellites in the fields of communications and meteorology.

The FY 1968 budget request is based upon the workload which will result from previously launched satellites that will continue to require support, plus additional satellites that are scheduled to be launched during the period. Not only is there a projected increase in the number of satellites to be supported in FY 1968, but the satellite systems and the on-board experiments will be of greater complexity. This will result in an increase in the orbital computations, telemetry data processing, and mission related computer support. The projected workload for FY 1968 is well above the current year and will require a corresponding increase in funds.

Equipment

	1966	1967	1968
Manned space flight network.....	$48,523,000	$25,550,000	$24,000,000
Satellite network.....	14,500,000	11,300,000	10,000,000
Deep space network.....	13,420,000	10,100,000	9,800,000
Other instrumentation.....	3,500,000	4,500,000	4,500,000
Communications.....	7,200,000	6,200,000	4,700,000
Data processing.....	2,612,000	2,000,000	2,100,000
Total.....	$89,755,000	$59,650,000	$55,100,000

Manned Space Flight Network Equipment

During 1966, the Manned Space Flight Network stations used Gemini network systems to support the final Gemini and early Apollo Uprated Saturn I missions. Concurrently, the stations were being modified and augmented for support of the more complex missions of the later Apollo Uprated Saturn I and Apollo Saturn V programs. This modification and augmentation program is continuing, and all stations, including ships and aircraft, are scheduled to be fully operational for Apollo lunar mission support by early 1968.

The FY 1968 budget includes funds for design improvements and equipment modifications required as a result of tests and simulations to ensure station readiness for Apollo lunar mission support. In addition, once this readiness has been achieved, a continuing effort is required to: (a) maintain the demonstrated capability throughout the flight program, (b) improve systems capabilities for more effective operations, (c) provide equipment for requirements peculiar to specific missions, and (d) meet new requirements such as the recently defined Apollo Uprated Saturn I rendezvous missions.

The multiple launch rendezvous missions as currently planned in the Apollo Applications program will require dualizing the five single Unified S-Band stations to provide the number of RF channels which are needed. Initially, design of the Unified S-Band systems at the stations at Canary Island; Bermuda; Antigua; Texas; and Guaymas, Mexico, was based on requirements for their support of single launch, nonrendezvous, Apollo Uprated Saturn I orbital missions and earth orbital phases of the Apollo Saturn V lunar missions. These mission phases require only two Unified S-Band RF links as compared to a maximum of four links required from stations supporting the translunar and lunar phases of Apollo lunar missions. All Manned Space Flight Network land stations, except the five noted above, have been designed with the "dual" Unified S-Band capability.

Recent manned space flight mission planning has incorporated multiple launch rendezvous missions in the Apollo Uprated Saturn I mission series and four Unified S-Band RF links will be required at stations supporting these missions. Funds are requested in FY 1968 for procurement of selected subsystem equipment necessary to provide this "dual" Unified S-Band RF capability at the five stations.

A more refined analysis of support workload at the new Unified S-Band station at the Merritt Island Launch Area (MILA) has revealed a need for a second antenna. Although the majority of the station's instrumentation is capable of performing important pre-launch and launch support tasks concurrently with actual mission support, the availability of only a single antenna system requires that these tasks be accomplished sequentially.

The overlapping Apollo Uprated Saturn I and Apollo Saturn V programs require simultaneous support of spacecraft in flight and also virtually continuous pre-launch checkout activities. To enable this simultaneous support, thus avoiding costly delays in pre-launch checkout of spacecraft subsystems, funds are requested in FY 1968 to provide an additional Unified S-Band antenna system for the MILA station. Funds are also requested for completion of the Unified S-Band contract which provided for the antenna and associated electronics for all network land stations.

As in the Gemini program, tracking and data acquisition requirements for missions in the Apollo program vary from mission-to-mission in accord with the mission objectives and flight plans. In general, it is necessary to make small changes in network equipment to enable support of these changing requirements. Equipment changes must also be made to improve systems performance to correct areas of marginal capability identified in prior mission support. Funds are requested in FY 1968 for provision of these mission-by-mission equipment changes in all systems areas.

During FY 1967 and 1968, the Apollo instrumentation ships will be subjected to evaluation and calibration tests. These tests are specifically designed to highlight any shortcomings in the functioning of the new electronic and navigation systems now being installed on the ships. Past experience of both the Department of Defense, in the case of the Advanced Range Instrumented Ship program, and NASA, in the case of the Gemini support equipment provided for the Rose Knot Victor and Coastal Sentry Quebec ships, has indicated that equipment modifications will be necessary to correct shortcomings found during the tests. The FY 1968 budget includes funds to meet the current estimate of the amount required for these changes.

Funds are requested in FY 1968 to cover the remainder of the estimated NASA share of costs for the eight Apollo/Range Instrumentation Aircraft (A/RIA) which are being modified under the management of the Air Force National Range Division of the Department of Defense.

Funds also are requested for network support to cover the engineering effort required for systems checkout, shipment of equipment to the network stations, provision of standard test equipment, minor facilities modifications, and station calibration and simulation equipment. Also included are funds for procurement of spare parts inventories needed to prevent long periods of station downtime during missions.

Satellite Network Equipment

During the past four years, the Satellite Network has been implemented to achieve a general purpose support capability. This implementation program was designed to ensure that the Network is responsive to the

tracking, command, and data acquisition requirements of individual satellites, and at the same time to provide the capacity for supporting upwards of thirty orbiting satellites. To meet this large and varied workload, a computer study was conducted on a site-by-site basis and a determination made of the equipment needs at each Space Tracking and Data Acquisition Network (STADAN) station. The resulting implementation is now nearing completion and during FY 1968 effort will be directed towards improving the utilization of existing capability.

Major emphasis will continue towards improving station turn-around time between spacecraft passes and toward automating selected station functions. Switching and calibration equipment will be added at each site so that the necessary ground support equipment for a given satellite can be quickly selected and checked out. This procedure will reduce the turn-around time which is the period during which a station is reconfigured to provide support for successive spacecraft passes. In addition, solid state command transmitters and encoders, which will replace obsolescent units at selected stations, are being designed with operational characteristics that are compatible with station operations control consoles for eventual automation.

The Minitrack frequency coverage will be extended from its present 136-137 Mc/s range to 136-138 Mc/s. The existing Minitrack frequency coverage forces the numerous scientific satellites to operate in a narrow frequency spectrum and results in radio frequency interference at the STADAN stations. The planned increase in the Minitrack frequency coverage will double the spectrum available for spacecraft assignments and markedly reduce the incidence of radio frequency interference. The necessary modifications to produce this extension of capability include readjustment of the antennas and changes in both the preamplifiers and RF portions of the receivers.

In addition to providing general purpose capability to meet the great majority of support requirements, certain project-unique equipment must be procured in FY 1968. Both selected stations and control centers will be augmented to meet new requirements caused by mission-to-mission changes in successive flights of ongoing programs such as the Applications Technology Satellite, Orbiting Geophysical Observatory, and Nimbus. These equipments include computer peripherals, displays, and pulse code modulation systems.

Funds for FY 1968 are also necessary for the more routine and sustaining type effort required to maintain a global network. This type of effort requires minor construction, repair and alteration of the stations, equipment for testing and calibration to maintain a high level of network proficiency, and specialized spare parts and components to sustain operations.

Deep Space Network Equipment

The projected workload for the Deep Space Network requires a continuing effort in FY 1968 to ensure an adequate level of support. In addition to normal updating and replacement of equipment to sustain the existing support capability, the effort includes equipment to accommodate mission-to-mission changes, and modifications and additions required for more efficient operation.

The major equipment augmentation in the Deep Space Network during the past three years has been for the station monitoring and control program. Originally, under this program, a single standardized set of equipment was installed at each site to serve the needs of multiple flight projects. In FY 1966 and FY 1967, equipment additions under this program provided the capability for continuous semiautomatic monitoring of equipment performance at three sites. Incorporation of this capability at the four remaining sites, which was deferred from the FY 1967 program, will be provided with FY 1968 funds.

Also during FY 1968, prototype modules will be procured for the receiver system to reduce the turn-around time when multiple missions must be supported. More reliable cryogenic equipment for cooling the receiver-maser system will be provided, and new components will be acquired for three stations to achieve interstation time synchronization which is needed for precise trajectory calculations.

In FY 1967, equipment for a high-voltage power supply for the transmitting system at the Goldstone 210-foot antenna site is being purchased. Additional equipment to complete the high power transmitting system, consisting of a specialized cassegrain cone and receiver-maser components is included in the FY 1968 request. This higher performance system is required to ensure positive spacecraft control under adverse attitude or other non-nominal conditions.

Estimates are included in the FY 1968 request for sustaining-type repairs and modifications to the antennas, servos, collimation towers, recorders, ranging, and timing subsystems. Modifications are required for and directed toward more reliable operation and reduced maintenance time.

In the Space Flight Operations Facility (SFOF) at the Jet Propulsion Laboratory, a Deep Space Network monitoring system will be added consisting of telemetry processing and digital display equipment. The flight mission areas of the SFOF will be provided special displays for support of the Mariner 1969 mission. Additionally, equipment will be acquired for the initial and long lead-time design and development of the data processing system required for support of Voyager-generation programs.

The FY 1968 program includes funds for network support and spares which are required to sustain current operations and to improve network performance and reliability. Included are such items as generators, power system modifications, microwave modifications, calibration and test equipment, interface and integration equipment, intrasite communications, and cabling.

Other Instrumentation Equipment

A wide variety of fixed and mobile equipment is used to provide instrumentation support for sounding rockets and re-entry vehicles launched from Wallops Station and other locations, and for flight research projects conducted at the Flight Research Center. This equipment is under a continuous preventive maintenance program to assure the necessary reliability for mission support. In addition, an improvement program is undertaken whereby individual subassemblies or components of major systems are modified or replaced to improve the range, speed, accuracy, and flexibility of the systems. The requirements for these improvements are generated by the large number and types of rockets in the current and planned launching schedules and by the high performance characteristics of the flight research projects.

At Wallops Station, funds will be required in FY 1968 to modify surplus Department of Defense radars for support of the International Cooperative Sounding Rocket Program, and to procure non-recoverable flight hardware required to support the various missions.

During FY 1968, the Flight Research Center will continue conversion of the Aerodynamics Test Range from S-Band to C-Band frequencies. FY 1968 funds are required for conversion of a surplus radar to C-Band, for integration of the system into existing instrumentation, and for associated ground support and test equipment. Also in FY 1968, new data readout equipment will be installed and telemetry data display equipment will be improved to provide real-time displays in support of the high speed aircraft research programs (XB-70, X-15, F-111, etc.), and the lifting body programs.

At Langley Research Center, FY 1968 funds are required for updating existing telemetry vans, and to initiate the conversion of the telemetry station to S-Band. Modifications will be made to equipment aboard the support aircraft operated by Langley for support of Radio Attentuation Measurement (RAM) and Scout re-entry program launches from Wallops, and the Planetary Entry Parachute program experiments at White Sands.

Communications Equipment

A major modification of the Goddard communications switching center was undertaken during FY 1967 to handle the high speed data transmissions

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required for Apollo. The major effort in FY 1968 will be to add equipment to the solid state switching centers at London, Honolulu, and Canberra, to use more efficiently the high speed data circuits primarily associated with Apollo. This project was originally planned for implementation in FY 1967, but was deferred because of fund limitations.

This high speed data transmission equipment will provide a transmission capability of up to 7200 bits per second as compared to the present 2400 bits per second over a standard voice/data circuit. A direct result is improved circuit utilization and a relative savings in circuit costs.

Telephone and teletype equipment will be installed at Madrid and Goldstone to permit communications between collocated 85-foot antenna sites. Funds are also included to improve the microwave systems at these sites.

The FY 1968 request also includes funds for replacement of equipments such as high frequency radio terminals, for small parts used in the fabrication of prototype assemblies such as control and indicator panels, and for the spares required to sustain the network.

Data Processing Equipment

The operational data processing equipment requires a continuing program of minor redesign, modification, and improvement, as well as normal maintenance and repair. While the data processing lines are designed to be as flexible as possible, changes and updating are necessary to meet the requirements of new programs and to accommodate mission-to-mission changes within existing programs. Changes are directed toward accelerating the reduction of data and thus preventing the acquisition of new processing lines. The FY 1968 budget includes funds to provide the components necessary for these modifications and improvements.

Efforts will also continue in FY 1968 to provide a "quick look" data analysis capability for the experimenters on scientific satellite programs. This is particularly important for large satellites such as the Applications Technology Satellite, the Orbiting Geophysical Observatory, and the Orbiting Astronomical Observatory which have a capability of operating in various modes based on decisions which are made on the ground and transmitted as commands to the spacecraft via ground stations. Additional recording and display equipment is required to present in rapid and meaningful form the information which is essential in making these decisions.

The FY 1968 budget includes funds to provide an improved data reduction capability at the Langley Research Center. Peripheral and interface equipment will be procured for use with the central computer to provide a near-real-time capability for processing telemetry data from programs

conducted by Langley such as the Radio Attentuation Measurement (RAM) and scout re-entry programs. This capability is necessary to assure that all significant data are available and analyzed prior to the next scheduled test.

Test equipment, spares, and replacement components are needed to maintain the data processing lines at peak operating efficiency. Funds are included in the FY 1968 request for these items.

Supporting Research and Technology

	1966	1967	1968
New systems.....	$1,163,000	$644,000	$1,144,000
Integrated systems analysis, development, and test.....	2,685,000	3,622,000	3,106,000
Antenna subsystems.....	2,146,000	1,598,000	1,272,000
Receiving and transmitting subsystems.....	2,704,000	2,426,000	2,525,000
Data handling and control.....	2,398,000	1,822,000	2,143,000
Data processing and reduction...	1,222,000	1,784,000	1,624,000
Spacecraft subsystems.....	1,482,000	1,904,000	1,986,000
Total.....	$13,800,000	$13,800,000	$13,800,000

Supporting Research and Technology (SR&T) is the activity whereby concepts, techniques, and hardware are developed, tested, and evaluated for use in the various networks to meet support requirements.

With the increasing number, complexity, and duration of the flight projects, the emphasis has been on the development of general purpose network capabilities to accommodate a wide range of project requirements. Associated with these general purpose capabilities has been a need for increased reliability and lifetime of hardware systems and improved operational techniques. This is reflected in the FY 1968 budget request as described below.

New Systems

The major new effort under this category is to investigate the feasibility of a Data Relay Satellite System (DRSS) which would use satellites in synchronous orbits to support earth orbital missions, particularly manned missions. Such a system could receive and transmit data between spacecraft and control centers resulting in reduced operations costs and improved reliability in the transmission of data. It is planned to enter the definition phase of this program in FY 1968.

Integrated Systems Analysis, Development, and Test

Effort in this category is addressed primarily toward solution of overall network problems. Mission and network analyses are conducted to determine changes which may be required within the network to ensure the rendering of proper future support. Existing operational techniques are also investigated and refined to facilitate and improve network operations. Finally, experimental sites are supported to evaluate and checkout, under field conditions, all advanced equipment and software techniques.

Antenna Subsystems

As a continuing effort, this category provides for the evaluation of the latest advances in antenna subsystem technology. Components of this subsystem, particularly the microwave elements and feed configuration, are vital elements in the spacecraft-to-ground communication link. Other continuing effort includes studies of antenna structure and surface distortions, antenna pointing precision, alignment, and servo drives.

Receiving and Transmitting Subsystems

In previous years, receiver development activity has been directed primarily toward increasing performance characteristics. In FY 1968, the effort will be directed toward improving the operational aspects of the receiver system which includes rapid checkout and calibration.

Work will also continue on the automation of receiver systems, the investigation of modulation and demodulation techniques for use in communication at planetary distances, and improvements to high power transmitter systems.

Data Handling and Control

In FY 1967, the effort under this task area has been directed toward providing greater operational flexibility in the networks. This flexibility is particularly critical in such areas as antenna repositioning, frequency changing, and shifting to different demodulation formats.

This effort will be continued in FY 1968, along with studies on a computerized technique for the rapid assessment of the operating status and position of satellites. Another area supported is the modification of station stored program computers to perform multiple functions such as ranging, tracking, data handling, and data compression.

Data Processing and Reduction

Effort in this area will continue to be directed in FY 1968 toward more efficient methods of processing, reducing, and displaying extremely large

volumes of scientific data. An investigation and prototype development program is underway to provide a progressively automated central data reduction capability at the Goddard Space Flight Center for scientific and application satellite support. Similar analyses and studies are underway at the Jet Propulsion Laboratory to develop the design criteria for the next generation data processing complex to support deep space missions.

Spacecraft Subsystems

The primary objective in this task area is to develop RF components and techniques for use on spacecraft subsystems. Work has been underway on a set of reliable solid state transmitters that can be applied to a wide variety of NASA programs. Similarly, in FY 1968, additional work will be undertaken to develop components and techniques applicable to handling and storing data on board the spacecraft.

OFFICE OF TECHNOLOGY UTILIZATION — TECHNOLOGY UTILIZATION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The primary objectives of the Technology Utilization program are to establish effective mechanisms and systems for assuring that all new scientific, technological and engineering knowledge resulting from NASA programs is identified, collected, evaluated and made available in the form which is most useful; to establish effective mechanisms for announcing and disseminating this new knowledge in order to assure the widest practical application and utilization thereof; and to improve our understanding of the management of large scale research and development programs and the impact of the space program on the nation's economy.

SUMMARY OF RESOURCES REQUIREMENTS:

	1966	1967	1968
Identification.....	$1,220,000	$1,265,000	$1,265,000
Evaluation.....	680,000	650,000	650,000
Dissemination.....	2,000,000	2,085,000	2,085,000
Analysis.....	850,000	1,000,000	1,000,000
Total.....	$4,750,000	$5,000,000	$5,000,000

Distribution of Program Amount by Installation:

	1966	1967	1968
NASA Headquarters.....	$4,750,000	$5,000,000	$5,000,000

BASIS OF FUND REQUIREMENTS:

Identification

Teams of specialists from universities, research institutions and private industry, with the assistance of Technology Utilization officers at NASA Headquarters and field installations, search through selected areas of NASA scientific and technical endeavor in order to record significant NASA advances which have potential utility for the nonaerospace sector of the nation. This activity is complemented by the identification of individual technological innovations by Technology Utilization officers at NASA field installations and by NASA contractors. Continued increased strong emphasis will be placed on the identification and reporting of new technology by NASA contractors.

Evaluation

Research institutions whose services are primarily directed toward industrial clients make preliminary evaluations of technological innovations reported to NASA, analyze and formulate potential industrial uses for selected innovations, and where appropriate, prepare brief reports describing these technological advances. These brief reports, along with the more comprehensive survey reports stemming from the aforementioned technology searches, are published and made widely available to the scientific, industrial and academic communities, but are especially directed toward the scientists and engineers of nonaerospace industry.

Dissemination

Universities and research institutions are employed to develop regional capabilities to store, retrieve, and interpret to local industry the technology developed by NASA. These information centers strengthen our national technical resources by encouraging rapid localized application of the technology generated in the course of NASA activities. Biomedical application teams assist medical research institutions in defining medical problems in engineering terms, scour NASA technology for solutions to these problems, and then assist the medical research institutions in adapting NASA technology to practical solution of the defined problems. This pilot program started this past year is proving to be a very effective mechanism to relate NASA information to the important unmet community needs in the field of medical research and health care. Experimental programs are underway to utilize the published and filmed results of NASA programs in university graduate classrooms, and to assist other Federal agencies, such as the Office of Saline Water, Bureau of Mines, Office of Law Enforcement of the Department of Justice, Vocational Rehabilitation Administration, etc., in achievement of their missions by application of NASA technology. Limited experimental use of demonstrations, models, motion pictures and exhibits in order to achieve better communication regarding the potentialities of the more significant new processes and techniques is planned. Determination of what problems exist at the man-machine interface in on-line information retrieval, learning how useful such a system could be to the practicing scientist or engineer, and determination of what human factors engineering changes are required for the most effective system, are being looked into in a small way now.

Analysis

A major area of concern is that of promoting a better understanding both within and outside the agency of new and improved techniques for managing large and complex research and development activities. This concern has included support of research in such areas as the organization and management of large R&D projects, the diversified roles of the research director, government-industry contractors systems, and top level policy and decision

making in large R&D organizations. A second area of concern has been the impact of NASA programs on the nation's economy. Studies are being conducted on the economic aspects of new technology resulting from the space program and generally promoting an understanding of how NASA functions within and influences the economy. During FY 1968 NASA will continue to support a program of research and analysis directed to these objectives.

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