National Aeronautics and Space Administration

BUDGET ESTIMATES

FISCAL YEAR 1966

Volume II

RESEARCH AND DEVELOPMENT

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1966 ESTIMATES

RESEARCH AND DEVELOPMENT

TABLE OF CONTENTS

VOLUME II

	Page No.
General statement	RD v
Summary of research and development budget plan as reconciled to financing schedule	SUM 1
Budget plan by program by cognizant office	SUM 3
Distribution of research and development budget plan by installation and fiscal year	SUM 5
Justification by program:	
MANNED SPACE FLIGHT PROGRAMS	
GEMINI	RD 1-1
Spacecraft	RD 1-2
Launch vehicles	RD 1-3
Support	RD 1-4
APOLLO	RD 2-1
Spacecraft	RD 2-3
Saturn I	RD 2-8
Saturn IB	RD 2-9
Saturn V	RD 2-13
Engine development	RD 2-17
Apollo mission support	RD 2-21
ADVANCED MISSIONS	RD 3-1
Studies	RD 3-1

SPACE SCIENCE AND APPLICATIONS PROGRAMS

PHYSICS AND ASTRONOMY ..... RD 4-1

Supporting research and technology ..... RD 4-3
Solar observatories ..... RD 4-6
Astronomical observatories ..... RD 4-9
Geophysical observatories ..... RD 4-11
Explorers ..... RD 4-13
Sounding rockets ..... RD 4-16
Data analysis ..... RD 4-18

LUNAR AND PLANETARY EXPLORATION ..... RD 5-1

Supporting research and technology ..... RD 5-2
Ranger ..... RD 5-5
Surveyor ..... RD 5-6
Lunar orbiter ..... RD 5-7
Mariner ..... RD 5-9
Voyager ..... RD 5-10
Pioneer ..... RD 5-11

SUSTAINING UNIVERSITY PROGRAM ..... RD 6-1

Training ..... RD 6-2
Research facilities ..... RD 6-3
Research ..... RD 6-5

LAUNCH VEHICLE DEVELOPMENT ..... RD 7-1

Supporting research and technology ..... RD 7-1
Centaur development ..... RD 7-2

LAUNCH VEHICLE PROCUREMENT ..... RD 8-1

Scout ..... RD 8-2
Delta ..... RD 8-3
Agena ..... RD 8-4
Centaur ..... RD 8-5
Atlas ..... RD 8-6

BIOSCIENCE ..... RD 9-1

Supporting research and technology ..... RD 9-2
Flight program (Biosatellite) ..... RD 9-5

METEOROLOGICAL SATELLITES ..... RD 10-1

Supporting research and technology ..... RD 10-2
Meteorological flight experiments ..... RD 10-3
Tiros ..... RD 10-4
Nimbus ..... RD 10-5
Meteorological sounding rockets ..... RD 10-7

COMMUNICATIONS SATELLITES ..... RD 11-1

Supporting research and technology ..... RD 11-2
Echo ..... RD 11-3
Relay ..... RD 11-4
Syncom ..... RD 11-4
Early gravity gradient experiment ..... RD 11-5

APPLICATIONS TECHNOLOGY SATELLITES ..... RD 12-1

Supporting research and technology ..... RD 12-2
Applications technology satellites ..... RD 12-3

ADVANCED RESEARCH AND TECHNOLOGY PROGRAMS

BASIC RESEARCH ..... RD 13-1

SPACE VEHICLE SYSTEMS ..... RD 14-1

Supporting research and technology ..... RD 14-3
Project FIRE ..... RD 14-10
Scout reentry project ..... RD 14-11
Lifting body flight and landing tests ..... RD 14-12
Project Pegasus (Saturn-launched meteoroid experiments) ..... RD 14-12
Small space vehicle flight experiments ..... RD 14-13

ELECTRONIC SYSTEMS ..... RD 15-1

Supporting research and technology ..... RD 15-1
Small flight projects ..... RD 15-8

HUMAN FACTOR SYSTEMS ..... RD 16-1

Supporting research and technology ..... RD 16-2
Small biotechnology flight projects ..... RD 16-5

NUCLEAR-ELECTRIC SYSTEMS ..... RD 17-1

Supporting research and technology ..... RD 17-2
SERT ..... RD 17-6

NUCLEAR ROCKETS ..... RD 18-1

Supporting research and technology ..... RD 18-2
NERVA ..... RD 18-6
Nuclear rocket development station operations ..... RD 18-9

CHEMICAL PROPULSION ..... RD 19-1

Supporting research and technology ..... RD 19-2

SOLAR AND CHEMICAL POWER ..... RD 20-1

Supporting research and technology ..... RD 20-2

AERONAUTICS ..... RD 21-1

Supporting research and technology ..... RD 21-2
X-15 ..... RD 21-6
Supersonic transport ..... RD 21-7
V/STOL ..... RD 21-8
Hypersonic ramjet experiment ..... RD 21-9
XB-70/SST flight research project ..... RD 21-10

TRACKING AND DATA ACQUISITION PROGRAM

TRACKING AND DATA ACQUISITION ..... RD 22-1

Operations ..... RD 22-2
Equipment ..... RD 22-8
Supporting research and technology ..... RD 22-17

TECHNOLOGY UTILIZATION AND POLICY PLANNING PROGRAM

TECHNOLOGY UTILIZATION ..... RD 23-1

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT

GENERAL STATEMENT

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

MANNED SPACE FLIGHT: Extended duration and rendezvous flights in earth orbit, and lunar landing and return.

SPACE SCIENCE AND APPLICATIONS: A broad program of scientific study of the Earth, Moon, Sun, planets, stars and interplanetary space, and the development of technology pertinent to applied uses such as meteorological and communication satellites.

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

TRACKING AND DATA ACQUISITION: A function pertinent to the support of the extensive NASA space flight program.

MANNED SPACE FLIGHT

A major part of the amount requested for FY 1966 will be applied to the manned space flight program. The broad objectives of this program which remain unchanged are: to increase and broaden our capability to support men in space and provide them with a space operation's capability for scientific and technological purposes. Toward this end there are projects Gemini and Apollo, as well as studies and supporting development needed for advanced manned flight missions. Gemini will furnish information on the operation of two men in space for periods of up to two weeks; and will provide for the development of space navigation, guidance, rendezvous and docking techniques. The objectives of Apollo are developing hardware, operational, and support systems to provide a broad national capability for a program of space exploration. This program has as a specific goal, in this decade, of achieving manned flight to the moon, lunar landing, limited lunar exploration and the safe return of the men to Earth. The advanced flight mission activity provides information and supporting developments pertinent to the extension of the current manned flight programs.

In FY 1966 the Gemini program will move into its long duration manned flight phase and the initial rendezvous flight will be undertaken. This activity will be of direct significance to Apollo. The Apollo program will be involved in extensive ground test activity in preparation for the first flight tests of the command and service modules with the Saturn IB launch

vehicle, which will take place in FY 1966, and in preparations for later flight tests of the Saturn V launch vehicle. In the area of advanced flight missions particular attention will be given to design studies and advanced component development to extend the usefulness of the Apollo spacecraft.

SPACE SCIENCE AND APPLICATIONS

A significant part of the budget requested for FY 1966 will support the space science and applications program. The objectives of the science part of the program are scientific studies of the Earth, space about the Earth, the Moon, the planets and interplanetary space. This program encompasses the following types of flight projects: Geophysical satellites, earth orbiting solar and astronomical observatories, soft landing lunar probes, lunar orbiting satellites, probes to the planet Mars and probes into interplanetary space. The biosatellite program, directed toward the study of the effects of space environment on biological systems, will be continued. In the area of applications, projects TIROS and Nimbus continue to reflect NASA support for the on-going operational weather satellite development for the Weather Bureau; in addition, the program provides for the technology required for future operational systems. Effort will also continue in the development of the Applications Technology Satellite, which will provide information required for the design and development of future communications, meteorological and scientific satellite systems.

ADVANCED RESEARCH AND TECHNOLOGY

The advanced research and technology effort constitutes a continuing overall program to support the current aeronautics and space programs and to assure the scientific and engineering bases for undertaking future programs. The major portion of this work, which looks beyond the present programs, is to develop new knowledge and technological advancements applicable to missions of the future. This program includes effort in the fields of spacecraft and launch vehicle technology, human factors, electronics, chemical and nuclear propulsion, space power systems and aeronautics including supersonic transport research.

TRACKING AND DATA ACQUISITION

A world-wide network of tracking and data acquisition stations is essential to support the broad space flight program of the agency. The tracking and data acquisition effort during FY 1966, as in prior years, will be directed to support the planned flight programs and provide, where necessary, increased tracking and data acquisition capability. Particular attention will be given to the support of the Apollo manned space flight program and to the large observatory class of unmanned satellites in the space science program.

TECHNOLOGY UTILIZATION

The technology utilization program provides for the identification, evaluation and dissemination to the industrial community, technical information gained from the various programs for which there are potential industrial and commercial applications. Included in the program are efforts to develop better methods for management of large-scale research and development programs, to improve our understanding of matters related to the growth of science and technology programs, and to the transfer of technological advances and innovations developed in the NASA program to industry at large.

FINANCING

The FY 1966 budget to support the research and development program, discussed in detail in this volume, is $4,575,900,000. This compares to a program totaling $4,268,632,000 for FY 1965.

The program amounts shown for FY 1964 and FY 1965 in this budget reflect two significant adjustments in comparison to the amounts appropriated for these two fiscal years. These are: 1 - Certain support services (principally housekeeping) are now included in the budget for the "Administrative Operations" appropriation; and 2 - Of the FY 1965 appropriation, $72,494,000 has been applied to the FY 1964 Apollo program.

Expenditures for the current fiscal year are estimated at $3,782,000,000 and $4,120,000,000 for FY 1966.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1966 ESTIMATES

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

	Fiscal Year 1964	Fiscal Year 1965	Fiscal Year 1966
Budget Activity:			
1. Manned Space Flight:			
(a) Gemini.....	$418,900,000	$308,400,000	$242,100,000
(b) Apollo.....	2,272,952,000	2,606,778,000	2,997,385,000
(c) Advanced mission studies.....	21,200,000	26,000,000	10,000,000
2. Scientific Investigations in Space:			
(a) Physics and astronomy.....	189,118,000	182,546,000	224,300,000
(b) Lunar and planetary exploration.....	267,445,000	281,803,000	294,515,000
(c) Bioscience.....	21,479,000	37,700,000	40,600,000
(d) Launch vehicle development.....	125,100,000	107,900,000	97,500,000
3. Space Applications.....	100,451,000	73,165,000	94,600,000
4. Space Technology.....	298,692,000	283,600,000	235,500,000
5. Aircraft Technology.....	21,795,000	35,240,000	42,200,000
6. Supporting Activities:			
(a) Tracking and data acquisition.....	194,347,000	274,750,000	246,200,000
(b) Sustaining university program.....	40,000,000	46,000,000	46,000,000
(c) Technology utilization.....	3,500,000	4,750,000	5,000,000
Total Budget Plan.....	$3,974,979,000	$4,268,632,000	$4,575,900,000

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1966 ESTIMATES

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

	Fiscal Year 1964	Fiscal Year 1965	Fiscal Year 1966
Financing:			
Appropriation.....	$3,926,000,000	$4,363,594,000	$4,575,900,000
Transferred to-			
"Construction of facilities" (77 Stat. 439).....	-20,046,300	---	---
"Administrative Operations" (77 Stat. 439).....	-15,685,000	---	---
Appropriation (adjusted).....	3,890,268,700	4,363,594,000	4,575,900,000
Transferred to "Construction of facilities" in FY 1965	-1,411,000	---	---
Prior year funding applied - available from adjustments to FY 1963 budget plan....	2,785,300	---	---
Transfers from prior years "Construction of facilities" funds.....	17,293,000	---	---
Reprograming to prior year budget plan.....	72,494,000	-72,494,000	---
Comparative transfer to "Administrative Operations"	-6,451,000	-22,468,000	---
Total financing of budget plan.....	$3,974,979,000	$4,268,632,000	$4,575,900,000

761-133 O-65--2

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1966 ESTIMATES

RESEARCH AND DEVELOPMENT

BUDGET PLAN BY PROGRAM BY COGNIZANT OFFICE

BUDGET ACTIVITY		FY 1964	FY 1965	FY 1966
	MANNED SPACE FLIGHT.....	$2,713,052,000	$2,941,178,000	$3,249,485,000
1a	Gemini.....	418,900,000	308,400,000	242,100,000
1b	Apollo.....	2,272,952,000	2,606,778,000	2,997,385,000
1c	Advanced mission studies.....	21,200,000	26,000,000	10,000,000
	SPACE SCIENCE AND APPLICATIONS.....	$746,879,000	$731,486,000	$797,515,000
2a	Physics and astronomy.	148,623,000	136,814,000	172,100,000
2b	Lunar and planetary exploration.....	205,762,000	206,150,000	215,615,000
6b	Sustaining university program.....	40,000,000	46,000,000	46,000,000
2d	Launch vehicle development.....	111,900,000	96,500,000	63,600,000
*	Launch vehicle procurement.....	129,986,000	154,672,000	194,500,000
2c	Bioscience.....	21,479,000	28,700,000	31,500,000
3	Meteorological satellites.....	63,177,000	31,200,000	42,700,000
3	Communications satellites.....	8,413,000	8,055,000	2,800,000
3	Applications technology satellites.....	17,539,000	23,395,000	28,700,000
	ADVANCED RESEARCH AND TECHNOLOGY.....	$317,201,000	$316,468,000	$277,700,000
4	Basic research.....	22,653,000	21,231,000	22,000,000
4	Space vehicle systems.	45,714,000	44,495,000	35,000,000
4	Electronic systems....	28,700,000	25,422,000	34,400,000
4	Human factor systems..	13,200,000	13,320,000	14,900,000
4	Nuclear-electric systems.....	45,963,000	42,492,000	27,000,000
4	Nuclear-rockets.....	79,176,000	56,731,000	58,000,000
4	Chemical propulsion...	46,000,000	63,792,000	30,000,000

BUDGET ACTIVITY	FY 1964	FY 1965	FY 1966
ADVANCED RESEARCH AND TECHNOLOGY (Cont'd)..			
4 Solar and chemical power.....	$14,000,000	$13,745,000	$14,200,000
5 Aeronautics.....	21,795,000	35,240,000	42,200,000
6a TRACKING AND DATA ACQUISITION.....	$194,347,000	$274,750,000	$246,200,000
6c TECHNOLOGY UTILIZATION.	$3,500,000	$4,750,000	$5,000,000
TOTAL PLAN	$3,974,979,000	$4,268,632,000	$4,575,900,000

* Funds for the procurement of launch vehicles are statistically distributed to unmanned flight programs (e.g. Physics and Astronomy, Space Vehicle Systems).

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1966 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	PACIFIC LAUNCH OPERATIONS OFFICE	WALLOPS STATION	AMES RESEARCH CENTER	ELECTRONICS RESEARCH CENTER	FLIGHT RESEARCH CENTER	LANGLEY RESEARCH CENTER	LEWIS RESEARCH CENTER	SPACE NUCLEAR PROPULSION OFFICE	HEADQUARTERS	WESTERN OPERATIONS OFFICE
Office of Manned Space Flight															
1964	2,713,052	49,881	1,356,036	1,266,424	206	-	-	75	-	-	2,017	2,975	-	35,091	347
1965	2,941,178	48,622	1,397,050	1,437,356	275	-	-	75	-	-	2,900	600	-	54,100	200
1966	3,249,485	69,345	1,465,040	1,656,600	500	-	-	200	-	-	3,700	300	-	53,550	250
Office of Space Science and Applications															
1964	746,879	1,819	3,256	780	235,148	-	-	25,843	-	44	35,168	197,522	-	87,202	160,097
1965	731,486	4,808	7,254	675	183,408	90	1,390	35,085	-	85	59,806	197,323	-	108,994	132,568
1966	797,515	4,225	17,800	13,440	227,712	-	4,500	28,305	-	100	51,860	196,730	-	105,375	147,468
Office of Advanced Research and Technology															
1964	317,201	-	3,702	31,821	8,252	-	-	14,404	-	8,447	38,741	99,759	60,355	25,026	26,694
1965	316,468	-	1,750	28,511	8,127	-	-	17,724	1,873	9,190	32,548	115,825	44,995	34,322	21,603
1966	277,700	-	3,235	18,035	9,300	-	-	16,945	5,200	16,530	42,776	61,595	48,900	33,638	21,546
Office of Tracking and Data Acquisition															
1964	194,347	-	-	2,900	132,817	-	5,100	-	-	1,800	2,450	-	-	7,210	42,070
1965	274,750	-	-	2,000	195,201	-	5,450	-	-	2,200	2,200	-	-	7,900	59,799
1966	246,200	-	-	1,500	173,400	-	5,900	-	-	2,000	2,500	-	-	7,900	53,000
Office of Technology Utilization and Policy Planning															
1964	3,500	-	-	-	-	-	-	-	-	-	-	-	-	3,500	-
1965	4,750	-	-	-	-	-	-	-	-	-	-	-	-	4,750	-
1966	5,000	-	-	-	-	-	-	-	-	-	-	-	-	5,000	-
Total Budget Plan															
1964	3,974,979	51,700	1,362,994	1,301,925	376,423	-	5,100	40,322	-	10,291	78,376	300,256	60,355	158,029	229,208
1965	4,268,632	53,430	1,406,054	1,468,542	387,011	90	6,840	52,884	1,873	11,475	97,454	313,748	44,995	210,066	214,170
1966	4,575,900	73,570	1,486,075	1,689,575	410,912	-	10,400	45,450	5,200	18,630	100,836	258,625	48,900	205,463	222,264

761-133 (Follows P. Sum 4) No. 1

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1966 ESTIMATES

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

(In thousands of dollars)

PROGRAM		TOTAL	J. F. KENNEDY SPACE CENTER, NASA	MANNED SPACECRAFT CENTER	MARSHALL SPACE FLIGHT CENTER	GODDARD SPACE FLIGHT CENTER	PACIFIC LAUNCH OPERATIONS OFFICE	WALLOPS STATION	AMES RESEARCH CENTER	ELECTRONICS RESEARCH CENTER	FLIGHT RESEARCH CENTER	LANGLEY RESEARCH CENTER	LEWIS RESEARCH CENTER	SPACE NUCLEAR PROPULSION OFFICE	HEADQUARTERS	WESTERN OPERATIONS OFFICE 1/
OFFICE OF MANNED SPACE FLIGHT, TOTAL	1964	2,713,052	49,881	1,356,036	1,266,424	206	-	-	75	-	-	2,017	2,975	-	35,091	347
	1965	2,941,178	48,622	1,397,050	1,437,356	275	-	-	75	-	-	2,900	600	-	54,100	200
	1966	3,249,485	69,345	1,465,040	1,656,600	500	-	-	200	-	-	3,700	300	-	53,550	250
Gemini	1964	418,900	-	418,900	-	-	-	-	-	-	-	-	-	-	-	-
	1965	308,400	-	308,050	-	-	-	-	-	-	-	-	-	-	350	-
	1966	242,100	-	241,700	-	-	-	-	-	-	-	-	-	-	400	-
Apollo	1964	2,272,952	49,481	933,486	1,257,179	206	-	-	75	-	-	-	2,975	-	29,293	257
	1965	2,606,778	48,172	1,080,800	1,429,406	275	-	-	75	-	-	1,200	600	-	46,050	200
	1966	2,997,385	68,945	1,221,940	1,651,300	500	-	-	200	-	-	2,000	300	-	51,950	250
Advanced mission studies	1964	21,200	400	3,650	9,245	-	-	-	-	-	-	2,017	-	-	5,798	90
	1965	26,000	450	8,200	7,950	-	-	-	-	-	-	1,700	-	-	7,700	-
	1966	10,000	400	1,400	5,300	-	-	-	-	-	-	1,700	-	-	1,200	-
OFFICE OF SPACE SCIENCE AND APPLICATIONS, TOTAL	1964	746,879	1,819	3,256	780	235,148	-	-	25,843	-	44	35,168	197,522	-	87,202	160,097
	1965	731,486	4,808	7,254	675	183,408	90	1,390	35,085	-	85	59,806	197,323	-	108,994	132,568
	1966	797,515	4,225	17,800	13,440	227,712	-	4,500	28,305	-	100	51,860	196,730	-	105,375	147,468
Physics and astronomy	1964	148,623	-	1,020	195	123,753	-	-	605	-	44	2,333	150	-	20,047	476
	1965	136,814	-	2,300	20	107,473	-	1,390	1,764	-	85	2,280	-	-	21,168	334
	1966	172,100	-	2,600	20	133,585	-	4,500	2,255	-	100	1,730	-	-	26,660	650
Lunar and planetary exploration	1964	205,762	-	1,867	505	1,084	-	-	15,382	-	-	20,146	-	-	9,521	157,257
	1965	206,150	-	4,429	535	1,111	-	-	16,054	-	-	43,050	-	-	10,667	130,304
	1966	215,615	-	14,000	300	900	-	-	8,600	-	-	37,300	-	-	9,500	145,015
Sustaining university program	1964	40,000	-	-	-	-	-	-	-	-	-	-	-	-	39,940	60
	1965	46,000	-	-	-	-	-	-	-	-	-	-	-	-	45,965	35
	1966	46,000	-	-	-	-	-	-	-	-	-	-	-	-	45,965	35
Launch vehicle development	1964	111,900	983	-	-	250	-	-	-	-	-	115	109,497	-	1,055	-
	1965	96,500	1,783	-	-	925	-	-	-	-	-	650	91,317	-	1,825	-
	1966	63,600	1,050	-	13,000	550	-	-	-	-	-	300	47,600	-	1,100	-
Launch vehicle procurement	1964	129,986	836	-	-	23,326	-	-	-	-	-	11,930	87,875	-	6,019	-
	1965	154,672	3,025	-	-	19,960	90	-	-	-	-	13,106	106,006	-	12,485	-
	1966	194,500	3,175	-	-	23,025	-	-	-	-	-	11,700	149,130	-	7,470	-
Bioscience	1964	21,479	-	234	-	250	-	-	9,856	-	-	-	-	-	9,896	1,243
	1965	28,700	-	475	-	250	-	-	17,267	-	-	-	-	-	9,209	1,499
	1966	31,500	-	1,000	-	250	-	-	17,450	-	-	-	-	-	11,550	1,250
Meteorological satellites	1964	63,177	-	135	80	62,346	-	-	-	-	-	444	-	-	172	-
	1965	31,200	-	50	120	29,575	-	-	-	-	-	420	-	-	1,035	-
	1966	42,700	-	200	120	39,720	-	-	-	-	-	530	-	-	2,130	-
Communication satellites	1964	8,413	-	-	-	7,661	-	-	-	-	-	200	-	-	552	-
	1965	8,055	-	-	-	1,415	-	-	-	-	-	300	-	-	6,340	-
	1966	2,800	-	-	-	1,500	-	-	-	-	-	300	-	-	1,000	-
Applications technology satellites	1964	17,539	-	-	-	16,478	-	-	-	-	-	-	-	-	-	1,061
	1965	23,395	-	-	-	22,699	-	-	-	-	-	-	-	-	300	396
	1966	28,700	-	-	-	28,182	-	-	-	-	-	-	-	-	-	518

761-133 (Follows P. Sum 4) No. 2

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1966 ESTIMATES

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

(In thousands of dollars)

PROGRAM		TOTAL	J. F. KENNEDY SPACE CENTER, NASA	MANNED SPACECRAFT CENTER	MARSHALL SPACE FLIGHT CENTER	GODDARD SPACE FLIGHT CENTER	PACIFIC LAUNCH OPERATIONS OFFICE	WALLOPS STATION	AMES RESEARCH CENTER	ELECTRONICS RESEARCH CENTER	FLIGHT RESEARCH CENTER	LANGLEY RESEARCH CENTER	LEWIS RESEARCH CENTER	SPACE NUCLEAR PROPULSION OFFICE	HEADQUARTERS	WESTERN OPERATIONS OFFICE 1/
OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY, TOTAL	1964	317,201	-	3,702	31,821	8,252	-	-	14,404	-	8,447	38,741	99,759	60,355	25,026	26,694
	1965	316,468	-	1,750	28,511	8,127	-	-	17,724	1,873	9,190	32,548	115,825	44,995	34,322	21,603
	1966	277,700	-	3,235	18,035	9,300	-	-	16,945	5,200	16,530	42,776	61,595	48,900	33,638	21,546
Basic Research	1964	22,653	-	-	986	235	-	-	1,692	-	-	1,466	3,464	-	7,831	6,979
	1965	21,231	-	-	916	257	-	-	1,881	-	30	1,861	2,234	-	8,260	5,792
	1966	22,000	-	-	920	260	-	-	1,900	200	30	1,920	2,750	-	8,220	5,800
Space vehicle systems	1964	45,714	-	629	13,569	878	-	-	1,942	-	1,403	15,257	3,186	-	3,282	5,568
	1965	44,495	-	730	16,744	956	-	-	2,922	-	2,020	9,659	2,326	-	5,700	3,438
	1966	35,000	-	855	4,490	930	-	-	2,655	-	1,180	13,461	1,770	-	6,519	3,140
Electronic systems	1964	28,700	-	1,079	4,644	3,274	-	-	2,399	-	1,072	8,848	463	-	4,087	2,834
	1965	25,422	-	475	3,469	2,797	-	-	3,650	1,873	1,103	6,390	445	-	2,493	2,727
	1966	34,400	-	880	4,525	3,035	-	-	3,390	5,000	1,400	9,120	580	-	3,270	3,200
Human factor systems	1964	13,200	-	1,900	235	-	-	-	3,820	-	1,342	1,835	137	-	3,931	-
	1965	13,320	-	445	220	-	-	-	4,113	-	2,000	3,204	230	-	3,108	-
	1966	14,900	-	900	300	-	-	-	4,680	-	1,500	4,450	200	-	2,870	-
Nuclear-electric systems	1964	45,963	-	94	263	1,320	-	-	-	-	-	-	41,719	-	685	1,882
	1965	42,492	-	100	290	1,142	-	-	-	-	-	400	37,038	-	1,186	2,336
	1966	27,000	-	100	400	1,200	-	-	-	-	-	-	22,700	-	1,000	1,600
Nuclear rockets	1964	79,176	-	-	7,153	-	-	-	-	-	-	-	11,330	60,355	-	338
	1965	56,731	-	-	1,280	-	-	-	-	-	-	-	10,450	44,995	-	6
	1966	58,000	-	-	1,300	-	-	-	-	-	-	-	7,800	48,900	-	-
Chemical propulsion	1964	46,000	-	-	3,542	375	-	-	-	-	-	1,144	31,205	-	3,194	6,540
	1965	63,792	-	-	3,592	550	-	-	-	-	-	1,480	45,227	-	8,760	4,183
	1966	30,000	-	500	5,100	800	-	-	-	-	-	1,980	8,095	-	8,825	4,700
Solar and chemical power	1964	14,000	-	-	1,429	2,170	-	-	105	-	-	710	6,403	-	630	2,553
	1965	13,745	-	-	2,000	2,425	-	-	191	-	-	690	4,309	-	1,009	3,121
	1966	14,200	-	-	1,000	3,075	-	-	170	-	-	740	5,000	-	1,109	3,106
Aeronautics	1964	21,795	-	-	-	-	-	-	4,446	-	4,630	9,481	1,852	-	1,386	-
	1965	35,240	-	-	-	-	-	-	4,967	-	4,037	8,864	13,566	-	3,806	-
	1966	42,200	-	-	-	-	-	-	4,150	-	12,420	11,105	12,700	-	1,825	-
OFFICE OF TRACKING AND DATA ACQUISITION	1964	194,347	-	-	2,900	132,817	-	5,100	-	-	1,800	2,450	-	-	7,210	42,070
	1965	274,750	-	-	2,000	195,201	-	5,450	-	-	2,200	2,200	-	-	7,900	59,799
	1966	246,200	-	-	1,500	173,400	-	5,900	-	-	2,000	2,500	-	-	7,900	53,000
Tracking and data acquisition	1964	194,347	-	-	2,900	132,817	-	5,100	-	-	1,800	2,450	-	-	7,210	42,070
	1965	274,750	-	-	2,000	195,201	-	5,450	-	-	2,200	2,200	-	-	7,900	59,799
	1966	246,200	-	-	1,500	173,400	-	5,900	-	-	2,000	2,500	-	-	7,900	53,000
OFFICE OF TECHNOLOGY UTILIZATION AND POLICY PLANNING	1964	3,500	-	-	-	-	-	-	-	-	-	-	-	-	3,500	-
	1965	4,750	-	-	-	-	-	-	-	-	-	-	-	-	4,750	-
	1966	5,000	-	-	-	-	-	-	-	-	-	-	-	-	5,000	-
Technology utilization	1964	3,500	-	-	-	-	-	-	-	-	-	-	-	-	3,500	-
	1965	4,750	-	-	-	-	-	-	-	-	-	-	-	-	4,750	-
	1966	5,000	-	-	-	-	-	-	-	-	-	-	-	-	5,000	-
TOTAL BUDGET PLAN	1964	3,974,979	51,700	1,362,994	1,301,925	376,423	-	5,100	40,322	-	10,291	78,376	300,256	60,355	158,029	229,208
	1965	4,268,632	53,430	1,406,054	1,468,542	387,011	90	6,840	52,884	1,873	11,475	97,454	313,748	44,995	210,066	214,170
	1966	4,575,900	73,570	1,486,075	1,689,575	410,912	-	10,400	45,450	5,200	18,630	100,836	258,625	48,900	205,463	222,264

1/Amount for Western Operations Office includes funds for the Jet Propulsion Laboratory as shown in the Research and Development program justification (Vol. II)

761-133 (Follows P. Sum 4) No. 3

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1966 ESTIMATES

OFFICE OF MANNED SPACE FLIGHT GEMINI PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Gemini program objectives are to develop an operational capability in Manned Space Flight and through this capability to conduct specific experiments and tests which support Apollo, Department of Defense programs and scientific investigations. In the Gemini program, the U.S. is developing the capability for flights up to 14 days' duration, rendezvous and docking, post docking maneuvers, extra-vehicular activity, and controlled re-entry.

The Gemini spacecraft systems are more sophisticated and versatile than those in the Mercury configuration, to accomplish progressively more complex mission objectives. Several subsystems for use in manned space flight are introduced for the first time in Gemini: ejection seats; fuel cells; on board propulsion; rendezvous radar; and inertial guidance system. The inertial guidance system used for rendezvous also provides an alternate capability in the event of failure in the launch vehicle primary guidance system.

To the degree that space, weight, and operational limitations permit, in-flight experiments will be conducted as part of a planned program to utilize the full capabilities of Gemini flights.

FY 1966 is a year of intensive delivery and operational activity. Manned Gemini missions are planned during each quarter of this period. Operations support of these manned missions includes astronaut training; pre-launch spacecraft testing and checkout at Cape Kennedy; and launch, flight, and recovery activities.

Scheduled flights will be used to evaluate systems and astronaut performance and will provide operational experience on various rendezvous modes. A rendezvous mission begins with the launch of a modified Agena D, which is used as the target vehicle. This target vehicle is placed in orbit by a standard Atlas. The spacecraft is then launched by a Gemini Launch Vehicle (GLV), a modified Titan II. Using radar for guidance, the astronauts bring the Gemini spacecraft within visual range of the Agena target. Electronic and visual aids are then used to mate the Gemini spacecraft and the Agena target vehicle to complete the docking maneuver.

A large number of experiments have been approved for inclusion in Gemini missions. Data gained from these experiments will significantly expand current knowledge of space, and permit a more realistic assessment of man's ability to perform in the space environment. Through FY 1963, a total of $343.9 million had been obligated for this program.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Spacecraft.....	$280,520,000	$165,300,000	$122,700,000
Launch vehicles.....	122,700,000	115,400,000	88,600,000
Support.....	15,680,000	27,700,000	30,800,000
Total.....	$418,900,000	$308,400,000	$242,100,000

Distribution of Program Amount by Installation:

Manned Spacecraft Center.....	$418,900,000	$308,050,000	$241,700,000
NASA Headquarters.....	---	350,000	400,000

BASIS OF FUND REQUIREMENTS:

Spacecraft

	1964	1965	1966
Spacecraft.....	$280,520,000	$165,300,000	$122,700,000

Spacecraft components and subsystems are subjected to exhaustive tests to certify that design requirements will be met under all anticipated conditions. Items procured from vendors must pass a pre-delivery acceptance test before shipment to McDonnell. There, every component undergoes a separate pre-installation test before final incorporation into a spacecraft system. This test and inspection program will provide greater assurance of astronaut safety and mission success.

After assembly, each spacecraft is checked for approximately 86 working days at McDonnell to verify that the components and subsystems perform according to specifications under simulated flight conditions. Final check-out requires approximately 40 working days and is conducted at the Kennedy Space Center where the spacecraft and launch vehicle are mated.

Approximately 99 percent of the spacecraft development and manufacturing effort is being performed by industry. The McDonnell Corporation has subcontracted over 50 percent of its effort to major subsystem suppliers located throughout the country. In addition, hundreds of other subcontractors, vendors, and suppliers are providing various components.

Launch Vehicles

	1964	1965	1966
Launch vehicles.....	$122,700,000	$115,400,000	$88,600,000

Three separate vehicles are required for the Gemini program: the Gemini Launch Vehicle (GLV), the Atlas, and the Agena. The GLV is an Air Force Titan II intercontinental ballistic missile which has been modified for manned flight. The modifications include incorporation of redundant electrical power supply and flight control systems, a malfunction detection system to warn the astronauts of a failure requiring abort, replacement of the Titan II inertial guidance with the radio guidance system used successfully in Mercury, and removal of items needed only for the booster as an ICBM. The Air Force Space Systems Division, acting in a capacity similar to a NASA prime contractor, is scheduled to deliver four GLV during FY 1966.

The GLV is subjected to a test program comparable to that for the spacecraft. In addition to the development and qualification tests prescribed for components and subsystems peculiar to Gemini, the engines are fully tested prior to installation in the vehicle. Martin-Marietta, contractor for the vehicle, conducts a 26-day all-systems functional test in its Vertical Test Facility at Baltimore before shipment to Cape Kennedy. At the launch pad, the GLV again undergoes a comprehensive 51-day checkout to verify compatibility and flight readiness. This includes 26 days of checkout following mating with the spacecraft.

The Air Force is procuring Gemini Launch Vehicles under four major contracts, in addition to Martin-Marietta: Aerojet supplies the engines; General Electric produces the guidance system; Burroughs fabricates the computer; and Aerospace Corporation is responsible for systems engineering.

The Gemini Atlas is an Air Force Standard Atlas Launch Vehicle. Three Atlas vehicles will be delivered in FY 1966.

The Gemini target vehicle is an Agena modified to provide (1) additional maneuverability in orbit, (2) command communications compatible with the spacecraft and ground station network, and (3) a docking mechanism. The modifications include changes to the electrical power supply, telemetry, spacecraft command subsystems, and propulsion system. To accomplish rendezvous maneuvers, the main engine was modified to provide a five-time restart capability while in orbit. A secondary propulsion system has been added to enable smaller velocity changes and propellant orientation for main engine start.

The extent of the modifications to develop a more sophisticated vehicle for Gemini has required a severe testing program. The structural, qualification, systems development, and propulsion systems testing will be essentially completed in FY 1965.

The Air Force is also contracting for the Atlas/Agena. Principal firms involved are General Dynamics/Astronautics Division for the Atlas, and Lockheed Missiles and Space Company for the Agena.

The FY 1966 vehicle funding requirements provide incremental funding to the Air Force for delivery and partial operational support of vehicles to be launched in FY 1966 and FY 1967.

	Support		
	1964	1965	1966
Support.....	$15,680,000	$27,700,000	$30,800,000

The manned missions planned in FY 1966 place heavy emphasis on Crew Operations, Flight Operations, and Spacecraft and Launch Vehicle Support, thereby characterizing the nature of the Gemini program during the period.

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

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

Mission Simulators - Each individual astronaut receives at least 125 hours of simulator training. The simulators are modified from time to time to update the configuration and procedures for progressively more sophisticated missions.

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

Flight Operations during FY 1966 will continue to stress planning, support, and actual flight test from lift-off to recovery. In long-duration missions, capability to sustain manned flight for a period equal to or longer than will be required in lunar missions will be demonstrated.

Another objective in FY 1966 is mastery of the operational aspects of space rendezvous and docking maneuvers. The first two flights scheduled for FY 1966 are long-duration missions. During the latter flight the astronauts will practice rendezvous using a pod equipped with radar transponder and lights, ejected from the spacecraft to simulate the Agena.

Later in the year, missions will involve actual rendezvous and docking of the spacecraft with an orbiting Agena target vehicle, using alternative guidance techniques to determine the optimum mode of rendezvous.

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

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

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

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

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

Requirements for this DOD support, the largest element in the Flight Operations budget, depend directly on the number of flights scheduled for a given year. Ship and aircraft costs are calculated on the average deployment times and other factors associated with each type of mission. The FY 1966 funding requirement also takes into account the effect of minimal delays in launch operations, re-cycle times, and total re-deployment of all recovery support forces.

Spacecraft and Launch Vehicle Support funds provide procurement and qualification testing of components and subsystems. Included is the procurement of life support systems and related extra-vehicular equipment. During FY 1966, the following types of items will be purchased: food and waste management systems, bioinstrumentation, pressure suits, personal hygiene equipment, and extra-vehicular equipment.

Astronauts will perform in-flight experiments on all FY 1966 Gemini missions. These experiments have been evaluated to define expected technical contribution, feasibility (from the standpoint of installation in a particular spacecraft), and cost in terms of dollars and weight. The objectives of these experiments are:

Medical experiments will yield data on psychological and physiological reactions to stress, and on man's performance capabilities during space flight.

Engineering experiments performed during FY 1966 will measure the space radiation environment just outside the orbiting spacecraft, and measure the direction and amplitude of the Earth's magnetic field relative to the spacecraft.

Scientific experiments will provide data in a number of fields, including effects of weightlessness on cell tissue, and the nature of interplanetary dust.

In addition to the experiments outlined above, NASA is conducting technological experiments for the DOD which will evaluate the astronauts' ability to observe objects on Earth and in outer space, and to navigate their spacecraft during periods in which there is little ground control.

761-133 O-65-3

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1966 ESTIMATES

OFFICE OF MANNED SPACE FLIGHT APOLLO PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The ultimate goal of the Manned Space Flight program is to provide a broad national capability for manned space exploration, which will achieve and maintain a position of leadership for the United States. A specific objective in acquiring this capability is to land man on the Moon and return him safely to Earth within this decade. The Apollo Program will meet the specific objective as well as provide a broad base of operational capability in manned space flight and the associated technology; a valuable complex of development, manufacturing, test, and operational facilities; and an experienced Government and industrial team.

To accomplish the objective of landing astronauts and their scientific equipment on the Moon and returning them safely to Earth, two launch vehicles must be developed and qualified for manned flight. In addition, the Apollo Program requires the development of a highly reliable spacecraft, capable of supporting three men in space for periods up to two weeks, docking in space, landing on the lunar surface and safely re-entering the Earth's atmosphere.

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

Manned earth orbital flights on the Saturn IB will include test of the command and service modules and the lunar excursion module. The command module will be manned in the long duration missions lasting up to 14 days. Both crew and equipment will be exposed to the rigors of space environment. An unmanned lunar excursion module will be remotely controlled and evaluated for the purpose of checking operation of the Lunar Excursion Module (LEM) system and performance of the descent and ascent engines after space vacuum and temperature exposure. Rendezvous and docking of the command and service module spacecraft with the unmanned LEM will be accomplished. In subsequent manned earth orbital testing, rendezvous and docking operations will be perfected. The guidance system and rendezvous trajectories will be checked; docking maneuvers will be demonstrated; and the necessary ground network support system will be verified.

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

Manned earth orbital flights, on the Saturn V, will be conducted with a fully loaded lunar space vehicle in simulation of the lunar mission. All phases of crew operations and equipment performance will be validated. Subsequently, manned lunar flights and the first manned lunar landing will be conducted.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Spacecraft.....	$876,575,000	$992,450,000	$1,118,840,000
Saturn I.....	187,077,000	55,450,000	4,400,000
Saturn IB.....	146,817,000	261,150,000	274,700,000
Saturn V.....	763,382,000	965,006,000	1,236,500,000
Engine development.....	166,000,000	153,400,000	140,700,000
Apollo mission support.	133,101,000	179,322,000	222,245,000
Total.....	$2,272,952,000 a/	$2,606,778,000	$2,997,385,000

a/ Includes $72,494,000 of the FY 1965 appropriation related to the FY 1964 supplemental.

Distribution of Program Amount by Installation:

John F. Kennedy Space Center, NASA.....	$49,481,000	$48,172,000	$68,945,000
Manned Spacecraft Center.....	933,486,000	1,080,800,000	1,221,940,000
Marshall Space Flight Center.....	1,257,179,000	1,429,406,000	1,651,300,000
Goddard Space Flight Center.....	206,000	275,000	500,000
Ames Research Center.	75,000	75,000	200,000
Langley Research Center.....	---	1,200,000	2,000,000
Lewis Research Center	2,975,000	600,000	300,000
NASA Headquarters....	29,293,000	46,050,000	51,950,000
Western Operations Office.....	257,000	200,000	250,000

BASIS OF FUND REQUIREMENTS:

Spacecraft

	1964	1965	1966
Command and service modules..	$545,874,000	$525,000,000	$550,000,000
Lunar excursion module.....	135,000,000	226,000,000	270,000,000
Guidance and navigation.....	91,499,000	80,000,000	108,700,000
Integration, reliability, and checkout.....	60,699,000	44,400,000	69,300,000
Spacecraft support.....	43,503,000	117,050,000	120,840,000
Total.....	$876,575,000	$992,450,000	$1,118,840,000

Through FY 1963 a total of $438.4 million had been obligated.

Command and Service Modules

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

In FY 1965, the program definition of the detailed design requirements for the Block I and the Block II command and service module will be completed. Six developmental spacecraft have been delivered and the final two will be delivered in FY 1965 to continue ground development tests and flight tests on Saturn I and Little Joe II launch vehicles. Two of these spacecraft will be used for micrometeoroid experiments on Saturn I. Two will be used for flight abort systems development on Little Joe II at White Sands Missile Range, New Mexico (WSMR). The remaining developmental spacecraft will augment the ground test program covering tests for flotation and handling, land and water impact, parachute drop tests, dynamic tests and system compatibility and integration tests.

Also in FY 1965, the first Block I production service module for ground propulsion tests will be delivered.

During FY 1966, a heavy ground test program will be in progress on delivered ground-development and Block I production spacecraft. Five additional Block I production spacecraft will be delivered in FY 1966 to

support this ground test effort. They will be used for pad abort tests at WSMR, structure tests, acoustic tests, spacecraft integration testing, and ground simulation tests of the temperature and vacuum conditions expected in space. Extensive testing of the spacecraft's propulsion system will continue at the White Sands Missile Range (WSMR).

In FY 1966, the first Block I flight spacecraft for the Saturn IB will be delivered and flight tested. This unmanned flight test will yield important information on the re-entry heat shield structure of the spacecraft. Two additional Block I flight spacecraft will have been completed for future scheduled spacecraft development tests on the Saturn IB. By the end of FY 1966 the remaining Block I flight spacecraft will be in various stages of manufacturing.

During FY 1966, manufacture of the Block II spacecraft will be initiated. These are the spacecraft that will be used for rendezvous missions on Saturn IB and for lunar mission simulations and lunar missions on Saturn V.

Lunar Excursion Module

Lunar excursion module (LEM) development was started by the Grumman Aircraft Engineering Corporation (GAEC) in December 1962. During FY 1964, the preliminary design effort was completed. Mockup reviews were held to determine crew visibility and mobility, and cockpit and equipment arrangements. Configurations for the landing gear, propellant tanks, front face, docking, and electrical power system were selected. Single cell development testing was started on the LEM fuel cell design and descent engine firings were accomplished. By the end of the year, four heavy-weight propulsion rigs were delivered for use in the test program.

During FY 1965, the program is undergoing a sharp build-up in development test activity. The LEM configuration was essentially frozen following a NASA/GAEC review of a hard metal mockup. Major subsystems components are under development.

A LEM test article (LTA) will be delivered to Marshall Space Flight Center for vibration tests with a Saturn test vehicle. A second LEM test article will be delivered to North American Aviation for electronic systems integration. By the end of the year, fabrication will have started on four additional test articles and the first LEM flight vehicle.

During FY 1966, design and engineering and component development tests will be completed and the qualification test program on prototype flight hardware will be started. Dynamic tests will continue at Marshall Space Flight Center on the LEM/Saturn V configuration, using the LTA vehicle delivered during FY 1965. Two additional LTA vehicles will be delivered

for the test program: one for static structural tests with the LEM/S-IVB adapter; and one for vehicle static and dynamic structural testing. The remaining three LTA vehicles will complete manufacturing and will enter installation and checkout. Manufacturing will continue on the first LEM vehicle for orbital flight. Five additional flight vehicles will be in production.

Guidance and Navigation

The Apollo guidance and navigation system will determine the position, velocity, and trajectory of the spacecraft and control the spacecraft's engines and re-entry lift for the precise maneuvers necessary during all phases of flight.

The Instrumentation Laboratory of the Massachusetts Institute of Technology is responsible for system development, fabrication of initial prototypes, and technical assistance to NASA in the direction of the industrial manufacture of production systems.

In preparation for the transition from the developmental phase to the production phase, a realignment of the guidance and navigation contractors has been accomplished during FY 1965. This contractor realignment assigns the NASA prime contract effort to AC Spark Plug and subcontract tasks to the Raytheon Company and the Kollsman Instrument Company. This team of production contractors will provide essentially identical guidance and navigation equipment for both the command module and the lunar excursion module.

During FY 1964, subcomponents of the command module guidance and navigation system were extensively tested. Five of the functional guidance and navigation systems were completed and underwent a variety of mechanical, electrical, thermal, and vibration tests.

In FY 1965, qualification and reliability testing of Block I Guidance and Navigation (G&N) hardware for the command module was continued. Eight command module Block I G&N systems, including two flight-qualified systems, will be delivered in support of the ground and flight testing program. During FY 1965, design of the Block II guidance and navigation system was established, a feature of which was the integration of the guidance and navigation system with the spacecraft's stabilization and control system. This integration provided for two independent guidance, navigation and control systems, primary and back up, with an over-all systems weight saving of almost 100 pounds. In addition, development of command module Block II and LEM equipment will be continued, and construction of experimental and developmental models will be started.

During FY 1966, ten flight-qualified command module Block I, and five command Module Block II G&N systems, are to be delivered for Apollo ground and flight test program. Eight developmental and functional guidance and navigation systems will be delivered in FY 1966 in support of LEM ground and flight test programs.

Integration, Reliability and Checkout

The Automatic Checkout Equipment (ACE) for the Apollo Spacecraft is being designed, developed, produced, installed, and operated by General Electric. In addition, equipment contracts have been negotiated with the Control Data Corporation and Radiation, Inc., in support of the General Electric contract.

The basic design of ACE ground stations was completed in FY 1964. Two stations are operational at North American Aviation's Downey Plant, California. In FY 1965, three additional ground stations will be operational. In FY 1966, five additional ACE ground stations will become operational.

In addition to the ACE hardware mission, the General Electric Company is responsible for the engineering support to Manned Spacecraft Center in the areas of ground support equipment; test programs; reliability and quality assurance; documentation; simulation and training programs; mission planning and analysis; and interface control.

FY 1966 plans include a continuation of the same tasks and emphasize Reliability and Quality Assurance coverage, including trend analysis of failure reports.

Spacecraft Support

Apollo Spacecraft support activities include the requirements for Little Joe II launch vehicles, testing support, logistic support, experiments, space medicine, and instrumentation and scientific equipment.

The Convair Division of General Dynamics was selected in May 1962 to design, develop and fabricate six Little Joe II launch vehicles. Subsequently, two vehicles were added to the contract. Seven of the vehicles have been delivered as of October 1964 and the remaining vehicle is scheduled for delivery during the third quarter of FY 1965. The Little Joe II is used to obtain necessary flight test data on the spacecraft abort and propulsion systems. Funds in FY 1966 will be used to support the test operations at White Sands Missile Range.

In the testing support area, funds are required to conduct the direct test and evaluation programs at Manned Spacecraft Center facilities, Houston, and other government testing laboratories. These tests are an integral part of spacecraft development. For example, the Arnold Engineering Development Center supports the testing of the LEM Propulsion System, Reaction Control System, and ascent and descent engines. Testing support includes the procurement of Government furnished equipment, testing hardware and supplies, guidance, navigation and control equipment, and related studies and analyses.

Included in logistic support are costs of transportation of spacecraft between Installations, reimbursement to the Department of Defense for inspection services, procurement of fuels and propellants for use at White Sands Missile Range, Manned Spacecraft Center, Kennedy Space Center, Arnold Engineering Development Center and at contractor sites.

The Apollo Experiments program was initiated in late FY 1964. FY 1965 represents the first full year of operation and the funds support the cost of program organization and initiation of work on the first of the Apollo flights to carry experiments.

FY 1966 Apollo Program funds are also planned for experiment development, procurement of flight hardware, integration, and operation of medical and engineering earth orbital experiments, and integration and operation of scientific and technological earth orbital experiments. Apollo Program effort in the planning and integration of lunar experiments into the space vehicles will be initiated.

Major effort in the space medicine area in FY 1966 will be devoted to the design and development of in-flight medical experiments for Apollo. These experiments will be primarily designed to measure man's response to the space flight environment, measuring the subtle medical changes. Should conditions dictate these data will be utilized to develop appropriate flight systems for the long duration Apollo flights.

Other areas of biomedical interest in Apollo include cardiovascular system studies, crew performance and radiobiology. In the last area, studies will be directed toward a method for more precise definition of the radiation exposure limits for various Apollo flights. Under cardiovascular systems, studies will be made of the effectiveness of weightlessness countermeasures in weightlessness simulation. Crew performance will include X-ray studies of limb movements of the Apollo suit and the establishment of baseline physiological data for in-flight monitoring purposes.

Funds requested for instrumentation and scientific equipment will be used to develop and procure the specialized flight research and test

instrumentation equipment required during the spacecraft developmental flight testing. Typical instrumentation includes signal conditioners, sensors, transducers, telemetry, transmitters, transmitting antennas, and ground support equipment. Scientific equipment includes special cameras, magnetometers, seismographs, and radiation measuring devices.

During FY 1965, emphasis was on the design, procurement, fabrication test and qualification of instrumentation needed for nine Apollo spacecraft tests and five LEM vehicle tests. Deliveries of instrumentation hardware were made to North American Aviation and Grumman Aircraft for installation and checkout in developmental spacecraft. FY 1966 funds will be employed to continue the design, procurement, fabrication and testing of flight R&D instrumentation. This instrumentation is scheduled for four major lunar excursion module tests.

Saturn I

	1964	1965	1966
S-I stage	$59,774,000	$9,300,000	$700,000
S-IV stage	82,624,000	19,500,000	1,500,000
Vehicle instrument unit	9,004,000	1,900,000	---
Ground support equipment	3,527,000	1,000,000	---
H-1 engine procurement	3,141,000	---	---
RL-10 engine procurement	3,700,000	---	---
Vehicle support	25,307,000	23,750,000	2,200,000
Total	$187,077,000	$55,450,000	$4,400,000

Through FY 1963 a total of $547.2 million had been obligated.

The Saturn program has been marked by a series of successful launches. The Block I phase of the program, which provided for flight tests of the first stage configuration, was completed in FY 1964 with the fourth successful flight. Two Block II vehicles, composed of live first and second stages, were successfully launched during FY 1964. Another successful Block II launch was conducted last September and the last three flights are scheduled during FY 1965 and FY 1966. These last three flights, which will place micrometeoroid detection systems into orbit, will complete the Saturn I series of launches.

The Saturn I program has made a significant contribution to the development of launch vehicles with substantially increased payload capability. The first stages of the Saturn I and IB vehicles have similar basic structural configurations and propulsion systems.

The first stage, S-I, was developed and produced by the Marshall Space Flight Center and the Chrysler Corporation. The second stage, S-IV, was

761-133 O-65-4

developed and produced by the Douglas Aircraft Company. The Rocketdyne Division of North American Aviation and Pratt & Whitney Aircraft developed and produced the H-1 and RL-10 engines, respectively, for the first and second stages. Through FY 1963 a total of $547.2 million had been obligated. FY 1966 funds provide for engineering services, materials, propellants, launch pad refurbishment, data reduction, post flight analysis, and completion of final reports.

Saturn IB

	1964	1965	1966
S-IB stage	$49,106,000	$67,600,000	$75,300,000
S-IVB stage	32,743,000	47,000,000	73,300,000
Vehicle instrument unit	12,985,000	40,000,000	39,900,000
Ground support equipment	23,622,000	36,700,000	9,700,000
H-1 engine procurement	6,548,000	12,400,000	9,700,000
J-2 engine procurement	6,360,000	11,400,000	14,000,000
Vehicle support	15,453,000	41,050,000	47,800,000
Saturn IB/Centaur design studies	---	5,000,000	5,000,000
Total	$146,817,000	$261,150,000	$274,700,000

Through FY 1963 a total of $22.0 million had been obligated.

The two-stage Saturn IB is essentially an uprated version of the highly successful Saturn I. The Saturn IB is required as a test vehicle for Saturn V components, for basic development of the S-IVB stage which will be the third stage of Saturn V, and to provide the capability for earth-orbital flight testing of Apollo spacecraft. The first two launches will take place during FY 1966. The first stage, the S-IB, is a modified version of the first stage of the Saturn I, and is being developed by the Chrysler Corporation. The S-IB will be powered by an uprated set of eight H-1 engines, produced by the Rocketdyne Division of North American Aviation, and capable of developing approximately 1.6 million pounds of thrust. The Douglas Aircraft Company is developing the second stage, the S-IVB. This stage is similar in basic design to the S-IV stage of the Saturn I, with increased propellant capacity and replacement of the cluster of six RL-10 engines with a single J-2 engine, produced by Rocketdyne. Payload capability for the first five Saturn IB flight vehicles will be about 32,000 pounds, while the payload capability for all remaining Saturn IB vehicles will be approximately 35,000 pounds.

S-IB Stage

Development of the S-IB Stage was started in FY 1963. FY 1964 development had progressed to the point where two flight stages were in manufacturing

and long lead-time hardware for two additional flight stages was procured. During FY 1965, the first two flight stages will be static tested; fabrication and assembly of the third flight stage will be completed; and assembly of the fourth flight stage will begin. In addition, parts qualification testing to assure systems reliability will be continued and long lead-time hardware for five additional flight stages will be procured.

Major effort in FY 1966 will be centered on ground and flight testing. During FY 1966, the first two flight stages will be launched; two additional flight stages will be delivered; and fabrication, assembly and checkout will be completed on the fifth and sixth flight stages. By the end of the fiscal year, checkout operations for the seventh flight stage and assembly operations on the eighth flight stage will begin. Effort on the remaining flight stages will be initiated by the end of the fiscal year. FY 1966 funds will also be utilized to support launch activity at Kennedy Space Center.

S-IVB Stage

Developmental effort for the S-IVB Stage is being funded in the Saturn V project. Funds requested for the S-IVB Stage include the engineering design effort and modifications required to adapt the stage for use in the Saturn IB; the actual hardware used in the project; and the cost of accelerating development to make the stage available for the Saturn IB flight schedule. Battleship testing began in the last part of FY 1964. Fabrication of stages for the dynamic, structural, and facility checkout ground tests and production of the first three flight stages were also under way. The fabrication, assembly and checkout of the remaining ground test stages will be completed in FY 1965. In addition, fabrication, assembly, and checkout of the first and second flight stages will be completed and fabrication and assembly of the third and fourth flight articles will be in process. Procurement of long lead-time items for six additional flight stages will also be initiated during this fiscal year.

FY 1966 activity will be highlighted by launch of the first two flight stages, delivery of two additional flight stages to the Kennedy Space Center, and fabrication, assembly, and checkout of the fifth flight stage. In addition, fabrication and assembly of the sixth flight stage will be completed and checkout will be under way. During FY 1966 the seventh flight stage will be ready for checkout and the eighth and ninth flight stages will be in assembly. Effort on the remaining three flight stages will be initiated. FY 1966 funds will also be used for contractor personnel and spare parts to support launch activity at Kennedy Space Center and for support of stage testing at Sacramento, California.

Vehicle Instrument Unit

The instrument unit contains the primary guidance, control telemetry, and measuring systems for the vehicle. The Saturn IB instrument unit has the same layout and components as the Saturn V instrument unit. FY 1964 funds provided for continuing design and development of Saturn IB peculiar equipment and procurement of long lead-time items for the first three Saturn IB units. During FY 1965, the first flight unit will be completed and assembled and fabrication of the second and third flight units will be under way. In addition, long lead-time procurement will begin for four additional flight units. During FY 1966, two instrument units will be used on Saturn IB flights. Two more flight units will be completed and delivered to Kennedy Space Center and the fifth unit will be in checkout. Efforts will continue on the sixth flight unit in the area of fabrication and assembly, while the seventh flight unit will be in the fabrication stage.

Ground Support Equipment

Based on a decision reached in March 1963, an automatic checkout system is being provided for the Saturn IB as a test unit for Saturn V checkout procedures. FY 1963 funding initiated development of a checkout prototype (breadboard). During FY 1964, the design effort was intensified and procurement was initiated. Additional engineering development and component testing for automatic checkout and associated equipment is being accomplished during FY 1965. In addition, electronic components for the breadboard for Launch Complexes 34 and 37B at the Kennedy Space Center are being delivered and procurement of the instrument unit checkout station will be completed. Outfitting of the west side of the static test stand at Marshall Space Flight Center will also be completed.

During FY 1966, the Mechanical Support Equipment (MSE) and Electrical Support Equipment (ESE) will be furnished for Launch Complex 37B. Additional engineering development and automatic checkout systems test units for complete automation will be continued for both the prototype and the launch complexes. Engineering effort will be provided throughout FY 1966 by the General Electric Corporation on the ESE and the Chrysler Corporation/ Space Division on the MSE.

H-1 Engine Procurement

FY 1964 funding provided for delivery of twelve engines and for procurement of long lead-time hardware for deliveries in FY 1965. The FY 1965 program included 42 engines to be delivered, and procurement of long lead-time hardware for engines to be delivered in FY 1966. FY 1966 funding covers delivery of 38 engines and procurement of long lead-time hardware for engines to be delivered in FY 1967. Estimates for all fiscal years include spares, support hardware and services, as well as propellants for acceptance testing.

J-2 Engine Procurement

FY 1964 funding provided for procurement of long-lead hardware for deliveries in FY 1965. FY 1965 funds cover eight engines to be delivered in FY 1965 and procurement of long lead-time hardware for engines to be delivered in FY 1966. FY 1966 funding covers seven engines to be delivered, and procurement of long lead-time hardware for engines to be delivered in FY 1967. Estimates for all fiscal years include spares, support hardware and services, as well as propellants for acceptance testing.

Vehicle Support

Vehicle support includes funds necessary to provide studies, services or equipment that are common to more than one stage or system of the vehicle. FY 1966 funding provides for engineering services; tooling and special test equipment; wind tunnel, dynamics and reliability tests; and fabrication services. The FY 1966 request will also fund communications, transportation, logistic support, propellants, expendable supplies, equipment, and launch pad refurbishment. Special studies will be supported in areas such as component failure analysis, Saturn guidance equation development, post-flight evaluation procedures, and stage and payload separation. Additional ground telemetry equipment, instrumentation, telemetry and GSE mating equipment will also be procured. In addition, FY 1966 funds will provide for contract administration, audit, quality assurance and inspection services performed by other Government agencies.

Saturn IB/Centaur Design Studies

The integration of the Centaur stage into the Saturn IB launch vehicle will provide an Earth-lunar transfer capability of 12,000 to 14,000 pounds and a Mars or Venus trajectory payload capability of approximately 9,500 pounds that will serve a variety of purposes, such as highly-eccentric, multiple-launch orbiting geophysical observatories, advanced technological satellites, and lunar and planetary missions. Fiscal years 1965 and 1966 funds will be used for design studies and supporting plans for use in initiating the hardware development involved in the subsequent test and production effort.

Saturn V

	1964	1965	1966
S-IC stage.....	$256,816,000	$235,356,000	$273,300,000
S-II stage.....	165,189,000	174,606,000	237,500,000
S-IVB stage.....	135,730,000	141,600,000	177,195,000
Vehicle instrument unit.....	54,522,000	81,000,000	84,243,000
Ground support equipment.....	16,281,000	62,716,000	87,677,000
F-1 engine procurement.....	41,000,000	68,100,000	99,000,000
J-2 engine procurement.....	29,150,000	57,965,000	87,800,000
Vehicle support.....	64,694,000	143,663,000	189,785,000
Total.....	$763,382,000	$965,006,000	$1,236,500,000

Through FY 1963 a total of $400.2 million had been obligated.

The Saturn V is a three-stage launch vehicle with the capability of placing a payload of approximately 280,000 pounds into low earth orbit and a payload of approximately 95,000 pounds into a translunar trajectory.

The Saturn V Project was approved in January 1962, following an extensive series of studies on vehicle configurations for the manned lunar landing program. The Boeing Company, Aerospace Division, was selected as the contractor for the first stage (S-IC); North American Aviation Inc., Space and Information Systems Division (S&ID), for the second stage (S-II); Douglas Aircraft Company, Missiles and Space Division, for the third stage (S-IVB); and International Business Machines, Federal Systems Division, for the Instrument Unit. The F-1 Engine used on S-IC Stage and J-2 Engine used on S-II and S-IVB Stages are being developed and manufactured by North American Aviation Inc., Rocketdyne Division. Work with North American was initiated in October 1961, with Douglas in December 1961, with Boeing in February 1962 and with IBM in May 1963. The F-1 and J-2 Engines are provided to the stage contractors as government furnished equipment.

S-IC Stage

The Marshall Space Flight Center, with Boeing's assistance, will assemble the first ground test stage and the first two flight stages at Huntsville, Alabama.

During FY 1962 and continuing into FY 1963, major effort was placed on design, facility planning, research studies and acquisition of tooling and test equipment. Component testing was started in FY 1963 and fabrication was initiated on the first ground test stages. FY 1964 activity

included the start of assembly of the All-Systems Stage, Structural Test Stage, and Dynamic Test Stage and the initiation of hot firing propulsion system tests with the F-1 Engine. In FY 1965, the assembly of all ground test stages is well underway, as well as the assembly of the first three flight stages. In addition, two major ground test programs, the All-Systems and the Structural, will begin in FY 1965. FY 1966 will be marked by continuation of All-Systems and Structural testing, initiation of Saturn V Dynamic testing, and start of checkout of Launch Complex 39 at Kennedy Space Center with the Facilities Checkout Stage. Manufacturing checkout on the first two flight stages is scheduled for completion and the first flight stage will enter the acceptance test phase. In addition, assembly of additional flight stages will be undertaken at the Michoud Plant in Louisiana.

S-II Stage

In fiscal years 1962 and 1963, the major S-II efforts were concerned with preliminary and detail designs, procurement of special tooling and test equipment, procurement of components for design verification and qualification testing, long lead-time hardware procurement for early ground test stages and start of assembly of the Battleship and Structural Test Stages. During FY 1964, fabrication and assembly continued on the Battleship and Structural Test Stages; and assembly of the All-Systems, Dynamic and Facilities Checkout Stages was initiated. During FY 1965, the Battleship Stage was completed and tests were begun. Structural Test Stages will also be completed and the Structural Test Program and assembly of the first flight stage will be initiated. FY 1966 will see the completion of the assembly of the All-Systems, Dynamic and Facilities Checkout Stages, the start of the All-Systems Stage and Dynamic Vehicle Test Programs and the facilities checkout of Launch Complex 39 at Kennedy Space Center. The first two flight stages will complete manufacturing checkout at Seal Beach, California and the first flight stage will enter the acceptance test phase at the Mississippi Test Facility. In addition, assembly of additional flight stages will be undertaken.

S-IVB Stage

Although the S-IVB Stage will also be used on the Saturn IB Vehicle, the common development costs are being funded by the Saturn V Program. As with the S-IC and S-II Stages, funding during FY 1962 and FY 1963 was used to provide design, facilities planning and tooling and procurement of long lead-time hardware. Qualification testing was also started during that period. In addition, fabrication of the Battleship and Structural Test Stages was started. During FY 1964 assembly of the Battleship and Structural Test Stages was completed and the Structural test program was initiated. Structural assembly of the All-Systems, Dynamic and Facilities Checkout Stages was also begun in FY 1964. In FY 1965, the decision was made to

modify the ground test program by deleting the All-Systems Stage requirement and using the hardware as a Facility Checkout Stage. These ground test stages are scheduled to be completed in time to support the Saturn IB requirements. The Battleship test program has also been initiated. Ground Support Equipment for automatic checkout of S-IVB stages is to be completed, and assembly of the first two flight stages has been started in FY 1965.

FY 1966 will see the initiation of Saturn V Dynamic Testing at the Marshall Space Flight Center and checkout of Launch Complex 39 at Kennedy Space Center with the Facilities Checkout Stage. Also during FY 1966, manufacturing checkout of the first two flight stages is scheduled for completion at Huntington Beach, California, in preparation for acceptance test at the Douglas Sacramento, California, Test Site. Assembly of additional flight stages will also be undertaken during FY 1966.

Vehicle Instrument Unit

The vehicle instrument unit includes a structural system, environmental system, guidance system, control system, electrical system, and telemetry and measuring systems. The Saturn V instrument unit is being developed by the Marshall Space Flight Center; flight units will be assembled by International Business Machines (IBM). The major guidance components are provided by the Bendix and IBM corporations. Fiscal year 1962 and 1963 funds provided for initial design, component testing and a continuation of guidance system research and development, based on experience with the Saturn I project. In FY 1964, design and engineering of components continued and structural fabrication of the first three ground test units, system test, and facilities checkout were completed. The procurement, fabrication, and acceptance testing of components is being continued during FY 1965. Structural and vibration testing is under way. The assembly of the facilities checkout structure, flight systems, and vibration test units is also scheduled for completion. During FY 1966, vibration and structural testing will be completed and flight systems testing will be initiated. Saturn V Dynamic testing with the Dynamic Test Unit and checkout of Launch Complex 39 at Kennedy Space Center with the Facilities Checkout Instrument Unit will also be started. Assembly of the first two flight units will begin and the first flight unit is scheduled to be completed during FY 1966.

Ground Support Equipment

Ground Support Equipment (GSE) consists of non-facility hardware required to functionally check out assembled Saturn V vehicles. Fiscal year 1964 and 1965 funds were used for design and initiation of long lead-time procurements of mechanical and electrical checkout equipment for use at Launch Complex 39. In addition, fabrication of a prototype set of equipment (Breadboard) was begun and checkout equipment was procured for

the first facility checkout at Complex 39. Funds were also used to develop and procure special test equipment and components, such as hardware for the Umbilical/Swing Arm Test Facility.

In FY 1966, the Saturn V breadboard is scheduled to become operational and delivery, installation, and checkout of equipment is scheduled to be completed at Launch Complex 39 for the first Saturn V launch operation. The General Electric Company is under contract for design, fabrication, and support of the vehicle electrical support equipment. The first delivery is scheduled for October 1965, and FY 1966 is planned as the peak year for manufacture, delivery, and checkout of electrical support equipment for Launch Umbilical Towers and Launch Control Centers numbers 1 through 3. In the mechanical support equipment area, the Boeing Company will follow through on a make-or-buy basis to assure the complete provisioning and integration of all vehicle mechanical support equipment. The Boeing Company will also operate the Saturn V Equipment Management System to provide a master equipment records system for all Vehicle Ground Support Equipment. The Radio Corporation of America will complete the delivery of necessary computer systems, together with initiation of maintenance and support operations. FY 1966 will also mark the final delivery by Sanders Associates of the display systems required for Launch Complex 39 checkout operations.

F-1 Engine Procurement

FY 1965 funding provides for delivery of 17 engines and procurement of long lead-time hardware. FY 1966 estimate provides for delivery of 23 engines and procurement of additional long-lead hardware. These funds also cover procurement of spares, support hardware, services and propellants for acceptance testing of the engines scheduled for delivery.

J-2 Engine Procurement

FY 1965 funding provides for delivery of 21 engines and procurement of long lead-time hardware. The FY 1966 estimate provides for delivery of 41 engines and procurement of additional long-lead hardware. Funds in both fiscal years also cover spares, support hardware, support services and propellants for acceptance testing of the engines scheduled for delivery.

Vehicle Support

Vehicle support funds are required to provide services and equipment that are common to more than one stage of the vehicle. Fiscal years 1964 and 1965 funding includes instrumentation, recording and data reduction equipment for the Saturn V Dynamic Test Stand at Marshall Space Flight Center; developmental and operational transportation costs which include use of marine vessels and aircraft for movement of stages and outsize cargo; activation of the Mississippi Test Facility; operation of the Slidell Facility; range safety and tracking devices; propellants, equipment and

engineering support associated with vehicle checkout at Kennedy Space Center; computation services; engineering services; quality control and inspection, contract administration, audit and property administration services by other Government agencies; a wide spectrum of developmental testing including categories such as (1) determination of bending modes and resonant frequencies of Saturn V, (2) liquid hydrogen and liquid oxygen propellant feed systems, (3) welding techniques. Also included in vehicle support is an extensive Systems Engineering and Systems Integration effort which insures proper interface control of all stages, systems and structures.

In FY 1966 testing of S-IC and S-II Stages will begin at the Mississippi Test Facility necessitating increases in plant and technical support activities at that location. Vehicle support will also include funding of propellants used in the testing of these stages. Particular emphasis will be placed on the activation and operations of the Dynamic Test Stand at Marshall Space Flight Center. Transportation requirements will increase consistent with the delivery of more stages. Systems Engineering and Systems Integration functions will be intensified to their planned peaks. Other efforts will include vehicle flight control systems studies; reliability programs; acoustical environmental determination; ground wind load tests; intensified qualification testing and vehicle propellant blast hazard testing.

Engine Development

	1964	1965	1966
H-1 engine.....	$11,531,000	$4,800,000	$4,800,000
RL-10 engine.....	15,022,000	14,400,000	1,900,000
F-1 engine.....	61,954,000	54,400,000	52,500,000
J-2 engine.....	48,284,000	46,202,000	45,500,000
Propellants and related engine support.....	29,209,000	33,598,000	36,000,000
Total.....	$166,000,000	$153,400,000	$140,700,000

Through FY 1963 a total of $319.0 million had been obligated.

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

H-1 Engine

The H-1 engine, which is being developed by the Rocketdyne Division of North American Aviation, Inc., is used in clusters of eight per stage to propel the first stages of the Saturn I and Saturn IB vehicles. This engine produces up to 200,000 pounds of thrust using liquid oxygen and RP-1 (kerosene) as propellants.

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

Development of a 200,000 pound thrust version of the engine for the Saturn IB is necessary to insure attainment of the required payload capability. This additional development effort began in FY 1964 and has continued in FY 1965. The FY 1964 effort included a complete stress analysis of critical engine components at increased flight loads created by the higher engine thrust operating level, and a program of engine tests to determine operating limits. Only those components found to be marginal by the stress analysis and 200,000 pound thrust level testing were redesigned. The FY 1965 up-rating effort consists of a development and testing program, involving approximately 1,000 ground tests and requiring 18 engines through complete engine **qualification** at the 200,000 pound thrust level by the end of the fourth quarter of fiscal year 1965. In FY 1966, the development program will consist of launch support, testing, flight evaluation, and support of the production program. This effort includes maintaining the capability for design and development, approximately 250 ground tests, and retrieving, evaluating, and reporting data evolved from the Saturn I and IB flights.

RL-10 Engine

The RL-10 engine is being developed by Pratt & Whitney Aircraft for use in the second stage (S-IV) of the Saturn I vehicle and the Centaur stage of the Atlas-Centaur vehicle. The S-IV Stage uses a cluster of six

engines and the Centaur a cluster of two engines. Each engine, using liquid hydrogen and liquid oxygen as propellants, develops 15,000 pounds of thrust.

Development of the RL-10 A-3 engine was initiated by NASA in 1961, and was a follow-on program to the RL-10 A-1 engine program initiated by the Air Force in 1958. The RL-10 A-3 engine successfully completed its Preliminary Flight Rating Tests (PFRT) in July 1962 and its Qualification Tests in September 1964. RL-10 engines have flown successfully in three Saturn flights and three Centaur flights.

In FY 1964, the Centaur Program Office, located at Lewis Research Center, Ohio, requested that the RL-10 engine be modified to provide an increased specific impulse that would enable Centaur to meet its payload requirements. This effort, initiated in April 1964, requires the development of a recontoured thrust chamber, an increased performance injector, and a modified turbopump. FY 1965 activity will include completion of initial design and fabrication, and initial testing of prototype hardware.

The RL-10 engine development effort in FY 1966 is primarily devoted to providing an increased specific impulse for Centaur payload requirements. The Manned Space Flight FY 1966 request will be used to support the last Saturn I launch and provide for post-flight evaluation of Saturn I flight data.

F-1 Engine

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

Development of the F-1 engine was begun in January 1959 when a contract was awarded to Rocketdyne for development, through Preliminary Flight Rating Tests (PFRT), of a 1,500,000 pound thrust LOX-RP-1 rocket engine. In June 1961, the test firing of the first F-1 engine was accomplished. Since that time, F-1 engines have achieved rated thrust and duration (150 seconds) runs well over 100 times. During the latter part of calendar year 1962 combustion instability reached serious proportions. This instability problem was attributed to difficult detailed design problems associated with extremely large injectors and turbopumps. A task force composed of NASA, Department of Defense, University, and Industry experts was assigned to attack this problem and recommend solutions. This effort has resulted in several injector designs which produced stable combustion. However, a substantial program of testing must still be accomplished to ensure that other

engine requirements, such as performance, durability, and pressure drop, are not compromised by an injector of satisfactory stability. The final release of the design of the Flight Rating Test (FRT) engine was made in the first quarter of FY 1964, and testing is scheduled for completion in the third quarter of FY 1965.

In FY 1965 and again in FY 1966, approximately 350 separate engine system ground tests will be performed. These tests are part of the approximately 1,500 planned engine system tests that must be performed to qualify the engine for manned flight. Major efforts programmed for FY 1966 include: completion of component qualification; continued demonstration of the engine's ability to recover from induced combustion instability and perform at a specific impulse compatible with vehicle requirements; and release of final design of a qualification engine. To maintain this extensive testing program in fiscal year 1966, building of five new engines, rebuilding of 14 engines, and production of the equivalent of 10 engines in test components are scheduled.

J-2 Engine

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

Development of the J-2 engine began in September 1960 with the award of the development contract to Rocketdyne. In October 1962, the engine achieved its first full thrust (250-second duration) run. The first 500-second duration run necessary to meet the finalized requirements of the Saturn IB and V vehicles was successfully conducted on November 27, 1963. Other accomplishments during FY 1964 included demonstration of gimbal capability, nominal performance, the propellant utilization system and the first PFRT-type engine test.

During FY 1965, approximately 500 ground tests will be performed. Additional accomplishments include completion of PFRT and demonstration of engine restart. Start and cutoff impulse and thrust alignment and vibration limitations will also be demonstrated by the end of the fiscal year.

In FY 1966, approximately 500 ground tests will be performed. Testing for qualification of the fuel turbopump, gas generator, LOX turbopump, engine controls and engine flight instrumentation, started in FY 1965

and is scheduled to be completed in FY 1966. The J-2 engine qualification Test Program will be conducted during FY 1966. In the process of accomplishing these tests, eight new engines will be built and 12 engines will be rebuilt.

Propellants and Related Engine Support

Propellants and ancillary fluids required by the contractors in their test programs are procured and provided as Government furnished material. The primary products used are liquid oxygen, liquid hydrogen, kerosene, liquid nitrogen and helium. Based on a NASA/DOD agreement, the Air Force procures and delivers all required propellants, with the exception of liquid hydrogen. NASA procures liquid hydrogen from private producers. The FY 1966 Engine Development Test Program will require approximately 205,000 tons of liquid oxygen, 13,000 tons of liquid hydrogen, 8 million gallons of kerosene, 44,000 tons of liquid nitrogen, and 50 million cubic feet of helium. Engine support funds in FY 1966 will provide for services, supporting research and equipment associated with contractor effort. Engine support will also fund contract administration, audit, property administration, and quality and inspection services by other Government agencies.

Apollo Mission Support

	1964	1965	1966
Systems engineering.....	$28,877,000	$41,000,000	$41,000,000
Launch operations and instrumentation.....	22,759,000	20,572,000	37,245,000
Mission control systems.....	47,530,000	38,500,000	36,400,000
Apollo space operations.....	3,663,000	25,350,000	37,000,000
Supporting development.....	30,272,000	53,900,000	70,600,000
(Apollo extension systems)...	---	(14,000,000)	(48,000,000)
Total.....	$133,101,000	$179,322,000	$222,245,000

Through FY 1963 a total of $107.1 million had been obligated.

Apollo mission support provides for the supporting development and program-wide technical effort; and equipment and technical and engineering effort for the development and maintenance of the launch and flight operations capability necessary to accomplish the Manned Lunar Landing program.

Systems Engineering

This activity covers program-wide technical review and analysis, in addition to technical support needed for the successful accomplishment of Apollo. This effort gives assurance that program functional and performance requirements are compatible with mission objectives. FY 1965

and prior fiscal year funding provided for efforts which supported mission description and planning, test objectives and integration, program and systems specification, guidance and navigation studies, including trajectory analysis, communications and tracking networks, checkout effectiveness, and documentation. FY 1966 funding provides for an extension of most of the analyses. Emphasis will shift to reliability studies, including mission safety analysis, mathematical model development and failure effects analysis, as the hardware program progresses. The principal systems engineering contractors are Bellcomm and General Electric.

Launch Operations and Instrumentation

Funds for Launch Operations provide for contractor supported services in the Merritt Island Launch Area (MILA), including major items of equipment required to support these contractors. In addition, the funds also cover reimbursements to the Air Force for support services. Fiscal Years 1965 and 1966 requirements are based on an accelerated program to support Saturn V and the Manned Lunar Landing Program, and Saturn IB launches from Complex 34. Apollo activities at the Kennedy Space Center are increasing as construction of facilities at MILA progresses toward completion.

FY 1965 funds provided for Launch Instrumentation improvements to support the Saturn launch vehicle development program. Telemetry, tracking, facility and environmental measurement, and other instrumentation systems were expanded and improved. For example, additional tracking receivers were implemented to achieve greater system accuracy, and the data reduction system was augmented to provide near real-time performance.

During FY 1966, continued expansion and improvement of Launch Instrumentation systems are required because of increasing complexity of launch vehicles and the activation of additional launch facilities. Specific improvements include increased efficiency and reliability in handling digitized telemetry data, development of a close-in prototype tracking system, expansion of the timing distribution system, development of a large-screen display system, expansion of the flight TV system to dual-pad capability, and expansion of facility and environmental instrumentation. Funds are also required for equipment operation, maintenance and rental, and for prototype fabrication.

Mission Control Systems

Mission Control Systems include development, operation, and maintenance of the Mission Control Center (MCC) at the Manned Spacecraft Center and associated interfaces at the Kennedy Space Center. It also provides for the technical integration of the MCC with the worldwide Manned Space Flight Network and for the compatibility testing of spacecraft electronic systems with the entire Ground Operational Support System (GOSS).

Construction of the MCC building is complete. Four large digital computers have been installed and checked out, and are being used for mission monitoring, computer program testing, and operational planning. An additional computer system is to be installed in FY 1965. This equipment must be further augmented in FY 1966 to provide sufficient capability for the simulation, operational, and programming activities required for Gemini and Apollo missions. Technical systems have been installed and will be used for mission monitoring during FY 1965. The integrated checkout of the systems within the MCC and its interface with the worldwide network for single vehicle earth-orbital Gemini missions will be completed during FY 1965.

FY 1966 funds are required to perform integrated MCC checkout for Gemini rendezvous and earth-orbital Apollo missions, to accomplish necessary modifications to equipment as a result of mission experience, for testing of the Apollo Launch Data System (interface equipment at Cape Kennedy), for continued rental of computing and teletype equipment, and for operation and maintenance during scheduled missions. FY 1966 funds are also needed for the compatibility testing of Saturn IB/Apollo Spacecraft electronic systems with the MCC and the Manned Space Flight Network.

Apollo Space Operations

These funds provide for flight crew, pre-flight and flight operations support for the Apollo program.

Flight Crew Operations support all phases of crew training and the integration of crew activities with the engineering design of the Apollo spacecraft and related mission planning activities. Accomplishments planned during FY 1966 include delivery and checkout of the command module mission simulator and procurement of two lunar landing training vehicles (in the LEM configuration). FY 1966 funds will also be used for flight training and pilot qualification and for modification of the Gemini docking trainer into the Apollo configuration.

Pre-flight operations consist of the preparation, checkout and prelaunch activities for the Apollo spacecraft and the auxiliary systems relating to the launch.

In FY 1965, activation of checkout facilities at MILA will be continued to insure adequate checkout capability for the first Apollo spacecraft to be launched from Cape Kennedy on a Saturn IB vehicle in FY 1966. Activation of checkout facilities for the Apollo spacecraft will require the major portion of the funds requested for FY 1966.

Flight operations include mission planning and analysis, flight control, and recovery operations.

Mission planning and analysis covers the development and optimization of all operational trajectories for Apollo space flight missions. Funds are needed in FY 1966 to continue contract support in the development of real-time computer programs for the Apollo missions; development of mathematical techniques required for trajectory programs; and modification of computer equipment and continuation of mission analyses begun in prior years.

Flight Control includes the development of detailed flight control plans, training of flight controllers at the Manned Spacecraft control centers and at Manned Space Flight Network remote stations for ground monitoring; and, as necessary, control of the Apollo missions. FY 1966 funds are required for continuation of contractor support personnel for flight monitoring; remote-site operation; determination of flight control procedures and flight controller training; and purchase of auxiliary flight controller equipment.

Recovery operations include planning and operational supervision of all recovery support services for the Apollo missions. FY 1966 funds will support the Department of Defense recovery forces required for Apollo flights. These DOD services include deployment of ships, aircraft and communications equipment and providing a capability of spacecraft location in the event of contingency landings. In addition, funds are required for the test, evaluation, and procurement of retrieval and location equipment issued to Department of Defense recovery forces and modification of existing equipment.

Supporting Development

Supporting Development consists of individually selected engineering tasks primarily supporting the Apollo program. Included are studies and hardware developments which provide increased assurance of meeting the performance and reliability requirements of Apollo missions, including both early manned lunar landing missions and alternate missions using the Apollo hardware. Supporting Development tasks are related to the spacecraft, launch vehicle, propulsion, and launch operations hardware programs of the Manned Space Flight Centers, and provide alternate and improved systems, subsystems, components and materials which can be phased in on a scheduled basis.

Alternate system developments provide for substitute hardware, of other designs meeting approved specifications, which can directly replace present systems where development problems in the mainstream program have been encountered or may occur. Improved system developments provide for hardware designs offering increased performance which may be required to complete an approved mission objective.

761-133 O-65-6

FY 1966 Supporting Development tasks will continue current efforts to develop alternate and improved systems and subsystems for the early lunar landing configuration of the Apollo spacecraft and the Saturn IB and V launch vehicles, stages, instrument units, and ground support equipment. Typical tasks are: Alternate Structures for use in Saturn IB and Saturn V vehicles; Improved Propellant Tank Manufacturing Techniques; Thermal Protection Materials Improvement; Improvement of Saturn Retro Motors; Development of Alternate Welding and Weld Inspection Techniques for Saturn IB and Saturn V Vehicle Structures; Miniaturization of Control System Circuits and Components.

Supporting Development funds for FY 1966 will also be utilized for identification and advanced development of long lead-time Apollo spacecraft modifications of subsystems and components, of in-flight and lunar surface experiments, and for final design which would be necessary prior to undertaking flight hardware and experiments development.

Apollo Extension Systems would utilize the capabilities inherent in the Apollo program to extend the fund of knowledge and operational experience by the exploration and scientific investigation of near-earth space and the moon itself. To utilize this capability and implement space exploration objectives, detailed program definition is being accomplished. This preliminary effort paves the way for undertaking those advanced development activities which will be required for timely Apollo program extensions.

Advanced development and final design activities during FY 1966 are to be devoted particularly to modifications of electrical power, reaction control and life support subsystems and components necessary to extend their capability to 4 to 6 weeks in earth orbit and up to 2 weeks lunar surface staytime. Early identification and advanced development of experiments is essential to the preparation of flight mission plans. Categories of experiments already being identified for advanced development funding are those related to the investigation of zero gravity and artificial gravity; to meteorology; to geological and geophysical experiments related to the earth and to the lunar surface; to astrophysics; and to the performance of tests, in the space environment, of systems, subsystems and components for future missions. Particular emphasis during FY 1966 will be placed on the advanced development of the actual devices proposed for the conduct of experiments during the early mission opportunities. Mockups and prototypes and, in some cases, flight articles of experiment packages will be fabricated to establish their relationship to crew activities and their location in the spacecraft and to determine their power, weight and volume requirements which are important considerations in arriving at final subsystems, components and experiments design.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1966 ESTIMATES

OFFICE OF MANNED SPACE FLIGHT — ADVANCED MISSIONS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

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

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Advanced missions program.....	$21,200,000	$26,000,000	$10,000,000
Distribution of Program Amount by Installation:			
John F. Kennedy Space Center, NASA.....	$400,000	$450,000	$400,000
Manned Spacecraft Center.....	3,650,000	8,200,000	1,400,000
Marshall Space Flight Center..	9,245,000	7,950,000	5,300,000
Langley Research Center.....	2,017,000	1,700,000	1,700,000
NASA Headquarters.....	5,798,000	7,700,000	1,200,000
Western Operations Office.....	90,000	---	---

BASIS OF FUND REQUIREMENTS:

	1964	1965	1966
Advanced studies.....	$21,200,000	$26,000,000	$10,000,000

Advanced studies enable NASA to direct its future manned space flight program planning. Specific areas of investigation include: manned earth orbital, lunar, and planetary missions. During FY 1965, major emphasis is placed on program definition studies of Apollo Extension Systems (AES). These studies are designed to exploit the technology and capability being developed in the Apollo Program to extend the orbital and lunar stay-time beyond current Apollo requirements. The AES will utilize only basic Apollo-type hardware. The FY 1966 requirements reflect a major reduction from the FY 1965 level because of the evolvement of extended Apollo systems from the definition and preliminary design phase to a selective study and advanced component development phase.

Manned earth orbital mission studies completed to date have established the feasibility of earth orbiting space stations. Two concepts have been selected for further definition. One is based on the utilization of Apollo systems to conduct extended earth orbital missions, and the other is based on the development of a modular space station capable of serving a variety of needs over an extended period.

The FY 1966 effort will be directed primarily in two areas. The first is to continue to identify and evaluate potential experimental payloads for manned flights which could be used to obtain beneficial returns from space exploration. These payload studies include methods of remotely sensing the condition of the earth's atmosphere for use in weather prediction; methods of observing the earth's surface for use in cartography and in resource utilization planning; and optical and radio telescopes for use in astronomy and astrophysics. The second area of effort is continued study and refinement of space station concepts to accomplish extended earth orbital missions. With the definition of Apollo extensions, the relationship between these missions and extended earth orbital missions can be studied particularly in terms of in-flight testing of subsystems, components and operations in the process of defining a true space station.

Manned lunar mission studies have been directed toward identifying and defining the most effective systems to support lunar exploration missions following the initial Apollo landings. Studies are now underway to define systems to support initial lunar orbital missions and surface reconnaissance operations following the manned lunar landing and to explore systems suited to more extensive lunar operations and scientific exploitation of the moon.

Through the use of the extended Apollo systems, it will be possible to demonstrate capabilities (1) to acquire scientific lunar data from a manned lunar orbiting spacecraft using specialized cameras, non-photographic sensors and orbit-to-surface probes; and (2) to conduct extensive geological and geophysical surveys of selected areas on the moon to provide a phased expansion of the data obtained from earlier NASA missions. The principal system being investigated for subsequent, more extensive operations, is the Lunar Exploration System for Apollo.(LESA). LESA is a flexible system which, in its growth capability, could provide a lunar base. It is conceived as a modular set of lunar surface hardware which can be tailored quickly to support a wide range of lunar exploration missions. The system includes surface vehicles, shelters, nuclear power plant, appropriate support equipment, and regenerative systems to reduce supply requirements. From the family of LESA modules, sets of equipment could be assembled to meet the needs of several astronauts for lunar surface missions of either short or long duration.

Manned planetary mission studies to date have established the feasibility of a number of mission modes and system concepts, however the complexity of these missions and the extensive resources required for such an undertaking make it imperative that a comprehensive study program be accomplished during the next few years before program initiation is considered. The planetary mission studies in FY 1966 will place primary emphasis on more

detailed analysis of system feasibility and concepts. Studies of scope, objectives, schedules and cost will be necessary to select the most promising concepts for detailed engineering analysis in later years.

In addition to the studies of manned missions in earth orbit, to the moon, and to the nearby planets, a number of studies will be made to define potential launch vehicles for use in each of the mission areas. These vehicle systems include improved versions of vehicles presently under development, larger vehicles utilizing the major new propulsion systems under development, and vehicles embodying reusable concepts.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1966 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS PHYSICS AND ASTRONOMY PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objective of the Physics and Astronomy Program is to increase our knowledge of the space environment of the Earth, the Sun and its relationships to the Earth and the interplanetary medium, the geodetic properties of the Earth, and the fundamental physical nature of the universe. To achieve this objective, research is carried out with respect to the upper atmosphere and the ionosphere, the region included in the Earth's magnetic field or magnetosphere, the region of interplanetary space beyond the boundaries of the magnetosphere, the solar radiations in these regions and their interactions with the regions, the Sun and its emission of radiations, stars and other celestial bodies, galactic and solar cosmic rays, and the geodesy of the Earth. Research is carried on with experimental apparatus carried by balloons, airplanes, sounding rockets, earth satellites, and space probes.

Increased knowledge of the space environment surrounding the Earth is important to the continued advancement of man's efforts to understand and control his environment. Knowledge of the structure and dynamics of the upper atmosphere is basic to an improved understanding of meteorology. It is also important in understanding the problems of spacecraft reentry. An improved understanding of the characteristics of the ionosphere will advance radio communications between points on the surface of the earth as well as communications with spacecraft. A more complete understanding of the characteristics of the radiation belts and the earth's magnetic field will help us to understand the phenomena of the atmosphere and ionosphere and will also provide an improved assessment of the radiation hazard to manned space flight. These studies of the environment of the Earth also provide a frame of reference for studies of other planets.

The Sun exerts a dominant influence over the entire solar system. Any effort to understand our space environment or to explore the moon and planets without understanding the characteristics of the sun would be impossible. The low energy solar plasma and the energetic cosmic rays emitted by the Sun control the environments of the Earth, the Moon and the other planets. They also provide the environment through which man must travel in interplanetary space. The environment created by the Sun varies not only with the eleven year solar cycle but also with the individual solar flare events. The mechanisms which produce these phenomena are not understood. A comprehensive study of the Sun and its influence involves ground based observations, observations of the Sun's electromagnetic radiations from above the Earth's atmosphere, and measurements of the particles, plasma and magnetic fields in the vicinity of the Earth and in interplanetary space.

The Earth is approximately an oblate spheroid, but its surface is neither smooth nor regular and the exterior shape of the Earth does not define exactly the distribution of the mass in the interior. Satellites provide a unique opportunity to learn more about these geodetic properties than can be learned from the surface of the Earth. Accurate measurement of satellite positions and orbits permits tying points on the surface of the Earth into a complete world geodetic net with an accuracy not possible before. The orbits of earth satellites are perturbed by irregularities of the distribution of mass within the Earth. A National Geodetic Satellite Program is now in progress to meet the requirements of the Department of Defense, the Coast and Geodetic Survey, and NASA for geodetic data and to provide for exchange of geodetic data on an international basis.

From the earliest days of recorded history man has raised questions concerning the stars and the fundamental physical nature of the universe. While our own solar system naturally attracts the preponderance of the effort in the NASA program, space technology also provides a new opportunity for gaining knowledge about the rest of the universe. The ability to place astronomical instrumentation above the atmosphere makes it possible to view the stars, nebulae, interstellar dust and gas, and galaxies in wavelengths not accessible from the surface of the Earth. It also eliminates the distortion caused by the Earth's atmosphere in those wavelengths that penetrate the atmosphere. In the future, deep space probes will present opportunities to make direct observations of interstellar conditions in the regions beyond the primary influence of the solar wind. These studies of the rest of the universe, when considered in context with studies of our own solar system, broaden our opportunity to learn about the behavior of matter and energy and present important clues to the nature and evolution of the universe.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Supporting research and technology.....	$17,666,000	$20,100,000	$25,200,000
Solar observatories.....	20,005,000	17,303,000	37,000,000
Astronomical observatories..	35,608,000	31,210,000	32,500,000
Geophysical observatories...	42,868,000	30,242,000	31,700,000
Explorers.....	15,526,000	21,959,000	25,700,000
Sounding rockets.....	16,950,000	16,000,000	17,000,000
Data analysis.....	---	---	3,000,000
Total.....	$148,623,000	$136,814,000	$172,100,000

Distribution of Program Amount by Installation:

Manned Spacecraft Center.....	$1,020,000	$2,300,000	$2,600,000
Marshall Space Flight Center.	195,000	20,000	20,000
Goddard Space Flight Center..	123,753,000	107,473,000	133,585,000
Jet Propulsion Laboratory....	476,000	334,000	650,000
Wallops Station.....	---	1,390,000	4,500,000
Ames Research Center.....	605,000	1,764,000	2,255,000
Flight Research Center.....	44,000	85,000	100,000
Langley Research Center.....	2,333,000	2,280,000	1,730,000
Lewis Research Center.....	150,000	---	---
NASA Headquarters.....	20,047,000	21,168,000	26,660,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1964	1965	1966
Particles and fields.....	$4,173,000	$5,300,000	$6,900,000
Ionosphere and radio physics...	879,000	1,100,000	1,400,000
Planetary atmospheres and space chemistry.....	3,154,000	---	---
Interplanetary dust and cometary physics.....	864,000	1,110,000	1,400,000
Solar physics.....	2,420,000	2,700,000	3,100,000
Astronomy and geodesy.....	3,007,000	3,145,000	3,600,000
Spacecraft technology.....	---	300,000	600,000
Interdisciplinary space science.....	1,503,000	2,145,000	1,700,000
Manned space science.....	1,666,000	3,700,000	5,600,000
Advanced studies.....	---	600,000	900,000
Total.....	$17,666,000	$20,100,000	$25,200,000

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

The FY 1965 and FY 1966 programs reflect a minor reorganization of the Supporting Research and Technology program. Work in the disciplines of Planetary Atmospheres, Space Chemistry and Planetary Astronomy was transferred to the Lunar and Planetary Program. Work in the disciplines of Particles and Fields, Solar Physics, Interplanetary Dust and Cometary Physics, and Interplanetary Spacecraft Technology was transferred to the Physics and Astronomy Program.

Particles and Fields

Work in this area concerns the development of new instruments for measuring the direction, magnitude and time variations of magnetic fields and for measuring the energy, direction and mass of charged particles. It also consists of theoretical research and ground and balloon borne observations which will aid in the interpretation of space measurements. The major areas of increased emphasis in FY 1966 will be research in very high energy cosmic rays and development of a new type of magnetometer based on plasma resonances which were discovered by the Alouette satellite. Recently developed research techniques have made it practical to conduct research on high energy particles in the energy range above 100 billion electron volts. Laboratory particles accelerators will not be available in this energy range for several years, but by using balloons to carry spark chambers and counters above the lower atmosphere, it is possible to study the interactions between high energy cosmic rays and hydrogen, and to measure the energy and direction of the high energy particles. This information can be expected to make important contributions to the science of nuclear physics and to aid astronomers in their understanding of conditions in interstellar and intergalactic space.

Ionospheres and Radio Physics

Ionospheres and Radio Physics involves ground based observations, theoretical studies and instrument development relating to the ionized regions of the atmospheres of the earth and other planets and of interplanetary space. The increased budget in FY 1966 will provide for additional theoretical and laboratory plasma studies and for attempts to interpret recent discoveries concerning the diurnal, seasonal and latitudinal variations in the structure and composition of the topside of the ionosphere.

Planetary Atmospheres and Space Chemistry

Planetary Atmospheres and Space Chemistry was transferred to the Lunar and Planetary Program.

Interplanetary Dust and Cometary Physics

Interplanetary Dust and Cometary Physics involves the study of extra terrestrial particulate matter; its behavior, structure, composition, origins; and its significance in providing information on the physical properties of the solar system and the galaxy. New efforts in FY 1966 will include studies of the formation of aggregates of particulate matter and of the condensation processes of cometary and interstellar gases.

Solar Physics

Solar Physics involves ground, aircraft, and balloon borne observations; theoretical studies; and instrumentation development related to orbital observations of the Sun. Primary emphasis in FY 1966 will be on the development of advanced instrumentation capable of obtaining better spacial and spectroscopic resolution of the Sun's structure and activity.

761-133 O-65-7

Astronomy and Geodesy

Astronomical research and technology efforts include theoretical studies of stellar astrophysics; laboratory spectroscopy; research on optical materials; advanced development of instruments; and ground based, balloon, and aircraft observations. Work is also being done leading to the development of extremely precise gyroscopes which could be used in a zero G satellite for tests of Einstein's theory of relativity. Theoretical studies in celestial mechanics and geodesy are also included. These efforts will be continued in FY 1966 and some preliminary investigations will be started on optics and subsystems suitable for a large orbiting telescope which would be erected and maintained by men in space.

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 initiated in FY 1965 and will be continued in FY 1966. In addition, work will be initiated on improved electronic and power supply components for Explorer satellites.

Manned Space Science

This area involves the preparation of scientific experiments and equipment for flight on manned space missions, training of the astronauts in space physics and astronomy, and environmental data support for the Apollo program.

Five experiments, making use of man's unique visual and manual capabilities during flight to achieve the desired scientific data, are nearing readiness for flight during calendar years 1965 and 1966 on Gemini missions. Development of about 15 additional experiments for Apollo Earth Orbital flights will be initiated before the end of FY 1965, with principal flight hardware costs anticipated in FY 1966. Studies are underway to define the instrumentation, procedures and support requirements necessary to carry out more advanced investigations on potential future manned space missions, with the planned level of effort in FY 1966 for these activities approximately the same as in FY 1965.

During FY 1965 the enlistment of promising young scientists as astronauts was actively initiated. Scientific training of the present astronauts and the new "scientist astronauts" will be continued in FY 1966, including both classroom instruction and the practice of investigatory procedures under simulated space environment conditions.

Environmental data is supplied for the Apollo program, including information regarding solar flares and the resulting solar proton radiation, other space radiation, meteoroids, and micrometeoroids. Theoretical and laboratory studies are conducted to evaluate the potential hazard which these space phenomena may present to manned space flight.

Advanced Studies

Advanced Studies are being initiated in FY 1965 to formulate basic mission requirements and characteristics, explore the feasibility of specific spacecraft and ground equipment designs, and define the scope and technical plans for future projects.

Studies leading to the development of standardized modules for Explorer spacecraft are under consideration. These studies, if successful, can be expected to reduce the cost of future missions and increase reliability and spacecraft lifetime. FY 1966 studies will include feasibility studies for Explorers to conduct gravitational and relativity experiments.

Observatory studies will include the development of concepts for manned orbiting telescopes to be assembled and maintained by men in space. Preliminary studies will be conducted of several types of instruments for highly detailed studies of the solar structure and activity, and large diameter telescopes for studies of stars and interstellar matter. In addition, studies of advanced radio astronomy observatories are planned.

Studies leading to interplanetary, solar and galactic probes are also planned for FY 1965 and FY 1966. These include feasibility studies for relatively small spacecraft capable of making measurements in the interplanetary medium to within 0.1 astronomical unit of the Sun, and studies of the feasibility of launching spacecraft to the outer reaches of the solar system to measure the extent of the Sun's influence on interplanetary and galactic space.

Solar Observatories

	1964	1965	1966
Orbiting Solar Observatory (OSO):			
Spacecraft.....	$8,476,000	$5,624,000	$6,100,000
Experiments.....	5,317,000	4,279,000	5,300,000
Subtotal OSO.....	$13,793,000	$9,903,000	$11,400,000
Advanced Orbiting Solar Observatory (AOSO):			
Spacecraft.....	$4,705,000	$5,766,000	$19,200,000
Experiments.....	1,472,000	1,571,000	5,900,000
Ground operations.....	35,000	63,000	500,000
Subtotal AOSO.....	$6,212,000	$7,400,000	$25,600,000
Total OSO and AOSO Spacecraft and Support....	$20,005,000	$17,303,000	$37,000,000

	1964	1965	1966
Delta (Launch Vehicle Procurement Program).....	($3,650,000)	($361,000)	($1,400,000)
Total (including launch vehicles).....	($23,655,000)	($17,664,000)	($38,400,000)

The objective of the Orbiting Solar Observatories is to support the program in Solar Physics in NASA by providing stabilized platforms which will carry into space scientific instrumentation to study the solar ultraviolet light, gamma rays, and X-rays which are absorbed in the Earth's atmosphere. The last flight of the presently planned Orbiting Solar Observatory (OSO) missions and the first flight of the initial Advanced Orbiting Solar Observatory (AOSO) missions are scheduled in 1969. This will give reasonable insurance of continuous coverage of solar phenomena during the period of maximum solar activity.

The OSO program, which now contemplates a total of eight missions, will provide solar astronomers with their first opportunity to study the sun over long periods of time by placing instrumentation above the Earth's absorbing and obscuring atmosphere so that measurements of solar electromagnetic radiations can be made.

The first solar observatory, OSO-I, was launched on March 7, 1962, into a circular orbit of approximately 300 nautical miles in altitude at an inclination of 33 degrees to the equator by a Delta launch vehicle.

OSO-I provided over 2,000 hours of observation of the solar spectrum in the ultraviolet and X-ray regions. These data showed a systematic variation in the intensity of emission lines of radiation generated in the high solar atmosphere with the passage of active regions across the visible disk of the Sun; extremely rapid fluctuations in the X-ray flux emitted by the Sun; and a direct correlation of the temperature of the Earth's upper atmosphere with the intensity of the ultraviolet radiation from the Sun. These results provide important clues for the study of solar processes and will be used as a basis for the design of experiments for future solar observatories. The remaining seven OSOs, each of which will carry different instrumentation, will be generally similar in spacecraft appearance and capability. Experimentation through the fifth mission has been selected and the selection process for the sixth mission is currently underway.

The OSO spacecraft consists of two sections: the upper fan shaped section, which carries the solar cells for spacecraft power and scientific instrumentation, continually points at the center of the solar disc with an accuracy of approximately one minute of arc. Beneath this pointing section, and attached to it by a shaft, is a nine sided wheel which continually rotates to give the satellite its stability. This section carries scientific instrumentation which does not need to be continuously pointed at the Sun and carries the spacecraft "housekeeping" components, such as the batteries

and telemetry system. In addition to the spacecraft's ability to point instrumentation at the center of the solar disc, it has the capability of performing a raster scan across the whole disc so that maps of the entire Sun may be made.

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

FY 1964 funds provided for rebuilding the second observatory (OSO-B), which was heavily damaged in an accident during launch preparations in April 1964; for continuing work on the third observatory (OSO-C), scheduled for launch in 1965; and for the initiation of hardware development for the next observatories. With FY 1965 funds, these efforts are being continued as well as the start of experiment development for the sixth observatory.

FY 1966 funds will provide for completion of data analysis for OSO-I and for analysis of data from OSO-B and C. These funds will also provide for the continuing development of OSO spacecraft and experiments and for the field operations associated with the launching of OSO-D.

The FY 1963 and prior years funding for this eight flight program including launch vehicles amounted to $21,622,000. Funding requirements for FY 1967 to completion are estimated to be $29,115,000.

While OSO has opened a new era in solar astronomy, the spacecraft does not have the capability of carrying large instruments with high spectral and spatial resolution which is necessary in order to provide detailed study of specific regions on the Sun. Recognizing these limitations, NASA initiated studies in 1962 leading to the development of an advanced Orbiting Solar Observatory (AOSO). This spacecraft, which is in its final phase of design, will enable scientists to gain a better understanding of the mechanisms of the Sun by providing a stabilized platform which will be able not only to look at the whole solar disc but also to direct the instruments on command to specific regions of the Sun. Because of its larger size, instrumentation of greater focal length can be carried which will provide for higher resolution. It is planned to place the AOSO into a retrograde polar orbit which will enable the satellite to view the Sun continuously for up to nine months at a time.

The spacecraft consists of a cylindrically shaped structure, at the base of which are eight solar paddles providing an average of 300 watts of power. A tube in the center of the cylinder is used to mount the scientific payload and acts to maintain spacecraft rigidity. Drawing upon previous experience, many of the subsystems, such as the tape recorders, star trackers and inertial controls, will utilize designs developed in other observatory programs. This will increase AOSO's reliability while reducing cost. A fine Sun sensor is being developed which will enable AOSO to point at the Sun with precision to an order of magnitude greater than OSO. And finally, unique instruments are being developed which are expected to reveal details of solar phenomena never before seen.

Management responsibility for the AOSO project has been assigned to the Goddard Space Flight Center. The spacecraft is being developed under a prime contract with Republic Aviation Corporation.

FY 1964 funds provided for a Phase I project definition and system detail design, and for initiation of experiment development. FY 1965 funds provide for the completion of this effort and for initiation of hardware development. FY 1966 funding will allow the start of full-scale flight unit development in addition to continuation of the on-going work. It is presently planned to procure four flight spacecraft with the first AOSO scheduled for launch during 1969.

The FY 1963 and prior years funding for this four flight program amounted to $1,700,000. Funding requirements for FY 1967 to completion including launch vehicles are estimated to be $126,510,000.

Astronomical Observatories

	1964	1965	1966
Spacecraft	$25,098,000	$21,890,000	$25,600,000
Experiments	10,510,000	9,320,000	6,900,000
Total Spacecraft and Support...	$35,608,000	$31,210,000	$32,500,000
Atlas Agena (Launch Vehicle Procurement Program).....	(5,626,000)	(9,039,000)	(15,100,000)
Total (including Launch Vehicles).....	($41,234,000)	($40,249,000)	($47,600,000)

Development of the Orbiting Astronomical Observatory (OAO) was initiated in 1960. It is designed to provide a precisely stabilized observatory above the atmosphere for astronomical observations in the extensive regions of the electromagnetic spectrum which do not penetrate the atmosphere and for high resolution observations in the visible and other regions of the electromagnetic spectrum which are disturbed as they penetrate the atmosphere. It was recognized that this development would require a major advancement of the state-of-the-art, especially in the fields of stabilization and control, command and data handling, and image tube development. The technical difficulties have been great; but the major development problems have been solved, and the first OAO will be launched in late 1965 or early 1966.

The first OAO (OAO-A) will contain the broadband ultraviolet photometers and the spectrometers developed by the University of Wisconsin for studies of individual stars and nebulae. The four broadband television photometers being developed by the Smithsonian Astrophysical Observatories to perform a sky survey in the ultraviolet will not be ready for the first observatory because of problems encountered in the production of the image tubes. In its place will be a backup package of astronomical instruments designed to conduct

soft X-ray, hard X-ray, and gamma ray surveys of the sky. These instruments, being developed by the Lockheed Research Laboratories, the Goddard Space Flight Center, and the Massachusetts Institute of Technology will provide an opportunity to exploit recent important discoveries of stellar X-ray and gamma ray sources.

The second OAO, scheduled for flight in 1966, will carry a fast 36 inch Cassegrain reflecting telescope combined with a large aperture spectrophotometer. It is designed to obtain absolute spectrophotometric data on stars, nebulae, and galaxies in the ultraviolet region of the spectrum.

The third and fourth observatories will be launched in 1967 and 1968; one consisting of the prototype spacecraft, refurbished after completion of the prototype tests, carrying the Smithsonian and Wisconsin experiments; and the other a telescope developed by Princeton University. The prototype spacecraft has been added to the schedule to provide a flight opportunity for the Smithsonian experiment which was delayed beyond OAO-A by the difficulties in producing image tubes.

The Princeton experiment consists of a 32 inch reflecting telescope combined with a grating spectrograph. The objectives are to study the composition and physical condition of the clouds of interstellar gas which may be the beginning of stellar evolution, and to obtain high dispersion ultraviolet spectral studies of the stars. This observatory will also carry telescopes developed by the University College, London to study the X-ray emission of stars and nebulae.

The fifth observatory, to be launched in 1969, will carry an experiment employing optics and spectrometry similar to those developed for earlier spacecraft. It is probable that guest observers will propose a majority of the observations to be conducted with this observatory. The OAO program aims to develop long-lived, high performance observatories that will be used for many years in a variety of programs as ground observatories are used. Thus, both United States and foreign astronomers can propose relatively short term viewing programs in their individual areas of interest. A similar observing program, but with a more limited number of guests, is planned for the first four OAOs.

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

FY 1964 and FY 1965 funds provide for continuation of work on the first three observatories and the prime experiment for the fourth observatory. They also provide for the initiation of the procurement of the spacecraft for the fourth observatory. FY 1966 funds will provide for the continuing development and procurement of subsequent observatories, for the support of OAO-A launch and for initial OAO-A data analysis.

The FY 1963 and prior years funding including launch vehicles amounted to $87,346,000. Funding requirements for five OAO missions for FY 1967 to completion are estimated to be $86,500,000.

Geophysical Observatories

	1964	1965	1966
Spacecraft	$34,536,000	$17,017,000	$18,800,000
Experiments	7,452,000	12,362,000	12,200,000
Ground operations	880,000	863,000	700,000
Total Spacecraft and Support	$42,868,000	$30,242,000	$31,700,000
Atlas Agena (Launch Vehicle Procurement Program)	(6,959,000)	(3,672,000)	(13,598,000)
Thor Agena (Launch Vehicle Procurement Program)	(3,213,000)	(4,454,000)	(802,000)
Total (including Launch Vehicles)	($53,040,000)	($38,368,000)	($46,100,000)

The Orbiting Geophysical Observatory (OGO) program was initiated in 1960 to meet the need of a spacecraft larger than the Explorer with stabilized orientation, more experiment power, and higher data rates that would be uniquely capable of performing many simultaneous, detailed, high resolution correlative measurements of the space environment. Since simultaneous observation of significant phenomena occurring in the Earth's environment is not possible from one satellite, two types of orbits are combined in a two-fold program of correlative measurements. Missions placed in highly elliptical orbits are intended to concentrate on measurements in the outer reaches of the magnetosphere and in the interplanetary medium; while low polar orbits concentrate on near earth measurements. Together these OGO missions represent a comprehensive, coherent approach to the investigation of Earth-Sun relationships.

The first OGO, OGO-I, was launched on September 4, 1964, into the highly elliptical orbit with an apogee of 92,721 miles. The mission is officially listed as a failure because the satellite failed to secure the planned stabilization in orbit when the horizon scanners failed to acquire the earth. Fortunately, the satellite went into a spin-stabilized mode in which the spin axis is fixed in inertial space.

In the months since launch, the apogee of the OGO-I orbit has rotated from a point well within the tail of the magnetosphere to a point outside the magnetosphere on the sunward side. OGO-I has made measurements of both the magnitude and fluctuations of magnetic fields and of the flux of energetic and thermal particles associated with the magnetosphere, the transition boundary, and interplanetary space. Within the magnetosphere, extensive data on

trapped radiation have been obtained, particularly with regard to energetic electrons in a large energy range. Ion and electron data have been recorded by on-board instrumentation, and electron densities have been studied by the transmission of radio signals from distances extending to apogee. Although further evaluation will be required, preliminary data indicates the existence of very low frequency noise at apogee distances within the tail of the magnetosphere and of unusual solar radio bursts.

In spite of the mechanical failure, OGO-I, has demonstrated that a large number of sensitive scientific instruments can be operated simultaneously aboard a single satellite to make an integrated survey of the space environment. In addition, it has dramatically illustrated the importance of diagnostic instrumentation and extensive command capability in rescuing failing satellites.

The second OGO will be launched in 1965 into a low altitude, near circular polar orbit. It will carry twenty experiments to make related measurements of the Earth's atmosphere, ionosphere, and magnetic field; cosmic radio noise; trapped radiation and aurora; airglow; micrometeorites; and solar radiations. An important aspect of this mission is a comprehensive survey of the Earth's magnetic field. This survey is expected to be a major contribution to the World Magnetic Survey. Modifications are being incorporated into this spacecraft, and additional tests are planned to avoid the difficulties experienced with OGO-I and to provide greater assurance of the success of this mission.

The third OGO, to be launched in 1966, will continue, in general, the investigations currently being conducted by OGO-I. Experiments will be updated by functional and operational modifications based on OGO-I results. The fourth OGO is also to be launched in 1966 to continue the near earth studies of the second OGO.

The fifth OGO, scheduled for 1967, will carry a new group of highly advanced scientific instruments. Along with other scientific objectives, this mission will investigate the role of electrons in the near earth and interplanetary medium. Twelve of the twenty-two experiments under development for this flight will be combined to study electrons over the complete energy range from thermal to cosmic ray levels.

Experiments for the sixth OGO, which will have a circular polar orbit, are to be selected in FY 1965. This observatory, which will also be launched in 1967, will make use of the prototype spacecraft but will have a set of new experiments.

The seventh OGO is planned for launch into a highly elliptical orbit in 1968. Experiments for this mission will be selected in FY 1966. Additional observatories in highly elliptical and circular polar orbits are planned during the 1968-1970 time period with the objective of continuous observation during maximum solar activity.

761-133 O-65-8

Management responsibility for the OGO project has been assigned to the Goddard Space Flight Center. The spacecraft are being developed under contract with Space Technology Laboratories.

FY 1964 funds provided for preparations for launching OGO-I and for continuation of the development of the second and third observatories. Procurement of the fourth and fifth observatories was also initiated with FY 1964 funds. Development of the experiments for the fifth observatory has been initiated with FY 1965 funds as well as the initial data analysis for OGO-I. FY 1966 funds will continue these efforts, provide for subsequent observatories, and for launch support and initial data analysis for OGOs B and C.

The FY 1963 and prior years funding including launch vehicles amounted to $69,231,000. Funding requirements for these seven OGO missions for FY 1967 and to completion are estimated to be $68,450,000.

Explorers

	1964	1965	1966
Geophysical and interplanetary explorers	$13,316,000	$16,774,000	$15,600,000
Astronomy explorers	---	1,100,000	6,100,000
Geodetic explorers	2,210,000	4,085,000	4,000,000
Total Explorers	$15,526,000	$21,959,000	$25,700,000
Scout (Launch Vehicle Procurement Program)	(6,600,000)	(4,296,000)	(7,700,000)
Delta (Launch Vehicle Procurement Program)	(11,750,000)	(12,350,000)	(9,500,000)
Thor Agena (Launch Vehicle Procurement Program)	(2,697,000)	(11,560,000)	(4,100,000)
Total (including launch vehicles)	($36,573,000)	($50,165,000)	($47,000,000)

The Explorer class of satellites has produced a large percentage of the scientific data acquired in the NASA program. Explorers still provide the most efficient and economical means of accomplishing certain scientific missions. These smaller spacecraft, most of which can be launched by the relatively inexpensive Scout and Delta vehicles, are specifically designed to accomplish a particular scientific investigation. They are flown in orbits peculiar to the type of investigation planned.

The spacecraft are developed by NASA Installations, universities, industry, or cooperating countries. Because of their relative simplicity, they make

it possible for smaller organizations to participate in spacecraft development efforts. They provide an opportunity for a research group to conceive an idea for space research, develop the complete system for conducting the research, and complete the investigation within a relatively short period of time. Once the system is developed, it is often used again for additional investigations by the same investigators or others.

Explorers are being used for studies of the environment of the Earth and solar, terrestrial, and interplanetary relationships; for astronomical observations; and for geodetic investigations.

Geophysical and Interplanetary Explorers

Most of the Explorers developed have studied the Earth's environment including the atmosphere, the ionosphere, the radiation belts, and the Earth's magnetic field. 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 beginning to come into focus.

By tracking Explorers and from direct measurements made by Explorers, many solar interactions with the atmosphere have been discovered. The atmosphere expands and bulges out on the dayside in a direction toward the sun. The density in the exosphere increases nearly ten times in the bulge. The solar rotation induces a 27 day cycle on atmospheric density. The entire exospheric atmosphere expands out to several times its volume at solar maximum compared to solar minimum. Solar flares and geomagnetic storms increase the temperature and density of the atmosphere within a few hours. The composition at satellite altitudes is predominantly the atomic species of oxygen, hydrogen, and helium. Helium is mainly important where the atmosphere is at high temperatures.

Explorers have made substantial contributions to the study of the Earth's ionosphere and its relationship to other geophysical phenomena. The instrumentation on Alouette has produced data on the spatial distribution and velocities of the free electrons in the upper portion of the ionosphere which could not be obtained from ground based observatories. The observed velocities of the electrons are much higher than the velocities of the molecules in the surrounding neutral atmosphere. The composition of the ionized atoms and molecules in the ionosphere is observed to vary with latitude.

The spatial and mass distribution and penetration probability of micrometeorites have been measured from Explorers. It was discovered that near the Earth, an extremely high flux of dust particles exists which is more than 1,000 times greater than fluxes in interplanetary space. Several dust streams were detected by the satellites. The high impact rate of particles near the Earth has not been explained. Experimental penetration measurements have shown that the likelihood of penetrating a space vehicle is much smaller than many estimates used in the design of manned spacecraft and accordingly the weights previously believed to be required for shielding may be utilized for other purposes.

Explorers have provided most of the data obtained in the space program on the radiation and magnetic environment of the Earth. They were used to discover the radiation belts. They have provided data on the artificial radiation belts created by high altitude nuclear explosions. They have made definitive measurements of the lower end of the energy spectrum of solar protons. They have provided the data used to establish the shielding requirements for the Apollo spacecraft.

A picture is beginning to emerge about the properties of the solar wind and its interaction with the geomagnetic field. Two boundaries are produced in this interaction. Explorers XII and XIV observed one magnetospheric boundary about 40,000 miles away from the Earth in the solar direction. Explorer XVIII found a second boundary at 55,000 miles which constitutes a shock front and separates the region of the undisturbed solar wind from the largely disordered flow produced by the interaction of the solar wind with the Earth's magnetic field. The properties of this transition region are being measured by Explorers XVIII and XXI.

The Earth's magnetic field is swept out behind the Earth by the solar wind. Explorer XVIII has mapped this magnetospheric tail out to 130,000 miles, or more than half the distance to the moon. Indications are that this tail extends well beyond the moon and resembles in many respects the tail of a comet.

Explorers have also made observations of galactic cosmic rays in the energy range from about 20 million to several hundred million electron volts. Only a small fraction of these cosmic rays penetrate the solar system down to the Earth because the interplanetary magnetic field provides an effective shield. An actual cut-off in the flux at the lower energies was observed, and intensity modulations in the flux can be related to the variable properties of the solar wind.

The level of effort in this area is being increased in FY 1965 and FY 1966 to provide for extension of the exploration of the magnetospheric boundary to include Explorers anchored in an orbit around the moon. This orbit will make it possible for the spacecraft to remain in the interplanetary medium or in the magnetospheric boundary area all of the time and to complete a circle around the earth every twenty-eight days. Atmospheric and ionospheric investigations and studies of cosmic dust will also be continued, and emphasis will be placed on the polar and equatorial regions and on the interactions with solar radiation and the trapped radiation in the Earth's magnetic field. International cooperative efforts in this area are underway with the United Kingdom, Canada, France, Italy, and the European Space Research Organization (ESRO). Other nations are involved in acquiring data and conducting research based on signals received from these satellites.

Astronomy Explorers

Experiments conducted with sounding rockets have demonstrated the feasibility of conducting astronomical observations in the radio and X-ray

regions of the electromagnetic spectrum using small spacecraft. In the radio region, it is necessary to place the spacecraft above the ionosphere to make measurements in those wavelengths which do not penetrate this ionized region of the Earth's upper atmosphere. Development of a satellite especially designed for this purpose is being initiated in FY 1965. It will be placed in a high altitude circular orbit to optimize the measurements. In addition to continuing the development of Radio Astronomy Explorers in FY 1966, it is planned to initiate the development of a small X-ray Astronomy Explorer to exploit recent discoveries of stellar X-ray sources.

Geodetic Explorers

Accurate tracking of satellite orbits provides data which can be used for geodetic investigations. Satellites developed for geophysical studies have been equipped with reflectors and beacons which facilitated accurate measurements of positions.

The optimization of geodetic investigations, however, requires orbits and equipment especially selected for the mission. The ANNA satellite launched by the Department of Defense was the first satellite especially tailored to this mission. Building on the ANNA experience, a program has been developed, in coordination with the Department of Defense and the Coast and Geodetic Survey, which involves the launching of active and passive satellites into orbits selected for these missions. The program involves participation by universities and other research organizations in the United States and in cooperating countries. Active satellites will be launched in 1965 and 1966 employing a variety of optical and electronic techniques. Passive satellites consisting of Echo type balloons with beacons will be launched into high altitude circular orbits in 1966 to supplement the active satellite program. Comparison studies are planned to evaluate the various techniques employed and to provide a check on the accuracy of individual measurements. The program is planned to continue with flights beyond 1966, with additional active satellites tentatively scheduled. The specific equipment to be incorporated in the later missions will be dependent upon the results obtained from the earlier missions.

Sounding Rockets

	1964	1965	1966
Experiments	$ 8,797,000	$ 7,790,000	$ 8,200,000
Rocket development	601,000	644,000	700,000
Attitude control systems	1,406,000	1,098,000	1,500,000
Engineering support	470,000	347,000	500,000
Test and evaluation	100,000	221,000	200,000
Ground instrumentation	3,123,000	2,800,000	2,800,000
Rocket procurement	2,453,000	3,100,000	3,100,000
Total	$16,950,000	$16,000,000	$17,000,000

Sounding rockets are small vehicles that are particularly well adapted for studies at altitudes between those reached by balloons and the perigees of low Earth satellites. They are used for studies of the atmosphere, ionosphere, and radiation that reaches the vicinity of the Earth, either as energetic particles or as electromagnetic radiation. They serve as inexpensive carriers to test instrumentation being designed for use on satellites. The usefulness of sounding rockets, particularly for solar and other astronomical observations, has been greatly increased by the development of attitude control systems.

Profiles of atmospheric density and temperature have been made with sounding rockets in various parts of the world and at frequent intervals for a number of years. It has been found that there is little variation in atmospheric temperature and density throughout the solar cycle at altitudes near 60 miles. However, there are large variations in temperature and density in the auroral regions and considerable heating near 50 miles altitude during solar disturbances.

Sounding rockets have been used to measure the amounts of molecular and atomic oxygen, atomic nitrogen, nitric oxide, hydrogen and helium at various levels of the atmosphere. Studies have been made of airflow and its effects on astronomy and astronaut seeing.

The dynamics of the ionospheric region of the atmosphere have been measured by vapor releases from sounding rockets. Turbulence, mixing, extreme wind shears, and large scale motions and global patterns have been discovered.

Sounding rockets with recovery devices have been used for successful recovery of dust of cometary and astrodial origin. Noctilucent clouds formed by cosmic dust surrounded by an ice condensate have been studied in Sweden. The composition of various meteor streams has been probed.

Sounding rocket experiments have related the causative solar flux to the resultant electron densities in the lower ionosphere. They have shown a relationship between the thin, dense, sporadic E layer and wind shears. Progress has been made in developing mass spectrometers, for both ionized and neutral constituents, and composite payloads are being developed to measure a variety of parameters from the same rocket. The currents in the E region have now been directly measured with magnetometer payloads, launched both at the magnetic equator and at medium latitudes. More such flights are needed to define this current system better in time and latitude and to relate it to the dynamics of the ionosphere.

Sounding rockets have made important astronomical observations. The first solar ultraviolet spectra were obtained from sounding rockets; X-ray emission from the sun was found with sounding rockets; and stellar X-ray sources have also been discovered. Ultraviolet observations of the planets Venus, Mars and Jupiter have been made.

Management responsibility for sounding rocket experiments is assigned to each participating Installation, with NASA Headquarters retaining responsibility for managing the development of experiments by other research organizations.

One hundred sounding rockets were launched in 1964 from sites in the United States, Canada, Pakistan, India, Norway, Sweden, and from a converted Navy aircraft transport ship. The shipboard launchings were conducted as a part of a shakedown cruise for an expedition planned for 1965. This expedition, which is part of the international cooperative effort for the International Quiet Sun Year, will involve launchings through areas of the upper atmosphere and ionosphere which cannot be reached by land based rockets. The launchings will take place in the South Pacific Ocean near the west coast of South America near the geomagnetic equator and south to as far as 60 degrees south latitude. Of primary interest on this expedition will be studies of the "equatorial electrojet", a system of electrical currents circulating in the ionosphere in the region of the magnetic equator.

Future use of sounding rockets is expected to follow the pattern of past usage. Several types of experiments that are already begun will be continued; such as measurements in the atmosphere and ionosphere, collection of cosmic dust, atmospheric motions and winds observed through chemical releases, and observations of the Sun, planets, stars, and other celestial bodies in the ultraviolet, X-ray and radio frequencies. The relatively small cost and the comparatively short lead-time for rockets will continue their use for pioneering experiments as new ideas are developed by scientists.

The decrease in the sounding rocket program costs for FY 1965 is primarily the result of decreasing the number of new experiments started. Emphasis in FY 1965 is being placed on completion of development efforts started in FY 1964 and prior years. FY 1966 funds will provide for an increased number of new experiments in preparation for an expanded program of solar terrestrial investigation during the period of the active sun.

Data Analysis

	1964	1965	1966
Data center operation	---	---	$ 600,000
Support of research tasks	---	---	2,400,000
Total	---	---	$3,000,000

NASA has the obligation to make available to the public the information gained from space exploration. The accumulation of data from flight programs provides a pool of scientific data that will be useful to scientists, particularly as it permits the use of data from a number of satellite, sounding rocket, and space probe experiments.

A scientific data center is being established at Goddard Space Flight Center to catalog these data and make them available to interested researchers

in a form which can be readily used. The initial contract for operation of the data center was funded under the FY 1965 Supporting Research and Technology Program. This new project will provide for continued operation of the data center and for support of promising research proposals that would make use of the data in storage.

The initial analysis of data from a flight experiment is funded under the flight project. The experimenter prepares a plan for analysis of the data from his experiment. As the data becomes available from the spacecraft, it is processed to provide the necessary information to establish the circumstances, such as time and spacecraft position, under which the data was taken. The experimenter has an agreed upon period of exclusive use of the data during which time he makes the initial analysis and reduces the data to a form which has scientific meaning. In some cases arrangements are made for immediate exchange of data between experimenters, so that they may correlate the results of simultaneous measurements. After expiration of the agreed upon period of exclusive use, the data passes into the public domain. Meanwhile, the experimenter publishes the results of his experiment.

After these initial results have been obtained, additional analysis of these data will, in many cases, produce further useful scientific information. The experimenter or another interested scientist may then propose a new research task which will involve additional correlative computations and evaluation. In the past, such efforts have been funded primarily under the flight projects; but, beginning in FY 1966, the funding of the flight projects will include only first run data analysis.

This new approach to the management of the data analysis is expected to produce a greater scientific return for the investment made in the flight program. It will broaden the participation of scientists throughout the nation and encourage them to use all of the available information in their theoretical research. Meanwhile, it will free the managers of individual flight projects from continuing data reruns on completed flights, since now their responsibility for a mission will terminate after first run data analysis is completed.

The responsibility for overall management of the Data Analysis Project will be retained in the NASA Headquarters. The Goddard Space Flight Center has been assigned responsibility for management of the data center.

OFFICE OF SPACE SCIENCE AND APPLICATIONS

LUNAR AND PLANETARY EXPLORATION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The primary objective of the Lunar and Planetary Exploration program is to carry out the scientific exploration of the solar system by both unmanned space flights and Earth based research. This requires the extension of spacecraft technology vital to future manned and unmanned missions. The program supports the manned space flight effort by measuring the environment in space and the characteristics of the Moon and the planets.

The primary objectives of the lunar program are to obtain data on the structure and topography of the lunar surface, the lunar environment and the physical, chemical, geodetic, and gravitational properties of the Moon. The data gathered as a result of these investigations will be of importance in seeking to understand the origin of the solar system and in determining accurately the environment in which manned spacecraft must operate. Another objective of lunar exploration is to search for extant or extinct life forms on the Moon, evidence of which would contribute to the overall theory of the origin of life in the solar system.

The lunar program includes three types of mission. The Ranger is providing initial visual data about the surface of the Moon. Surveyor missions will be aimed initially at selecting suitable landing areas for manned flights. The Lunar Orbiter will complement the Ranger and Surveyor missions by providing data obtained from the vantage point of an orbiting spacecraft.

The planets present an interesting attraction because they all differ markedly from the Earth. In these differences may lie clues to the nature, origin and evolution of the solar system. Therefore, our objective is to explore the planets, their moons and other interplanetary phenomena with unmanned spacecraft in conjunction with ground based research. The successful Mariner II flight added significantly to scientific knowledge of the planet Venus. The planet Mars is the next objective. The Mariner IV spacecraft, currently on a trajectory that will pass close to Mars, is expected to provide invaluable scientific information including relatively close-up photographs of the planet's surface. During the remainder of this decade and into the next, emphasis will be placed on the unmanned exploration of Mars.

The definition of the next series of flight missions to Mars is being initiated to meet the opportunities in 1971 and subsequent years. The spacecraft for these missions would be much larger and more sophisticated than previous planetary spacecraft and would be designed to perform experiments on

761-133 0-65-9

the surface and in orbit about the planet. This effort is identified as the Voyager Program, and will be the first program to concentrate on studying the evidence of the existence and nature of extraterrestrial life.

Interplanetary investigations will continue with Pioneer missions scheduled to begin the latter part of 1965.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Supporting research and technology/advanced studies	$22,000,000	$28,749,000	$36,800,000
Ranger	30,306,000	15,251,000	1,415,000
Surveyor	70,704,000	76,000,000	85,600,000
Lunar orbiter	20,000,000	42,400,000	37,000,000
Mariner	49,152,000	21,000,000	3,800,000
Voyager	---	7,750,000	43,000,000
Pioneer	13,600,000	15,000,000	8,000,000
Total	$205,762,000	$206,150,000	$215,615,000

Distribution of Program Amount by Installation:

Marshall Space Flight Center	$505,000	$535,000	$300,000
Manned Spacecraft Center	1,867,000	4,429,000	14,000,000
Goddard Space Flight Center	1,084,000	1,111,000	900,000
Ames Research Center	15,382,000	16,054,000	8,600,000
Langley Research Center	20,146,000	43,050,000	37,300,000
NASA Headquarters	9,521,000	10,667,000	9,500,000
Western Operations Office	157,257,000	130,304,000	145,015,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1964	1965	1966
Lunar and planetary science	$12,145,000	$12,486,000	$12,000,000
Advanced technical development	4,700,000	7,513,000	7,000,000
Advanced studies	2,236,000	2,390,000	2,300,000
Manned lunar science	2,919,000	6,360,000	15,500,000
Total	$22,000,000	$28,749,000	$36,800,000

Supporting Research and Technology provides the capability to carry out vital work associated with but not specifically a part of currently approved flight missions.

The science program provides scientific data necessary for the design and calibration of flight experiments and the basic data for the analyses and interpretation of the results of flight experiments. The program provides the means of exploring new concepts and ideas, and of developing those of high potential to the stage where they can be proposed for flight experiments. Scientists at NASA Research Centers, Universities, Industrial Research Laboratories, and other Government Laboratories throughout the country carry out this program of laboratory, theoretical, and observational research. The observational program in optical and radio astronomy is limited to investigations of the moon and the planets and has the objective of supplying information essential to the scientific flight program. It also provides information essential to the design of spacecraft and the selection of experiments for lunar and planetary investigations. The most important problems being investigated in this area are the nature and bearing-strength of the lunar surface, and the variation of pressure with altitude in the Martian atmosphere. Increased knowledge of lunar surface characteristics is desirable for safe exploration by man, and for the successful performance of soft landing scientific payloads. The characteristics of the Martian atmosphere have become of major concern in the past year when recent ground observational investigations indicated that the surface pressure of the Martian atmosphere may be one-half or less of the formerly accepted value of 85 millibars. In the 25 to 80 millibar pressure range, the efficiency of an entry capsule in carrying useful scientific payload decreases drastically with smaller atmospheric pressure values. Further studies of the Martian atmosphere by astronomical spectroscopic techniques will be conducted during 1965 to provide more precise values and permit the design of efficient entry capsules.

A contribution of knowledge concerning the environment in which the Apollo astronaut must function was made by field study of terrestrial counterparts of lunar processes and features, such as meteor craters, and by laboratory experiments with lunar surface simulation. Studies were made of the behavior of possible lunar surface materials under hypervelocity bombardment by meteorites and micrometeorites, and under conditions of wide temperature fluctuation, solar radiation, low lunar gravity and near vacuum atmosphere. Topographic and geologic maps of the visible portions of the moon are being prepared. The equatorical belt, which includes the initial target areas for Ranger, Surveyor, Orbiter, and Apollo, is scheduled for completion about mid-year.

New or improved theories, techniques, and instrumentation for scientific observation and measurement of the moon and planets, both from the Earth and from the spacecraft are developed by the supporting research program. The X-ray diffractometer, gamma ray spectrometer, neutron and alpha particle sensors, seismometer, magnetometer, and gas chromatograph are among those in various stages of development.

The Advanced Technical Development Program is directed principally toward the development of equipment and technology for flyby, orbiting, and landing

missions to Mars. These missions impose stringent requirements for the development of reliable equipment that will survive the rigors of sterilization and long time exposure to deep space, and will take fullest advantage of the improved capability of launch vehicles to be available a few years hence. In the FY 1965 program, principal emphasis was in the areas of communications and guidance and control. Under FY 1966 funds requested, emphasis on communications will continue toward a system that will transmit large quantities of scientific data over the immense interplanetary distances. Increased attention will be given to landing capsule technology, particularly to insure safe passage through the atmosphere of Mars and landing on its surface. To permit the recognition and identification of extraterrestrial life, planetary landers must be made sterile. The sterilizing procedures required, drastically compromise the reliability and operational life of much of the current state-of-the-art spacecraft equipment. FY 1965 and prior year funds began the development of equipment that will operate reliably after sterilization. Funding in FY 1966 will continue development and testing of these items, and initiate work on other equipment needed for planetary landers.

The advanced studies effort is essential to future lunar and planetary mission planning. Studies of space flight mechanics and planetary trajectories identify favorable launch opportunities and establish the energies required. Comparing these energy requirements with launch vehicle performance yields control weights for spacecraft planning. Preliminary mission flight profiles were generated for unmanned missions to the Moon, Jupiter, Venus, Mercury, comets and asteroids with FY 1965 funds, which also provided for conceptual designs of spacecraft for missions to Mars (Voyager). The FY 1966 effort will include additional mission profile studies of Jupiter, Mercury, comets and asteroids, as well as spacecraft conceptual designs for missions to Venus, Jupiter, Mercury, comets and asteroids. Primary emphasis will be on the Venus and Jupiter missions.

The Manned Lunar Science program objective is to maximize the scientific benefits derived from man's ability to explore the moon. It provides the space science activities which relate directly to the manned lunar missions of the Apollo program. The initial lunar manned missions will undertake investigations in the disciplines of geology, geochemistry, geophysics, atmospheric physics, particles and fields, and the biosciences. Initial development of investigations and supporting equipment began in FY 1964. Procurement of test and flight hardware for the earliest Apollo missions accounts for most of the difference between FY 1965 and FY 1966 requirements. This hardware includes both remote sensing instrumentation for observation of the moon from lunar orbit and instrumentation for lunar surface exploration, sample collection, and analysis.

Earth based support for Apollo science encompasses training of the astronauts in the general scientific disciplines and specific experiments in which they will be participating, compilation of plans of overall scientific activities to be carried out on each mission, testing investigatory procedures

and equipment to train the astronauts under the simulated lunar conditions, and development of facilities, equipment, and procedures for the analysis of the samples which will be returned from the moon.

	Ranger		
	1964	1965	1966
Spacecraft	$19,520,000	$8,362,000	$600,000
Experiments	3,926,000	4,142,000	815,000
Ground operations	6,860,000	2,747,000	---
Total Spacecraft and Support...	$30,306,000	$15,251,000	$1,415,000
Atlas-Agena (Launch Vehicle Procurement Program).....	(14,863,000)	(3,136,000)	(200,000)
Total (including launch vehicles).....	($45,169,000)	($18,387,000)	($1,615,000)

The objective of the two remaining Ranger flights is to obtain television pictures of the lunar surface which will be of benefit to both the scientific program and the United States manned lunar program. These two Rangers will photograph different areas of the Moon and under different lighting conditions than those of the successful Ranger VII.

The pictures obtained from Ranger VII provided a final resolution more than 2,000 times better than any previously available Earth based photography. The pictures which will be acquired from the two remaining flights are expected to be of the same resolution as those obtained from Ranger VII.

Overall management of the Ranger Program is the responsibility of the Office of Space Science and Applications, NASA Headquarters. Project management is the responsibility of the Jet Propulsion Laboratory. Design and fabrication of the spacecraft is a laboratory in-house effort while the television system is procured from the Astro-Electronics Division of the Radio Corporation of America.

FY 1964 funds were used primarily for the assembly, test, and launching of Rangers VI and VII. Included in this were the test and rework efforts required to correct faulty electronics components (diodes) discovered late in 1963 on Ranger VI, as well as the retest and redesign efforts to insure against a recurrence of the failure of the TV system on Ranger VI. The FY 1965 funds are being used for the assembly, test, and launching of Rangers C and D as well as the post-flight analysis of the photographic data. The FY 1966 funds will be used primarily for the post-flight evaluation of engineering data (spacecraft) and the interpretation and analysis of the photographs obtained which will directly support both the Surveyor unmanned lunar program and the Apollo manned lunar program.

The FY 1963 and prior years funding for this nine-flight program, including launch vehicles, amounted to $198,616,000. The FY 1966 request will complete the funding for Ranger.

Surveyor Lander

	1964	1965	1966
Spacecraft	$61,904,000	$64,460,000	$64,870,000
Experiments.....	3,600,000	6,890,000	15,970,000
Ground operations.....	5,200,000	4,650,000	4,760,000
Total Spacecraft and Support..	$70,704,000	$76,000,000	$85,600,000
Atlas-Centaur (Launch Vehicle Procurement Program).....	(32,000,000)	(47,814,000)	(50,400,000)
Total (including launch vehicles).....	($102,704,000)	($123,814,000)	($136,000,000)

The Surveyor spacecraft is being developed to accomplish the first soft landings on the Moon. On the lunar surface, these spacecraft will survey various landing areas of interest as possible sites for later manned landings and make measurements to improve our understanding of the nature of the Moon. Landed Surveyors will transmit to Earth a variety of data, such as high resolution television pictures of the lunar terrain, measurements of the surface texture, hardness, and other physical and chemical properties, lunar seismic activity, and the meteorite environment near the surface. The Surveyor mission requires the development of a technology far more advanced than that employed in the Mariner II and Ranger spacecraft. Not only must Surveyor navigate through the space between the Earth and the moon, but it must land softly on the moon, essentially by backing down a multi-stage rocket to a landing 240,000 miles and 66 hours removed from the launching site.

The prime purpose of Surveyor is to provide information on lunar surface characteristics which will assure the high confidence required before manned landings are attempted. A great deal of study effort has been expended to determine the best strategy by which Apollo landing sites can be verified, considering both the safety aspects and economics. The results of these studies indicate that the most timely and economical method for site verification is through the combined efforts of the Surveyor and the Lunar Orbiter. The operational plan calls for Surveyor landing attempts in different regions with "aerial survey" of the Surveyor landing sites and surrounding areas by the Lunar Orbiter. This combination will provide for detailed analyses of small areas through the Surveyors which then can be extended to the much larger area coverage of the Orbiter photographs.

In addition to direct manned flight support, unmanned spacecraft offer a distinct complementary function to the manned missions. Many regions of interest on the moon (such as the Crater Aristarchus where gaseous emissions have been observed) are likely to be inaccessible to man because of the hazards of landing. Landings on the backside of the moon, for example, would be of extreme interest to our total lunar exploration program. Surveyor landings on the backside with a communication link through the Orbiter would not involve the risks which would result if a manned landing were made without direct communication to Earth except through an orbiting spacecraft.

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

FY 1965 funds are being used to complete spacecraft system functional testing, environmental testing (thermal vacuum, shock, and vibration), mission simulation testing, field crew training by mock operations, and tests of dynamic models on Centaur Development flights. Program definition effort and long lead time procurements in the spacecraft and payload areas for the follow-on Surveyors are also being provided for with current year funds.

The funds requested for FY 1966 will provide for the completion of ground based development testing of the basic Surveyor spacecraft system and for the initiation of test flights early in the fiscal year. The funding during FY 1963 and prior years for this seventeen flight program, including launch vehicles, amounted to $111,641,000. Funding requirements for spacecraft and launch vehicles from FY 1967 to completion are estimated to be about $290,000,000.

Lunar Orbiter

	1964	1965	1966
Spacecraft	$20,000,000	$40,600,000	$32,900,000
Experiments	---	---	500,000
Ground operations.....	---	1,800,000	3,600,000
Total Spacecraft and Support....	$20,000,000	$42,400,000	$37,000,000
Atlas-Agena (Launch Vehicle Procurement Program).....	(170,000)	(2,335,000)	(22,200,000)
Total (including launch vehicles).....	($20,170,000)	($44,735,000)	($59,200,000)

The Lunar Orbiter will complement the Surveyor Lander as part of the unmanned lunar reconnaissance team. The Orbiter will take wide area photographs from an orbit 30 miles above the surface while the landed Surveyor conducts its investigations on the surface of the moon itself. The Lunar Orbiter camera system will take high and medium resolution photographs simultaneously. The medium resolution photographs provide stereo coverage of broad areas, while those of high resolution will show detail comparable to the final Ranger pictures but of hundreds of thousands of times as much area. The combination of such pictures will permit topographic mapping of considerable regions of the lunar surface. The information gained from the Orbiter photography will be used to screen out obviously undesirable sites for Surveyors, improving the probability of successful landings. The Orbiter and successfully landed Surveyor can then team to verify suitable sites for Apollo manned landings.

In addition to the photographs, the Lunar Orbiter will yield, as a by-product, information on the lunar gravitational field which will greatly benefit all subsequent lunar missions. Analysis of the orbit will help determine the mass distribution of the moon far more precisely than it is known at present; consequently, guidance calculations for Apollo will be much improved. The irregularities in lunar mass distribution these orbital analyses will reveal are closely linked with questions of seismic activity of the moon, its radioactivity, and the character of the lunar surface, which are basic to any discussion of the origin of the Earth-moon system. Once the primary photographic mission of the Lunar Orbiter has been accomplished, later spacecraft may include other instrumentation, within the available weight and power, to make other measurements in cislunar space.

Project management responsibility has been assigned to Langley Research Center and launch vehicle system management to Lewis Research Center. The prime contractor for design, fabrication and test of the 800 pound, attitude stabilized spacecraft is the Boeing Company. Major subcontractors are Eastman Kodak for the photo subsystem and the Radio Corporation of America for power and communications.

Current year funds have been devoted to completing the design of the spacecraft and all of the its subsystems; construction and testing of developmental test models to verify the design data; fabrication of test and flight hardware in accordance with the final design; and assembly of ground test spacecraft.

FY 1966 funds will be used to assemble the flight spacecraft, test and prepare them for launch, install the ground support equipment, train the launching and operating personnel, and conduct the first launch.

FY 1963 and prior year fundings for a five flight program, including launch vehicles, amounted to $10,098,000. Funding requirements for spacecraft and launch vehicles from FY 1967 to completion are estimated to be approximately $20,000,000.

Mariner

	1964	1965	1966
Spacecraft	$28,360,000	$14,055,000	$1,250,000
Experiments	8,920,000	2,466,000	1,800,000
Ground operations	11,872,000	4,479,000	750,000
Total Spacecraft and Support	$49,152,000	$21,000,000	$3,800,000
Atlas-Agena (Launch Vehicle Procurement Program)	(10,550,000)	(2,377,000)	(200,000)
Total (including launch vehicles)	($59,702,000)	($23,377,000)	($4,000,000)

Mariner is the United States program for early flyby missions to Venus and Mars. In 1962, Mariner II made history as the first successful planetary mission to Venus. Mariner IV, which was launched in late November 1964 on a flyby mission to Mars, is similar in design concept to Mariner II, although its technology is considerably advanced. Mariner IV is a 575-pound spacecraft carrying instruments to measure micrometeoroid impacts, magnetic fields, and atomic particles in space. During its close pass by Mars on July 14, 1965, it will take a series of TV pictures of the planet's surface. Also, passage of the spacecraft's signal through the Martian atmosphere will provide a measurement of the height and density of the atmosphere.

The Jet Propulsion Laboratory manages the Mariner Program and built the spacecraft in-house. Lewis Research Center was responsible for procurement of the Atlas-Agena launch vehicle.

The FY 1965 funds covered the extensive testing and prelaunch activities required for Mariner IV and the identical but unsuccessful Mariner III which was launched in early November 1964. The funds also will cover support of the major part of the in-flight phase of the program. This includes around the clock monitoring of the spacecraft condition, diagnosis of problems and exercise of the command function when required, and continuing analysis and reporting on the wealth of telemetry data being received.

The FY 1966 funds will continue the above support through the Mars encounter and postencounter phase and, in addition, will cover the major part of extensive post-flight data analysis and the preparation of final reports.

FY 1963 and prior years funding for this program, including launch vehicles, amounted to $115,569,000. Funding requirements for FY 1967 to completion are estimated to be $500,000.

Voyager

	1964	1965	1966
Spacecraft.....	---	$7,150,000	$40,000,000
Experiments.....	---	200,000	2,000,000
Ground operations.....	---	400,00	1,000,000
Total.....	---	$7,750,000	$43,000,000

The definition of the next series of Mars flight missions is being initiated to meet the 1971 and subsequent opportunities. The spacecraft for these missions are named Voyager and will have the primary objective of obtaining detailed information on the nature of the planet Mars, which includes the characteristics of its atmosphere, meteorology, its surface and subsurface conditions, trapped radiation belts and most importantly, information on the nature of any extraterrestrial life on the planet. The secondary objective will be to obtain scientific information on the interplanetary medium existing between Earth and Mars.

Such a mission requires a spacecraft capable of carrying large scientific payloads to the planet, telemetering considerable amounts of data back to earth and having long life in orbit about the planet, and on the planetary surface. Conceptual studies completed in FY 1964 indicated the spacecraft weight to meet these requirements would be in the 7,000 to 10,000 pound class. Such a spacecraft could be launched by a Saturn IB-Centaur launch vehicle. The spacecraft system concept indicated by the studies, which would meet the requirements of gathering data both in orbit and on the planetary surface would include three basic modules: the bus-orbiter module, the retro-propulsion module, and the capsule module. The Voyager system will be designed for use during several Mars opportunities, thus providing a base for a long range scientific exploration program. By completing the definition phase by FY 1966, the operational Voyager system could be launched during the 1971 Mars opportunity.

Overall management of this program is the responsibility of the Office of Space Science and Applications, NASA Headquarters. The Jet Propulsion Laboratory is responsible for management of the Voyager project including overall spacecraft system integration.

A project definition phase (Phase I) is being initiated in FY 1965 and is to be completed by the end of FY 1966. A separate industrial contract effort is planned for the spacecraft system (the bus, retro-propulsion module and overall integration) and another for the capsule system. System design, functional specifications for all subsystems, and selected subsystem development and breadboard testing will be accomplished under Phase I. Fabrication and testing plans, schedules, and detailed estimates of resource requirements will be generated by this effort. Based on the results of Phase I, a decision can be made regarding the initiation in FY 1967 of flight hardware development (Phase II).

FY 1965 funds are being used to initiate the spacecraft system design definition. This will cover preliminary design of the bus-orbiter module and the retro-propulsion module, preliminary definition of the capsule module interface, and preliminary investigation of the capsule and science integration with the spacecraft. The FY 1966 funds will be used to complete the Spacecraft System Phase I effort.

After evaluation of Phase I results, the total scope of the program will be established so that Phase II could be initiated in FY 1967.

Pioneer

	1964	1965	1966
Spacecraft	$10,805,000	$12,311,000	$5,500,000
Experiments	2,744,000	1,424,000	2,100,000
Ground operations	51,000	1,265,000	400,000
Total Spacecraft and Support	$13,600,000	$15,000,000	$8,000,000
Delta (Launch Vehicle Procurement Program)	(4,100,000)	(2,900,000)	(5,900,000)
Total (including launch vehicles)	($17,700,000)	($17,900,000)	($13,900,000)

Pioneer missions will measure interplanetary phenomena in deep space to provide simultaneous data with Earth satellites and to fill time gaps in monitoring in deep space between the widely separated flights of planetary spacecraft.

The Pioneer spacecraft will weigh about 140 pounds and will be launched by the Thrust Augmented Improved Delta launch vehicle. It will be spin stabilized for simplicity and reliability. The goal for the lifetime of the mission is six months or more. The first four spacecraft will alternate between missions toward, and missions away from, the Sun, approaching as close as 75,000,000 miles and going as far away as 110,000,000 miles.

A critical experiment on the spacecraft measures the extremely low level interplanetary magnetic field. For this reason, considerable effort is being expended to assure that the spacecraft will be as magnetically clean as the state-of-the-art will permit. Other experiments on the first two flights will measure the flux of atomic particles coming from the Sun, cosmic rays, and the electron density in space. Measurements of micro-meteoroid impacts will be added on the third and fourth flights.

The Office of Space Science and Applications is responsible for overall management of this program. Responsibility for project management rests with the Ames Research Center, and the Space Technology Laboratory is building the four spacecraft under a fixed price incentive fee contract.

The FY 1965 funds will cover assembly and testing of the prototype spacecraft, and the fabrication, assembly, and initial tests for the first two flight spacecraft. The FY 1966 funds will cover the final testing, launch, and post launch operations for the first two flight spacecraft as well as the assembly and start of testing for the third and fourth spacecraft.

FY 1963 and prior years funding for this four flight program, including launch vehicles, amounted to $2,614,000. Funding requirements for FY 1967 to completion are estimated to be $4,000,000.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1966 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS — SUSTAINING UNIVERSITY PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Sustaining University Program was planned and initiated to strengthen university participation in aeronautical and space science and engineering endeavors and to broaden NASA's sponsored research activities. The program's objectives are to: (1) increase the future supply of scientists and engineers required in space related science and technology; (2) build laboratories urgently needed for space research in selected universities; and, (3) improve the universities' role in support of NASA by encouragement of creative multi-disciplinary investigations, development of new capabilities, and consolidation of space oriented activities. These three aspects of the Sustaining University Program are complementary to project sponsored research and to each other.

Universities are the traditional source of both new knowledge and highly trained manpower. Only through a carefully designed program can the supply of scientific talent and the development of significant and relevant research capabilities keep pace with the demands of the national space effort. The training aspect produces skilled manpower, research scientists, technicians and instructors. Adequate facilities are essential, if scientific undertakings are not to be hampered further by an unsuitable environment. Additionally, by supporting research at selected institutions not currently participating in the space program, the number of universities and scientists involved in attacking some of the fundamental problems facing NASA has grown significantly.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Training.....	$19,811,700	$25,000,000	$25,000,000
Research facilities.....	12,000,000	10,000,000	8,000,000
Research.....	8,188,300	11,000,000	13,000,000
Total.....	$40,000,000	$46,000,000	$46,000,000

Distribution of Program Amount by Installation:

Jet Propulsion Laboratory.....	$60,000	$35,000	$35,000
NASA Headquarters.....	39,940,000	45,965,000	45,965,000

BASIS OF FUND REQUIREMENTS:

Training

	1964	1965	1966
Training.....	$19,811,700	$25,000,000	$25,000,000

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

The predoctoral research training program is designed to provide 1,000 persons receiving Ph.D.'s annually. This type of program has been strongly recommended by the President's Science Advisory Committee as necessary and reasonable. The Committee stated that a special effort must be made if the supply of highly trained scientists and engineers is to keep pace with the demand. It was further determined that there are adequate numbers of qualified students available who would not enter graduate research training unless new opportunities were made available. The Committee recommended that the national output of persons receiving Ph.D.'s should reach at least 7,500 annually by the year 1970. In 1963 the number of persons receiving the Ph.D. degree in the engineering, mathematical and physical sciences totalled 4,250.

1,071 new students began their three years of training under the NASA predoctoral program in September 1964. About 1,275 new students will begin their three years of training in September 1965. Under the proposed budget for FY 1966, about 1,300 new students would enter the program. Since this program funded smaller numbers of students in previous years, the NASA goal of an output of 1,000 Ph.D.'s per year will not be reached before FY 1968 or FY 1969. In order to ease a sudden manpower shortage, it should be noted that funds injected at a later date will not rapidly accelerate the availability of scientists and engineers.

Although a limited amount of time has elapsed since the first graduate students commenced their space related training under the Sustaining University Program, 38 students have now received their Ph.D. degrees. The fields in which their degrees were earned are: (a) the physical sciences - 17; (b) engineering disciplines - 9; (c) mathematics - 8; (d) life sciences - 3; and (e) other areas - 1. Since receiving their degrees the students have commenced the following activities: (a) university research and/or teaching - 24; (b) post-doctoral scholarships or Fulbright fellowships - 5; (c) employed in Government laboratories - 3; (d) employed in industrial laboratories - 6. Those graduates whose post-Ph.D. employment involves university research or teaching have remained within the university in order to continue work of a space related nature, and to participate in the production of highly trained new talent.

Specialized training for selected students offers the students identification with NASA's goals and problems and involves them directly in the new programs of the space age. In many cases the students' professors are also engaged in space research activities. The students thus have a unique relationship with NASA through contact with scientists and experiments generated by experienced senior investigators. Such close ties will provide the trainee with additional motivation for the continuation of studies and participation in the national space effort. A by-product of these traineeships is the incentive they provide to undergraduates who look forward to similar participation.

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

Research Facilities

	1964	1965	1966
Research facilities.....	$12,000,000	$10,000,000	$8,000,000

During the last year, NASA continued to move forward in its effort to help universities acquire the research laboratories necessary for space oriented work. Twelve more facilities grants were awarded to as many institutions which are already heavily committed to research and training in support of the national space program. Significant progress was made on the design and construction work of the fifteen prior year awards and, as a result, five buildings, representing over 150,000 square feet of additional laboratory type space, were completed and occupied by university scientists. When all of these structures have been erected, over a million square feet of critically needed laboratory space will have been added to the country's universities where the investment in research and training is substantial. Without a program of this type, an increasing number of universities will be constrained from accommodating any expanded amount of space oriented work. This expansion of high quality graduate research, and the construction of laboratories to make it effective for use in many disciplines, is essential to the successful accomplishment of NASA's mission in space. Although space oriented research extends through many fields of scientific investigation, it has one general requirement. This is a common need for more sophisticated and specialized facilities. Except for the relatively few theorists in their quiet offices, most of the scientists doing research with a space orientation must have laboratories adequate to house and service their equipment. The pattern followed by universities in the past, of building for the individual departments, has resulted today in the situation where it is frequently quite difficult or impossible to locate suitable laboratory space which will permit an efficient and broad attack on space research problems.

Examples of the significant achievements which are resulting from this program are the facilities completed to date. The first completed was the bio-medical annex to the Harvard Cyclotron. These modest sized facilities of 4,500 gross square feet are enabling eminent researchers from Harvard and the Massachusetts General Hospital to use the cyclotron for clinical and biological applications. Initially, twelve investigators together with their supporting staff are scheduled to use the facilities on research programs involving the irradiation of human and animal tissue and organs as a means of determining some of the shielding requirements for the Apollo mission. These facilities represent a relatively small investment which greatly enhances university scientists' capabilities to do important space related research.

The second completed project involved the addition of two floors to the University of Minnesota's Physics Building. The space is designed for research in the fields of atmospheric, solar, and cosmic ray physics, all subjects of particular importance to NASA. The 17,400 gross square feet of area will house and serve approximately 50 faculty members, research associates, and graduate students for their analytical and experimental research involving balloon and rocket flight experiments and mass spectroscopic examinations of planetary and upper atmosphere compositions.

The Laboratory for Space Sciences at the University of Chicago was also completed and occupied in 1964. These facilities are quite typical of one of the principal objectives of the program in which NASA encourages the establishment of interdisciplinary groups to do space research. The building contains 45,000 square feet of various types of research facilities for investigators who were formerly spread over the campus. The University researchers will have the required specialized facilities in which they may prepare flight experiments and analyze data obtained from nearly every unmanned scientific space flight to date. NASA supported pre-doctoral trainees are likewise profiting from this space oriented environment.

Other facilities completed to date comprise the following: a 108,000 square foot Materials Research Center at Rensselaer Polytechnic Institute funded by NASA, the National Science Foundation, and private donations, and facilities for propulsion sciences research at Princeton University. Princeton faculty members and graduate students are working on chemical, nuclear, and ion propulsion and have helped resolve some of the major combustion instability problems formerly inherent in large liquid rocket motors.

As can be ascertained from reviewing the facilities programs in process in other agencies, none has a program designed to serve the unique needs of NASA, nor is NASA's program fulfilling the missions of other agencies. However, the programs in toto are complementary. They are striking evidence of a continuing national commitment to graduate research and education as the key to our nation's social, technological, and economic progress. These programs are helping to meet the demands of our economy for more skilled personnel and knowledge. The laboratories will enable many more promising young scientists to cope with the explosion of new knowledge and to contribute effectively in a world of intellectual, political, economic, and technological complexity. Continuation of this effort will require $8 million in FY 1966 to acquire approximately 250 thousand square feet of laboratory space.

Research

	1964	1965	1966
Research.....	$8,188,300	$11,000,000	$13,000,000

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

Many of the scientific and technological problems facing NASA require an understanding of the behavior of large and complex systems that resist piecemeal attack, and their solution demands the concerted and cooperative effort that universities can provide by bringing together their many specialists from the varied technical and scientific disciplines. Additionally, by supporting research at selected institutions not currently participating in the space program, the number of universities attacking some of the fundamental problems of the space program is permitted to grow and thus broaden the base of the Nation's research capability. By providing new opportunities to these institutions to participate, many excellent research programs have already emerged and new talents and skills have been developed. Through this portion of the program, some $28 million at 56 institutions will have been invested through FY 1965 to obtain results which will help to determine the long-range course of space technology.

At universities where prior involvement in space research has been minimal, several projects have developed to a point where they have succeeded in obtaining support on their individual merits, either from other NASA program offices or other agencies. Thus, these grants have served to provide a basis for new researchers and have provided them with an opportunity to develop their work to a point where it can attract sufficient attention to be recognized and independently supported. In addition, by virtue of the stabilized, long-range funding provided under the grant, these schools have been able to hold and attract staff members who might have moved to other institutions more capable of providing research opportunities.

Reviews of the publications and progress reports by interested NASA program offices and the scientific community indicate that the smaller schools can be counted upon to make outstanding contributions to the space program if given the opportunity to participate. Examples of such work are materials research at the University of Denver, astrophysics at Montana State College, and studies of the planet Jupiter at the University of Florida. Engineering research in structures at Texas A&M has attracted considerable attention, and at William and Mary significant progress has been made toward the eventual utilization of the 600 megavolt synchrocyclotron under construction at the Langley Research Center for fundamental research in high energy physics.

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At the larger institutions, grants under this program have provided a broad base of support to NASA sponsored research projects, lending additional strength and breadth to these project efforts and permitting better long-range planning on the part of the institution. At UCLA, this program provided support for the development of a project for the collection of meteoroids in space, and has supported the design and fabrication of a unique testing chamber for spacecraft magnetometers. At the California Institute of Technology, the Graduate Research Center of the Southwest, and the University of California at Berkeley, grants have supported fundamental research which has resulted in the development of new flight experiment designs and new opportunities for the interpretation of data acquired from flight experiments. The University of Maryland Computer Center has developed new techniques in programming space science information. The University of Pennsylvania, through support provided by the Sustaining University Program, has created a unique capability in the development of unconventional power sources; this multidisciplinary effort draws upon the talents and skills of the many disciplines within the university. At the University of Washington (Seattle), a broad multidisciplinary program of ceramics research has been initiated.

In several instances the impact of these grants upon the university has been extensive. At William and Mary the grant was instrumental in supporting a new Ph.D. program in physics, while at several other institutions participation has resulted in large matching contributions from the university and private donors. These are examples of how this broad, flexible, and long-range form of support can stimulate the strengthening and development of selected institutions.

For the continuation and orderly growth of this special purpose research in FY 1966, approximately sixty-six projects will be supported at a cost of $13 million. Fifty-six of these grants will be for the continuation of projects supported in FY 1965, and the remainder will be to universities participating in this research program for the first time.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1966 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS — LAUNCH VEHICLE DEVELOPMENT PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The purpose of the launch vehicle development program is to ensure the timely availability of launch vehicle capability to meet mission requirements. Continuing surveillance of mission requirements establishes the needs for launch vehicle configuration, operating techniques, and systems technology. As mission requirements exceed existing launch vehicle capabilities, means to improve system performance are studied and defined. If major system development is required to meet new mission needs, implementation of the development would be within the launch vehicle development program. Scout and Delta development programs, generated and implemented in this fashion, were completed in FY 1963. The Centaur vehicle development is continuing in FY 1966 with the first operational flight scheduled for calendar year 1965.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Supporting research and technology..	$3,800,000	$7,100,000	$4,000,000
Centaur development.....	108,100,000	89,400,000	59,600,000
Total.....	$111,900,000	$96,500,000	$63,600,000

Distribution of Program Amount by Installation:

John F. Kennedy Space Center, NASA.	$983,000	$1,783,000	$1,050,000
Marshall Space Flight Center.....	---	---	13,000,000
Goddard Space Flight Center.....	250,000	925,000	550,000
Langley Research Center.....	115,000	650,000	300,000
Lewis Research Center.....	109,497,000	91,317,000	47,600,000
NASA Headquarters.....	1,055,000	1,825,000	1,100,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1964	1965	1966
Advanced studies.....	$180,000	$925,000	$1,500,000
Fluid behavior studies.....	480,000	---	---
Vehicle subsystem studies.....	316,000	1,475,000	750,000
Propulsion technology.....	491,000	2,000,000	1,000,000
Applied mathematics.....	433,000	100,000	250,000

	1964	1965	1966
Guidance technology.....	---	---	500,000
FLOX.....	1,900,000	2,600,000	---
Total.....	$3,800,000	$7,100,000	$4,000,000

The supporting research and technology program provides for advanced studies to identify new launch vehicle requirements and to determine alternative approaches to satisfy these requirements. In addition, efforts are continuing to provide an available source of data on new technology (vehicle subsystems, propulsion, guidance) and operational techniques which may be applied to vehicle improvements or new vehicle development, as required, to meet new mission requirements.

Funds provided in FY 1964 were utilized for studies including zero gravity fluid behavior phenomena and cryogenic propellant systems to increase the amount of thrust per pound of propellant.

FY 1965 funds are supporting studies of a kick stage for high velocity missions, spin motor technology and a continuation of the FLOX technology effort. A vehicle planning study effort has been initiated to assist in identifying and defining the data requirements of the program. Other study areas include solid propulsion accuracy prediction, atmospheric dispersion of toxic fumes, and fluorine technology.

The FY 1966 program will include increased effort on the kick-stage study and complementing technology efforts. Tasks will include guidance and propulsion technology and investigation of other vehicle subsystems. Also, applied mathematics efforts will concentrate on definition and utilization of computer program work in launch vehicle planning and technology.

Centaur Development

	1964	1965	1966
Vehicle development.....	$93,729,000	$77,320,000	$39,500,000
Supporting services.....	5,133,000	3,834,000	1,500,000
Tracking instrumentation.....	86,000	300,000	100,000
Atlas boosters.....	4,558,000	4,250,000	---
RL-10-A3 engine development.....	1,095,000	---	---
Propellants.....	3,499,000	3,696,000	5,500,000
RL-10-A3 engine improvements.....	---	---	13,000,000
Total.....	$108,100,000	$89,400,000	$59,600,000

The purpose of the Centaur Development Project is to develop a high performance liquid hydrogen fueled launch vehicle for NASA unmanned lunar and planetary missions. Centaur meets the requirement for a vehicle capable of carrying payloads too heavy for Atlas-Agena class vehicles and too light to

warrant use of the Saturn vehicles. The first operational use of Centaur will be for the Surveyor missions to the lunar surface. The Centaur vehicle consists of a modified Atlas booster and a high-energy upper stage (Centaur) employing liquid hydrogen and liquid oxygen propellants. The Centaur stage contains a light weight inertial guidance subsystem and other compact, lightweight subsystems to permit maximum payload capacity.

This development project includes design, development, fabrication and eight flight tests of the Centaur vehicle supported by an extensive ground test program. Four of these flight tests have been completed; the remaining four flight tests are planned to demonstrate proper guidance operation, direct ascent to lunar impact, the operational (production) configuration, and a two-burn capability. The development program will extend through calendar year 1966.

The ground test program includes such major tests as a full scale dynamic separation test of the Atlas from Centaur, static loading tests of the full scale Atlas vehicle, dynamic tests of the Atlas/Centaur/Surveyor combination, structural and fatigue testing of the Centaur tanks, and static firing tests of the test vehicles in flight configuration.

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

The NASA Office of Space Science and Applications has assigned management of the Centaur project to the Lewis Research Center. The RL-10-A3 engine development program is under the direction of the Marshall Space Flight Center since these engines are also used with the Saturn vehicle, but integration of these engines with the Centaur vehicle is under the management of the Lewis Research Center.

The Centaur project, initiated in 1958 by the Advanced Research Projects Agency of the Department of Defense and transferred to NASA in 1959, underwent a reorientation program after the failure of the first flight test on May 8, 1962. This reorientation included greater emphasis on ground testing prior to flight and a number of design and procedure changes to improve reliability and performance.

The second flight test of the Atlas-Centaur vehicle on November 27, 1963, was a complete success. The third flight was also successful, although one test objective was not fully achieved because of failure of one of the hydraulic systems in the Centaur stage. The fourth vehicle was launched in December 1964 and was successful, although a secondary test objective, an attempt to restart the engines after the Centaur was in orbit, did not succeed.

Funding for FY 1966 is for continuation of developmental effort on the Centaur vehicle such as engineering and design effort, ground test programs and flight tests. In addition, improvement effort on the RL-10-A3 engines,

formerly funded by the Office of Manned Space Flight, has now been included in the Centaur development project. RL-10 project history may be found in the Office of Manned Space Flight justification. This improvement effort along with the development of light weight subsystems, and an extensive program to reduce the overall weight of the vehicle is underway to increase the Centaur payload capacity.

Completion of the development project is expected in Fiscal Year 1967. Total project costs are estimated at $575 million including the RL-10-A3 engine improvement program. The cost of the Project through FY 1964 was $391.7 million.

OFFICE OF SPACE SCIENCE AND APPLICATIONS

LAUNCH VEHICLE PROCUREMENT PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

It is the objective of the Launch Vehicle Procurement program to provide launch vehicles for unmanned space missions. This program includes the purchase and adaptation of vehicle hardware for specific missions, the procurement of the necessary support, engineering and maintenance, and the procurement of services associated with the launching of the vehicle. The launch vehicles currently procured through this program are: Scout, Delta, Thor-Agena, Atlas-Agena, and Atlas-Centaur.

In previous budget submissions funding for procurement of these vehicles was shown as part of the cost of the various flight projects. In this submission vehicle costs are shown as a non-add notation with the specific missions supported only to permit an assessment of total project costs. Sustaining Engineering and Maintenance, previously Operational Vehicle Support presented under Vehicle Development, is not charged to the projects. For the first time, however, total vehicle procurement funding requirements are presented as a separate program. This has been done to provide a presentation that is more consistent with actual procurement practices.

The fabrication and adaptation of vehicles is initiated on the basis of projected launch requirements to insure that a vehicle will be available when each spacecraft is ready for launch. Various factors are evaluated in establishing the quantity of vehicles to be procured. These are: current and projected inventories, vehicles under contract but not delivered, current projected launch schedules, and future mission adaptation requirements. Procurement of vehicles is adjusted to maintain minimum inventories; however, maintenance of some inventory is necessary to provide the flexibility to meet changing requirements.

In addition to operational hardware procurement, a continuing engineering and maintenance effort is necessary to keep the current inventory of launch vehicles up-to-date and ready to meet changing spacecraft and mission requirements. The objective of this effort is to provide continuing support to launch vehicles that are operational, but can benefit from modification to improve performance and reliability. This effort is accomplished through product improvement programs, maintenance of ground support equipment, vehicle system engineering, and other supporting services.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Scout	$11,500,000	$13,196,000	$11,700,000
Delta	30,101,000	32,650,000	30,700,000
Agena	54,599,000	60,040,000	82,300,000
Centaur	32,000,000	47,814,000	69,800,000
Atlas	1,786,000	972,000	---
Total	$129,986,000	$154,672,000	$194,500,000

Distribution of Program Amount by Installation:

John F. Kennedy Space Center, NASA	$836,000	$3,025,000	$3,175,000
Goddard Space Flight Center	23,326,000	19,960,000	23,025,000
Pacific Launch Operations Office	---	90,000	---
Langley Research Center	11,930,000	13,106,000	11,700,000
Lewis Research Center	87,875,000	106,006,000	149,130,000
NASA Headquarters	6,019,000	12,485,000	7,470,000

The over all mission plan for launches during this period is:

Vehicle	Calendar Year 1964	Calendar Year 1965	Calendar Year 1966
Scout	8	6	9
Delta	5	7	9
Thor-Agena	2	2	4
Atlas-Agena	6	4	6
Centaur	0	1	3

BASIS OF FUND REQUIREMENTS:

Scout Procurement

	1964	1965	1966
Vehicles	$4,900,000	$4,096,000	$5,750,000
Motors	2,000,000	1,300,000	1,650,000
Logistics and other	1,200,000	300,000	300,000
Sustaining engineering and maintenance	3,400,000	7,500,000	4,000,000
Total	$11,500,000	$13,196,000	$11,700,000

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

There are two launch sites capable of launching the Scout vehicle: The Air Force Western Test Range in California, and Wallops Island, Virginia. Logistic support of these launch sites has been integrated into a single effort within this program.

The first operational Scout vehicle was launched April 26, 1962. There have been 24 launches through the end of calendar year 1964 for a wide variety of NASA, Department of Defense, and Atomic Energy Commission missions.

The FY 1966 funds for Scout Procurement will be applied to existing procurement actions and to the initiation of new procurements of first, second, third, and fourth stage motors to meet FY 1966 launch requirements. Funding is also provided for adaptation of the Scout vehicle to satisfy spacecraft and mission peculiar requirements.

To adequately provide Sustaining Engineering and Maintenance support for Scout missions, funds are required for improving vehicle system and subsystems deficiencies as they are discovered through operational use. In past years, funds have been utilized for nozzle redesign of the first stage motor, velocity control improvement, launch complex standardization, and other minor improvements.

In FY 1966, funds are requested for upkeep and replacement of ground support equipment to provide necessary capability for adequate ground test and launch of the Scout vehicle system. Funds requested in FY 1966 will also provide for the maintenance of the two launch complexes at the Wallops Island launch site, and the launch complex at the Western Test Range. In addition, funds are requested for adequate spares and vehicle instrumentation support.

Delta Procurement

	1964	1965	1966
Delta stages	$20,930,000	$14,996,000	$21,530,000
Thor boosters	4,815,000	10,200,000	3,700,000
Propellants	326,000	250,000	250,000
Third stages	430,000	265,000	420,000
Sustaining engineering and maintenance	3,600,000	6,939,000	4,800,000
Total	$30,101,000	$32,650,000	$30,700,000

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

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

Effort is underway using FY 1965 funding for improvement of the Delta vehicle to provide increased payload volume and weight. The improved performance will be obtained through improvements in the Delta second stage and use of thrust augmentation with the Thor booster.

Funds requested for FY 1966 will provide for launch services requirements for the Delta vehicle at the Eastern Test Range and to provide a new launch capability at the Western Test Range. Launch services associated with the Delta launch vehicle are procured on an annual basis. Included in the FY 1966 request are funds to continue procurement of Thor boosters, Delta second stages, and X-258 third stages to meet the launch schedule requirements for the Delta vehicle.

FY 1966 funds for Sustaining Engineering and Maintenance will provide for launch site and range safety improvements, new spin rockets, support of a Western Test Range launch capability, modification of miscellaneous test equipment, investigation of separation techniques, performance studies, and telemetry measurements.

Agena Procurement

	1964	1965	1966
Agena production.....	$14,087,000	$14,708,000	$17,261,000
Agena mission modifications.....	11,271,000	15,597,000	28,798,000
Thor procurement.....	894,000	4,827,000	3,985,000
Atlas procurement.....	22,057,000	10,211,000	26,091,000
Propellants.....	90,000	645,000	465,000
Sustaining engineering and maintenance.....	6,200,000	14,052,000	5,700,000
Total.....	$54,599,000	$60,040,000	$82,300,000

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

The Agena was developed by the Air Force as a second stage for use in its programs. Early in 1960, it was decided to use the Agena in combination with the Thor and Atlas rather than develop a similar stage. Each Agena must be modified, however, to meet mission requirements. NASA space missions utilizing the Thor-Agena include the Polar Orbiting Geophysical Observatory, the meteorological satellite Nimbus, the communications satellite Echo II, and the Canadian Topside Sounder, Alouette. All Thor-Agena vehicles are presently planned to be launched from the Western Test Range into polar or near-polar orbits.

NASA uses the Atlas-Agena for its unmanned lunar and planetary exploration missions, such as the Ranger and the Lunar Orbiter projects. The Atlas-Agena has placed Mariner spacecraft on trajectories to fly-by Venus and Mars. It has been used on the Ranger project, and will be employed to launch heavier scientific and applications satellites such as the Geophysical Observatories, the Astronomical Observatories, and the Applications Technology Satellite. The Atlas-Agena is predominantly launched from the Eastern Test Range to support NASA missions.

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

Funds requested for FY 1966 will provide for continued procurement of the basic Agena stage, Atlas and Thor boosters, and the modifications necessary to adapt the Agena stages for mission peculiarities. Funding is also provided for contractor launch services which include receipt, assembly, check-out, and launch of the vehicles.

FY 1966 Sustaining Engineering and Maintenance funds will provide for the continuation of the Atlas Improvement project jointly supported by NASA and the DOD, the development of a standard universal shroud, miscellaneous engineering support services and ground support equipment modifications at the Western Test Range for the Thor-Agena and at the Eastern Test Range for the Atlas-Agena vehicle system.

Centaur Procurement

	1964	1965	1966
Vehicle production	$19,151,000	$24,050,000	$28,920,000
System integration	2,443,000	2,038,000	3,990,000
Atlas procurement	7,156,000	12,598,000	12,740,000
RL-10 engine procurement	3,100,000	5,800,000	3,250,000
Propellants	150,000	3,328,000	1,500,000
Sustaining engineering and maintenance	---	---	19,400,000
Total	$32,000,000	$47,814,000	$69,800,000

The Centaur vehicle is a high performance, general-purpose launch vehicle for use on unmanned lunar and planetary missions which are beyond the capability of the Atlas-Agena vehicle. The present procurement of Operational Centaur vehicles is programmed to meet the launch vehicle requirements of the Surveyor unmanned lunar surface exploration project. The first Operational Centaur is scheduled for launch in calendar year 1965.

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

Funds requested for FY 1966 to continue Centaur Procurement in support of the Surveyor program, provide final increment of funding for Atlas boosters for the first seven Surveyor vehicles and an increment on the procurement of the next five vehicles. Funding is also included for the necessary systems integration of these vehicles with the Surveyor spacecraft.

Since the operational vehicle will be launched for Surveyor lunar missions, scheduled to begin in calendar year 1965, Sustaining Engineering and Maintenance is included for the first time in this request. Estimates are based on experience gained with other launch vehicles in early operational use. Services included are minor changes or improvements as discovered to be necessary through operational use, maintenance of ground support equipment and pre-flight and post-flight engineering analyses of performance and reliability aspects of the Operational Centaur.

Atlas Procurement

	1964	1965	1966
Atlas Vehicles.....	$1,786,000	$972,000	---

This project consists of procurement of Atlas launch vehicles for unmanned missions. At the present time, two vehicles are procured for the Office of Advanced Research and Technology, Space Vehicle Systems, project Fire. Project management for this project has been assiged to the Lewis Research Center.

FY 1963 and prior funding for this project amounted to $6.4 million. FY 1965 funding will complete the procurement of the vehicles for the Fire project.

SUMMARY OF LAUNCH VEHICLE PROCUREMENT FOR UNMANNED PROGRAMS

Program/Project	Vehicle	Fiscal Year 1964	Fiscal Year 1965	Fiscal Year 1966
Geophysics and Astronomy				
Orbiting Solar Observatory.....	Delta	$3,650,000	$361,000	$1,400,000
Orbiting Astronomical Observatory.....	Atlas-Agena	5,626,000	9,039,000	15,100,000
Orbiting Geophysical Observatory.....	Atlas-Agena	6,959,000	3,672,000	13,598,000
Orbiting Geophysical Observatory.....	Thor-Agena	3,213,000	4,454,000	802,000
Explorers.....	Scout	6,600,000	4,296,000	7,700,000
Explorers.....	Delta	11,750,000	12,350,000	9,500,000
Explorers.....	Thor-Agena	2,697,000	11,560,000	4,100,000
Lunar and Planetary Exploration				
Ranger.....	Atlas-Agena	14,863,000	3,136,000	200,000
Surveyor Lander.....	Atlas-Centaur	32,000,000	47,814,000	50,400,000
Lunar Orbiter.....	Atlas-Agena	170,000	2,335,000	22,200,000
Mariner.....	Atlas-Agena	10,550,000	2,377,000	200,000
Pioneer.....	Delta	4,100,000	2,900,000	5,900,000
Bioscience				
Biosatellite.....	Delta	---	9,000,000	9,100,000
Meteorological Satellites				
TIROS.....	Delta	3,800,000	1,100,000	-0-
Nimbus.....	Thor-Agena	3,516,000	6,358,000	6,200,000
Communications Satellites				
Echo II.....	Thor-Agena	805,000	---	---
Syncom.....	Delta	3,201,000	---	---
Applications Technology Satellites				
Applications Technology Satellites.....	Atlas-Agena	---	3,057,000	14,200,000

Program/Project	Vehicle	Fiscal Year 1964	Fiscal Year 1965	Fiscal Year 1966
Space Vehicle Systems				
Reentry.....	Scout	$1,000,000	$1,000,000	---
FIRE.....	Atlas	1,786,000	972,000	---
Nuclear Electric Systems				
SERT.....	Scout	500,000	400,000	---
Sub-total.....		$116,786,000	$126,181,000	$160,600,000
Sustaining engineering and maintenance.....		13,200,000	28,491,000	33,900,000
TOTAL.....		$129,986,000	$154,672,000	$194,500,000

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1966 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS — BIOSCIENCE PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objectives of the Bioscience program are to: (1) determine the location, origin, nature, and level of development of extraterrestrial life; (2) evaluate from a biological standpoint the origin and evolution of the solar system to acquire an understanding of the origin of terrestrial life; (3) determine the effects of the space environment on earth organisms with particular emphasis on factors which can assist in predicting their effects on man. This program will provide a better understanding of life and life processes, assist in the discovery of unique aspects of the space environment which are pertinent to life in space, and develop information which is essential to long duration manned space flight. A program of basic and applied research is being conducted to support the accomplishment of these program objectives.

In relation to these objectives it is noteworthy that the National Academy of Sciences - (National Research Council) Summer Study Group report of 1962 placed substantial emphasis on the exobiological goal of finding and exploring extraterrestrial life. More recently, the Space Science Board of the National Research Council recommended that unmanned exploration of the planet Mars, involving both physical and biological investigations, and expressly the search for extraterrestrial life, be made the primary objective of the Nation's space effort in the ten to fifteen years following the Project Apollo manned lunar landing.

In order to expedite the search for life on Mars and other planets, two actions were taken. The first was the establishment of a study effort which had as its objective the preliminary design of an automated biological experiment system which will provide a capability for detecting and describing planetary life and related environmental factors. This system is intended as a payload for Voyager missions to Mars. The second management action was the establishment of a program to integrate and expedite planetary quarantine efforts.

The Biosatellite program is directed toward the study of the biological effects of (a) weightlessness, (b) weightlessness combined with a known source of radiation, and (c) removal of living organisms from the 24-hour cycle of the Earth's rotation. The basic research with this Earth orbiting satellite is expected to provide quantitative data which will assist man in adapting to the space environment. From over 185 experiments submitted by the scientific community, 20 have been selected for flight. These have been packaged into 3 integrated experiment payloads. Three spacecraft have been assigned to these three principal payloads, plus three for backup, for a total of six planned flights.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Supporting research and technology	$12,979,000	$12,700,000	$15,500,000
Biosatellite	8,500,000	16,000,000	16,000,000
Total	$21,479,000	$28,700,000	$31,500,000

Distribution of Program Amount by Installation:

Manned Spacecraft Center	$234,000	$475,000	$1,000,000
Goddard Space Flight Center	250,000	250,000	250,000
Jet Propulsion Laboratory	1,243,000	1,499,000	1,250,000
Ames Research Center	9,856,000	17,267,000	17,450,000
NASA Headquarters	9,896,000	9,209,000	11,550,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1964	1965	1966
Exobiology	$5,200,000	$4,900,000	$5,000,000
Environmental biology	2,900,000	2,800,000	2,800,000
Behavioral biology	2,100,000	2,100,000	2,100,000
Physical biology	1,991,000	1,900,000	1,900,000
Planetary quarantine	---	---	1,000,000
Automated biological experiment system	---	---	1,000,000
Bioscience investigations for manned missions	788,000	1,000,000	1,700,000
Total	$12,979,000	$12,700,000	$15,500,000

Exobiology

The search for extraterrestrial life will be one of the prime objectives in the post-Apollo period. In managing this part of the program, NASA Centers, universities, and industrial research organizations, are using three approaches:

1. An attempt is being made to synthesize substances which will have characteristics similar to primitive single celled organisms.

2. The physical environments of the planets are being studied by instruments from the Earth, from high-altitude balloons, and from planetary fly-bys. Such measurements will assist in defining the planetary evironments and in determining whether life as we know it could exist on the planets, or whether the conditions are so severe that living processes are probably excluded. This data will also assist in the design of experiments appropriate to such diverse environmental conditions.

3. Life detection experiments are being designed for both unmanned and manned exploration. At present, several different automated life detector instruments are being constructed for the remote detection of extra-terrestrial planetary life using unmanned landing spacecraft.

The development of life detection techniques and instruments is primarily centered around the development of specialized instruments which will evaluate a specific facet of chemical composition, morphology, or physiological processes. About a dozen life detector instruments are being developed for remote sample collection and detection of life on Mars. Field tests have shown the Mark III Gulliver detector to be effective in environments hostile to life, such as the desert, highly saline areas, and a mountain top. Ball Brothers Research Corporation, in collaboration with Dr. Wolf Vishniac of the University of Rochester, has recently advanced the Wolf Trap to an engineering breadboard device.

An automated biological experiment system concept is being studied as a payload for the Mars-Voyager mission. This concept visualizes an integrated set of experiments designed for a lifetime of two Earth years (approximately one Martian year) on the surface of Mars to collect, detect, and describe biological and chemical evidence of life.

The Planetary Quarantine program, an outgrowth of the sterilization effort, requires increased emphasis commencing in FY 1966. Sterilization is essential to exobiological investigations of the planets because earth organisms might be landed on Mars and have an explosive growth which would interfere with subsequent scientific investigations. Another hazard is that of possible back contamination of the Earth at a later date. The sterilization program includes research to improve present methods and to develop new methods of sterilization compatible with reliability. At the present time, capsules of basic, simple design can be sterilized but further effort is required for complex capsules to define the effect of sterilization on reliability. Accomplishment of sterilization requires detailed standards, plans, and procedures for contamination control throughout manufacture, assembly, testing, launch and landing on the planet.

Environmental Biology

Research is being conducted on the biological effects of the space environment on living earth organisms. All known space factors are being studied in laboratories on Earth except such unique factors as weightlessness, removal from the effects of the Earth's rotation, and primary cosmic radiation. The Biosatellite program will study these unique factors in flight, and compare the results with Earth based studies.

In relation to the exobiology mission, the parameters of extraterrestrial environment within which given organisms can exist, is being defined. In support of this goal, various animals and plants are being subjected to simulated planetary conditions.

Research with biological organisms is underway to develop their application in space (1) in bioregenerative algal or bacterial life-support systems, (2) as test organisms to determine the biological safety of other planets, (3) for studying the potential of inducing hibernation or decreased metabolic activity in astronauts, and (4) for studying the biomedical effects of the space environment.

Bed rest studies for simulating weightlessness of 2-week and 1-month periods have been completed using human volunteers. Calcium loss of up to 10 percent from the skeleton (heel bone) was determined by X-ray techniques. Research by various NASA grantees has shown that numerous species of organisms can survive simulated Martian environmental conditions.

Behavioral Biology

Research is being conducted to determine the effect of the unique space environment on the orientation, behavior, and biological rhythms of various organisms. Neurophysiological, biochemical, and behavioral analyses are being accomplished to define brain behavioral relationships of importance to the organism in dealing with stress producing environmental factors. Living systems are being studied, using psychological, physiological, biochemical, and biophysical techniques, to determine the molecular basis of acquisition, processing, storage, and retrieval of information. The effects of prolonged confinement in small spaces and other types of environments which produce complex behavioral problems are being studied.

Examples of the work underway in Behavioral Biology are: (1) investigators at Princeton have designed equipment for detecting changes in temperature and activity in small organisms during orbital flight; and (2) at the University of Kentucky Medical School, primates are being used to study the effects of geophysical factors such as gravity and magnetic forces on biological rhythms.

Physical Biology

Research is being conducted into nutrition and metabolism as they affect energy exchange within living organisms exposed to various stresses which may be encountered in space flight. Studies are also being conducted on living organisms which are uniquely suitable for experimental biological investigation in orbiting vehicles and planetary probes.

Research is underway on an automatic electronic scanning device, utilizing computer analysis for recording, counting, and assorting chromosomes in order to show anatomical changes in blood cells and chromosomes. Such changes may be indicators of various environmental stress conditions being experienced in space flight.

In the area of biophysics, studies are being conducted on the dynamics of various physiological systems, directed toward explaining the adverse effects encountered by the astronauts during their orbital missions.

Bioscience Investigations for Manned Missions

This effort includes the research and development necessary to provide scientific experiments and associated equipment for flight on manned spacecraft. Four experiments for the Gemini missions are being prepared for flight during calendar year 1965. The development of an equal number of experiments will be initiated during FY 1965 for the Apollo Earth orbital missions. Effort will be continued to define those areas in which Bioscience investigations must be carried out to support manned space missions and in which an astronaut is necessary as a technician or scientist during the flight of the experiment.

Summary

The FY 1965 SR&T Advanced Studies effort includes increased emphasis on Exobiology with continuing research in Environmental, Behavioral, and Physical Biology. In FY 1966 the emphasis on Exobiology will be continued with a follow-on study effort on the automated biological experiment system and the fabrication and testing of hardware. Funding will continue in an effort to develop methods and procedures for effectively sterilizing spacecraft. The FY 1966 funds requested for Bioscience Investigations for Manned Space Missions are needed to continue preparation of the Apollo experiments for flight, and to determine future experiment requirements consistent with extended Apollo or Manned Orbiting Laboratory missions. Support of Gemini experiments will continue at approximately the same level as in FY 1965.

Flight Program (Biosatellite)

	1964	1965	1966
Spacecraft.....	$5,567,000	$11,190,000	$10,200,000
Experiments.....	2,921,000	4,560,000	4,200,000
Ground operations.....	12,000	250,000	1,600,000
Total Spacecraft and Operations..	$8,500,000	$16,000,000	$16,000,000
Delta (Launch Vehicle Procurement Program).....	(---)	(9,000,000	(9,100,000)
Total (including launch vehicles).....	($8,500,000)	($25,000,000)	($25,100,000)

The Biosatellite will consist of a spacecraft with a recoverable experiment capsule designed to orbit the Earth for periods ranging from 3 to 30 days, depending on the experiments aboard. It will investigate the effects of the unique environments of space upon lower forms of life, plants, small animals, and primates in order to obtain basic biological data, to determine and delineate those hazards which may exist for astronauts, and to define the degree of degradation in human performance during long term space flights.

The study of the effects of weightlessness will be given the highest priority. Also of importance will be the assessment of the effects of a known source of gamma radiation when combined with weightlessness. The

specimens will be shielded from most of the cosmic radiation, thereby removing the cosmic effect as an independent variable in these experiments. Ground based radiation experiments will be performed employing the same types of specimens as those within the Biosatellite in order to obtain data which excludes weightlessness as a variable.

The experiments used to explore the combined effects of radiation and weightlessness were selected because ground based laboratory experiments have shown that resulting genetic changes or damage can be consistently interpreted as resulting from a specific dose of radiation. Examples of the experiments selected are: the Tribolium or flour beetle which in its larval state is very sensitive to radiation so that embryonic development is affected and wing defects later occur; the genetic effect (lethal mutations) on Habrobracon (wasps); and the effects of zero gravity on radiation induced damage (mutation and chromosome breaking) in Drosophila (fruit flies). Identical experiments which are not irradiated will be flown aboard the Biosatellite as "controls" to separate the effect of weightlessness from the combined effects.

The circadian (about a day) rhythms that occur in all living cells form the basis for other experiments. Normally these rhythms follow the local light-dark or tidal cycle, and if the organism is removed from its normal 24-hour cycle it rephases itself with the new environment very slowly. The rhythmic changes in body temperature of a strain of rats will be examined in the Biosatellite while it is removed from the immediate effects of the Earth's periodic rotation for an orbital period of 21 days.

The most complex system studied will be that of the primate. The effects of weightlessness on its cardiovascular, skeletal, and central nervous sytems will be studied during orbits of 30 day's duration. With the aid of deeply implanted brain electrodes, the animals' sleep-wakefulness cycle, response to stimuli, and performance of simple tasks will be studied through the examination of electroencephalogram (brain wave) patterns. Venous and arterial pressures, cardiac output, electrocardiograms and urinary constituents will be studied to determine the effect of weightlessness on the circulatory system and metabolism in general. X-ray examination of the animals will be made pre-flight and post-flight to determine if there is a loss of calcium from the bones due to relative immobility in the weightless state.

The recoverable spacecraft is being designed by the prime contractor, the General Electric Company, Reentry Systems Division. Overall management and direction of the Biosatellite project is the responsibility of NASA Headquarters. Project responsibility has been assigned to the Ames Research Center. Most of the initial design has been completed. Fabrication of the experimental models of the heat shield and reentry capsule have been completed. Proof tests of the recovery parachute, and capsule and environmental tests of the experiments have commenced. An agreement has been negotiated with the Air Force to recover the Biosatellites (including prior testing of the recovery system) by the aerial recovery method, with provisions for a back-up recovery from the water in the event aerial retrieval is not successful.

The FY 1963 and prior years funding for this six flight program, including launch vehicles, amounted to $1,959,000. Funding for FY 1964 provided for the initiation of design, fabrication, and testing of the spacecraft. Funding for FY 1965 provides for the continuation of the fabrication and testing of the spacecraft and incremental funding for experiment development. Funding for FY 1966 will provide continued funding of the spacecraft contract, continued experiment development, and fabrication of flight ready hardware, and funding of recovery development and operations. Funding requirements for FY 1967 to completion including launch vehicles are estimated to be $20,000,000.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1966 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS METEOROLOGICAL SATELLITES PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objectives of the Meteorological Satellites Program are: (1) the development of advanced meteorological observation techniques, sensors, subsystems, and integrated systems for scientific study of the atmosphere and for obtaining operational weather surveillance and forecasting data; (2) to flight test and assess promising new techniques and hardware developments prior to commitment to operational systems; (3) to provide maximum interim operational weather observation data prior to the availability of the operational satellite system; (4) to assist the Department of Commerce, Weather Bureau with the development of Tiros Operational Satellite (TOS) system; and (5) to obtain meteorological soundings for scientific and forecasting purposes.

The development of advanced hardware and techniques (1 above) are accomplished, for general application, in the Supporting Research and Technology project. Specific experiments, subsystems, and techniques are also developed in the flight projects (Meteorological Flight Experiments, Tiros and Nimbus) to be tested along with the general developments produced under SR&T (2 above): Tiros VII and VIII and Tiros I (Eye) will provide interim weather surveillance (3 above). The direct implementation costs of the TOS program are funded by the Department of Commerce, Weather Bureau which reimburses NASA for TOS spacecraft procurement and launch operations. Prior year Tiros and Nimbus programs have provided for the development of the spacecraft and sensors utilized for the present TOS program and the Tiros project will provide for a continuing systems and technology improvement effort directly applicable to TOS (4 above). Meteorological Soundings is a continuing effort within the Meteorological Satellite Program (5 above).

Eight Tiros spacecraft have been launched since 1960 and the launch and operation in orbit of Nimbus I in the summer of 1964 have contributed to fulfilling these objectives. The TOS system, which is to become operational during 1966, is being developed from technology gained from the Tiros and Nimbus projects. Meteorological Sounding Rockets have provided data in the region from 20 to 60 miles indicating important temperature and wind velocity changes not previously known to exist.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Supporting research and technology	$7,754,000	$7,500,000	$8,200,000
Meteorological flight experiments.	---	1,200,000	4,000,000
Tiros.....	11,506,000	4,100,000	4,800,000

	1964	1965	1966
Nimbus	$41,673,000	$16,000,000	$22,700,000
Meteorological soundings	2,244,000	2,400,000	3,000,000
Total	$63,177,000	$31,200,000	$42,700,000

Distribution of Program Amount by Installation:

Manned Spacecraft Center	$135,000	$50,000	$200,000
Marshall Space Flight Center	80,000	120,000	120,000
Goddard Space Flight Center	62,346,000	29,575,000	39,720,000
Langley Research Center	444,000	420,000	530,000
NASA Headquarters	172,000	1,035,000	2,130,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1964	1965	1966
Synchronous meteorological satellites	$210,000	$100,000	$100,000
Meteorological component development	2,790,000	2,214,000	2,000,000
Meteorological sensor development	1,342,000	1,546,000	1,100,000
Meteorological atmospheric research	2,155,000	2,420,000	2,300,000
Advanced systems and components	1,010,000	720,000	1,500,000
Applications for manned space missions	247,000	500,000	1,200,000
Total	$7,754,000	$7,500,000	$8,200,000

The objectives of the Supporting Research and Technology effort are: (1) to develop sensors, control and power components, and data conversion systems to facilitate the basic acquisition of meteorological data; (2) to investigate new techniques and data processing systems for obtaining improvements in data accuracy and coverage; (3) to evaluate data from satellites and sounding rockets for utilization in design improvement studies; (4) to investigate new applications of meteorological systems using current components; (5) to increase the reliability and life time of spacecraft instrumentation; and (6) to develop equipment for the observation of earth atmospheric phenomena from manned orbital spacecraft.

Project direction is by the Office of Space Science and Applications at NASA Headquarters, with implementation both by Headquarters and Goddard Space Flight Center.

Funds were expended in FY 1963 and prior years to support efforts in such areas as conducting a feasibility study of a synchronous meteorological satellite, camera resolution studies for the eccentric and synchronous orbit missions, for design and development work on telemetry systems and amplifiers for meteorological satellites, for a preprototype model of a dielectric tape camera system, sensor calibration, meteorological data analyses, and studies of methods of data handling. Funds for FY 1964 were utilized to continue developments previously initiated and for new studies and developments in components and systems for the synchronous meteorological satellite experiments, rocket wind measurements, sferics studies and for studies leading to an interrogation, recording and locating subsystem (IRLS) for collecting meteorological and oceanographic data from remote instrumented platforms.

FY 1965 funds provide for developments and studies initiated in prior years to be continued and initiation of effort in measurement of stratospheric temperatures and the thermal structure of the atmosphere, and microwave sensing techniques. Also, hardware developments are being initiated for preprototype cryogenic cooling systems for meteorological sensors, stabilization and control systems components with improved reliability and longer life, and improved solar paddles. Funding has also been utilized in FY 1965 to initiate advanced research and development on gyro-magnetic stabilization systems, long-life electronic instrumentation, and feasibility studies for an advanced meteorological satellite system.

Applications for manned space missions include the study and development of scientific investigations and advanced remote sensing equipment for the observation of atmospheric phenomena from manned orbital spacecraft. Several investigations of this type are to be undertaken on manned Gemini flights. Studies of experiments for later manned orbital spacecraft are programmed for FY 1965 and FY 1966 to be prepared to take full advantage of manned space flight missions and capabilities.

In FY 1966, in addition to continuing most of the areas identified above, efforts will be initiated in an improved automatic picture taking camera storage system, a preprototype bi-fold solar paddle array, a compatible ground station for an on-board digital TV system providing improved accuracy and longevity, a long-life control system, and on a preprototype interrogation, recording, and location subsystem to investigate satellite measurement of the atmospheric structure. Studies are also planned on automatic pattern recognition for interpretation and analysis of TV cloud pictures and on program definition of advanced meteorological satellite systems.

Meteorological Flight Experiments

	1964	1965	1966
Meteorological flight experiments.	---	$1,200,000	$4,000,000

The title of this project was changed since the FY 1965 budget submission from Synchronous Meteorological Satellite Experiments to Meteorological Flight Experiments because some experiments will be flown in other than

synchronous orbits. Meteorological experiments will be undertaken on the five Applications Technology Satellites (ATS) to explore the techniques of obtaining continuous cloud cover data, over both full and selected earth areas, from the vantage point offered at high altitude and synchronous orbits. The objective of this effort is to provide a capability for monitoring short-lived severe storms. The observations will also provide data on phenomena associated directly with energy transfer processes affecting the weather, including day-night transition effects. Prior to the flight experiments, studies will be conducted concerning the use of a line scan camera or a camera with image motion compensation for use on the spin-stabilized ATS flights.

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.

FY 1965 funds are being used to procure and modify high and low resolution camera systems, to procure zoom lenses for the high resolution camera, to provide for ground equipment and integration support for the 6,500 mile orbit missions (ATS-A).

In FY 1966, funds are required to procure high and low resolution cameras, including image dissectors (line scan) or image motion compensation devices, and additional zoom lenses for the high resolution camera for the ATS spin-stabilized, synchronous flights (ATS B and C).

Tiros

	1964	1965	1966
Spacecraft	$6,724,000	$1,400,000	$600,000
Ground support	4,782,000	1,250,000	1,800,000
TOS improvements	---	1,450,000	2,400,000
Total Spacecraft and Support	$11,506,000	$4,100,000	$4,800,000
Delta (Launch Vehicle Procurement Program)	(3,800,000)	(1,100,000)	(---)
Total (including launch vehicles)	($15,306,000)	($5,200,000)	($4,800,000)

The Tiros project has demonstrated the engineering and scientific feasibility of the accumulation and dissemination of meteorological information from earth orbiting satellites. The objectives of the continuing Tiros research and development project are: (1) to provide maximum interim operational data for use in weather analysis and forecasting prior to availability of data from operational systems; (2) to provide developmental support for the TOS system; and (3) to provide research and development toward advanced meteorological satellite systems.

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Eight Tiros spacecraft have been successfully launched since April 1960. The Tiros series satellites provided an average of 190 useable cloud cover pictures per day resulting in the preparation of approximately 40 special storm advisories per month and 15 improvements to weather analyses per month. The ninth spacecraft, Tiros I (Eye), the spin-stabilized "wheel" configuration, will be launched in 1965 to obtain earth oriented pictures and provide a capability of interim operational use by obtaining daily global cloud cover data. This configuration will be utilized for the Weather Bureau funded operational satellite system, called Tiros Operational Satellite (TOS) System.

Efforts are underway to develop flight hardware for improvements to the TOS system, to improve reliability and extend subsystems and component life and to meet operational data requirements.

The tenth and eleventh Tiros spacecraft will be utilized to provide research and development data for advanced meteorological satellite systems development.

The tenth and eleventh spacecraft are scheduled to be launched during 1966 into a highly eccentric orbit with apogee at approximately synchronous altitude. The spacecraft will be able to view the full disc of the Earth and selected geographical areas for periods of approximately three hours.

The Office of Space Science and Applications, NASA Headquarters, is responsible for the overall management of the Tiros project. Responsibility for project management is assigned to Goddard Space Flight Center. The major contractor is the Astro-Electronics Division of RCA.

The FY 1963 and prior years funding for the currently approved 11-flight program including launch vehicles amounted to $35.1 million. The FY 1964 funds were used to complete funding of the eighth spacecraft and for partial funding of three additional spacecraft (I, K, and L) and related ground equipment, and operations. The FY 1965 funds are to be utilized for the incremental funding for: (1) the Tiros I, K, and L spacecraft and related ground equipment; (2) ground operation to support Tiros VII and VIII in orbit and Tiros I; and (3) improvements to the TOS system.

FY 1966 funds will be used to complete funding for the K and L spacecraft and related ground equipment, for ground support for Tiros I and K, and for continued effort in the TOS improvement program. Funding requirements for FY 1967 and to completion are estimated to be $10.2 million.

Nimbus

	1964	1965	1966
Spacecraft.....	$34,173,000	$8,700,000	$10,800,000
Experiments.....	---	4,100,000	6,700,000
Ground operations and support.....	7,500,000	3,200,000	5,200,000
Total Spacecraft and Support....	$41,673,000	$16,000,000	$22,700,000

	1964	1965	1966
Thor-Agena (Launch Vehicle Procurement Program).....	(3,516,000)	(6,358,000)	(6,200,000)
Total (including launch vehicles).....	($45,189,000)	($22,358,000)	($28,900,000)

The overall project objectives of Nimbus are to provide sensor and subsystem testing of equipment prior to inclusion in prototype operational systems and to provide data for atmospheric research. Data obtained are made available for meteorological research and operational use to the Weather Bureau and other domestic and foreign weather services. Specific objectives of Nimbus are to conduct experimentation leading to obtaining: (1) full global daytime cloud cover data; (2) daytime cloud cover data for local users; (3) infrared measurements of the night time cloud cover; and (4) observation of pressure, temperature, wind and water vapor at several altitudes over the entire globe. The Nimbus spacecraft is larger than Tiros or TOS and is oriented to view the earth at all times. Nimbus provides a basic satellite system for testing a variety of subsystems, sensors and meteorological experiments. The Nimbus I spacecraft was successfully launched August 28, 1964. Due to a short second burn of the Agena B vehicle, the orbit achieved was much more elliptical than desired. All systems operated and the sensors provided excellent data throughout the one month active life of the spacecraft. A failure in the solar array drive mechanism terminated useful operation. Three cloud picture-taking experiments were flown. These included three vidicon cameras for global daytime cloud cover data, a high resolution infrared radiometer (HRIR) for global night time cloud cover data, and the automatic picture transmission (APT) system for direct transmission of real-time daylight cloud cover pictures to small local weather stations. The cameras tested have been selected for operational system use, and methods of adapting the HRIR to operational spacecraft are being investigated.

Nimbus C, scheduled for launch in 1966, will weigh about 900 pounds and will be an improved version of the Nimbus I spacecraft. Modifications will be made to solar array drive mechanisms and a Thrust-Augmented Thor-Agena B vehicle will be used to provide the additional thrust to lift the spacecraft into the planned circular polar orbit. This spacecraft will: (1) provide additional global research data from the HRIR and vidicon camera; (2) acquire additional lifetime data on sensors in orbit; (3) provide direct transmission of real-time daylight cloud cover pictures to local weather stations; (4) initiate experimentation with night time direct local readout of HRIR data through APT ground stations; and (5) provide unique data from the digital medium resolution infrared radiometer (MRIR). The MRIR experiment will permit a full global study of the earth's heat balance, and represents one of the most significant meteorological experiments so far undertaken.

The current Nimbus program includes the development of two additional spacecraft (Nimbus Band D) which are scheduled for launch in 1967 and 1968,

respectively. This represents a continuing effort to develop and test space meteorological observatories having adequate power, stabilization accuracy, and flexibility to accommodate a variety of experiments, many of which will be eventually applicable to the operational programs. The developmental hardware and techniques include: (1) experiments for atmospheric research such as an interferometer and the Weather Bureau spectrometer; (2) provision for the on-board recording of operational APT cloud cover data; (3) the initial experimentation of a satellite interrogation, recording and locating subsystem (IRLS); and (4) a 50-watt radioisotope thermoelectric generator (RTG) which will demonstrate the feasibility of long life power supplies for meteorological satellites.

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

FY 1963 and prior years funding including launch vehicles amounted to $60.7 million. The FY 1964 funds were utilized to complete the Nimbus I spacecraft, provide for related ground operations and support, and to initiate modifications of the controls for the Nimbus B spacecraft. FY 1965 funds are being utilized to complete the Nimbus C spacecraft, incremental funding of the Nimbus B spacecraft, and experiments and related ground operations and support. FY 1966 funds are required for final preparation, launch, and ground operations for Nimbus C, incremental funding to continue the Nimbus B spacecraft, experiments, ground operations, and support efforts, and initiate development of the Nimbus D spacecraft and experiments.

Funding requirements for FY 1967 to completion, through the "D" spacecraft and including launch vehicle costs are estimated to be $22.2 million.

Meteorological Sounding Rockets

	1964	1965	1966
Large meteorological sounding rocket project.....	$1,800,000	$1,920,000	$1,900,000
Development of small meteorological sounding rocket system.....	444,000	420,000	500,000
Field experiment support.....	---	60,000	600,000
Total.....	$2,244,000	$2,400,000	$3,000,000

The objectives of the Large Meteorological Sounding Rocket project are to develop and improve sensors and techniques for measuring the basic meteorological parameters in the region 40 to 60 miles above the earth and the exploration of the structure and behavior of the atmosphere in this region. Launchings from sites at several different latitudes provide data

concerning the magnitude and extent of the dynamic and thermodynamic variations of the atmospheric properties in the upper stratosphere and mesosphere.

The objective of the Small Meteorological Sounding Rocket project is to develop a reliable, simplified, self-sufficient sounding rocket system (rocket vehicle, sensors, and data acquisition) which will provide a capability for routine measurements of the basic meteorological parameters in the 20 to 40 mile region of the atmosphere.

Field experiment support provides for conducting sounding rocket experiments in cooperation with other countries. Through this support, data useful to NASA are obtained over the territories of cooperating foreign countries on a cost-sharing basis, involving no exchange of funds. Thus, NASA may supply rockets and training while the foreign agency furnishes the payloads and launching facilities.

The Office of Space Science and Applications, NASA Headquarters, is responsible for the overall management of the Meteorological Sounding Rockets project. Responsibility for management of large sounding rockets is assigned to Goddard Space Flight Center and responsibility for small sounding rockets is assigned to Langley Research Center. Implementation of field experiment support is assigned to Goddard Space Flight Center and Wallops Station.

In FY 1963 and prior years, a total of $1.7 million was utilized in large sounding rockets and $0.2 million in small sounding rockets. In FY 1964, twenty-six large sounding rockets were launched using three experiments: acoustic grenade, pitot-static tube, and sodium vapor. These launches provided measurements of the atmosphere and its variation from the tropical to subarctic regions and from season to season using launch sites at Wallops Station; Ft. Churchill, Canada; Ascension Island; and Kronogaard, Sweden. Also, about 100 small meteorological sounding rockets were launched with various types of sensor payloads including new separation and parachute recovery devices. During FY 1965, approximately fifty large sounding rocket launches are planned. The results are expected to lead to the refinement of measurement techniques and provide more extensive scientific data. Also, funds are being utilized for the purchase and flight test of about 100 small sounding rockets, post flight analyses and launch area safety studies. In FY 1966, funds are required to provide for launch of 45 to 50 large sounding rockets, launch of approximately 100 small sounding rockets and payloads, improvement of rocket systems, procurement of additional ground equipment, and initiation of design and development effort on an advanced system. Also, funds are required for the development of field experiment projects jointly with countries in South America, Europe, and Asia to study and observe the upper atmosphere through the use of small meteorological sounding rockets.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1966 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS COMMUNICATION SATELLITES PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objectives of the Communication Satellites Program are to assure that technology required for establishment of future communications satellite systems is developed; to study requirements for, and technically assess, the applicability of satellites to the future needs of communications systems; and to fulfill NASA's responsibility under the Communications Satellite Act of 1962. High frequency radio, used for much of the present world-wide communications system, is not a reliable means of communication. In addition, neither high frequency radio nor the current submarine cables can provide for television and high speed data transmission. Communications satellites offer the possibility of microwave communication over long distances by providing relay stations at altitudes where they can be viewed from widely distant points on the Earth's surface. Thus, they offer the potential for providing all types of telecommunication services on a world-wide basis.

There are growing demands for an improved world-wide navigation system, and for traffic control, search and rescue, and communication systems for aircraft and ships. Satellites offer great potential in this area. NASA, working jointly with five other Government Agencies, will determine the existing and estimated requirements, the cost effectiveness, and the potential capability of a satellite system to meet these future needs.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Supporting research and technology.	$1,637,000	$2,100,000	$2,500,000
Echo II.....	1,675,000	220,000	---
Relay.....	2,590,000	525,000	200,000
Syncom.....	2,511,000	210,000	100,000
Early gravity gradient experiment..	---	5,000,000	---
Total.....	$8,413,000	$8,055,000	$2,800,000

Distribution of Program Amount by Installation:

Goddard Space Flight Center.....	$7,661,000	$1,415,000	$1,500,000
Langley Research Center.....	200,000	300,000	300,000
NASA Headquarters.....	552,000	6,340,000	1,000,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1964	1965	1966
Communications.....	$1,587,000	$1,725,000	$2,100,000
Navigation.....	50,000	375,000	400,000
Total.....	$1,637,000	$2,100,000	$2,500,000

The supporting research and technology efforts have been concentrated in three areas: advanced passive and active communications satellite concepts; navigation-traffic coordination system feasibility; and experimentation on fundamental problems of electromagnetic propagation.

Although no additional passive communication satellite launches are planned, a modest effort on materials, structures, and erection system development for advanced passive satellites is underway and will continue during FY 1966. Exploration of passive satellite technology is being continued because such satellites have unlimited multiple access and frequency response capabilities, inherent long life and high reliability. Material and structure development efforts are directed toward providing greatly reduced weight and more efficient large reflecting areas. Studies are underway on gravity gradient stabilized lenticular structures and on the possible utilization of solar pressure for satellite period control. Erection systems are being studied which utilize the memory characteristics of certain materials as a means of reliably deploying and erecting lightweight structures in the space environment.

Investigation effort will continue in FY 1966 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 emergency land stations. Beginning in FY 1965 and continuing in FY 1966, investigations and experimental design efforts will be pursued on Time-Division Multiplex (TDM) systems. Recent studies indicate that TDM offers the greatest potential in multiple access communications with mixed and small size mobile terminals.

Navigation traffic coordination satellite system feasibility studies funded in prior years clearly 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, a formal agreement was made involving the Departments of Commerce, Defense, Interior, and Treasury, the FAA and NASA, whereby an ad hoc Joint Navigation Satellite Committee (JNSC) was established to determine and evaluate existing and future agency requirements, analyze and compare various navigation-traffic coordination systems (including satellites), and recommend a national program plan which will set forth the required future effort. In FY 1966, studies will be

conducted in the navigation-traffic control area to determine the technology needed to meet national program objectives, and investigations will be continued on promising position-fixing techniques utilizing existing NASA satellites and ground facilities.

Further advances in higher power communications satellites are foreseen. These satellites would be capable of broadcasting either voice or television directly to conventional home FM radio or television receivers of entire populations. In FY 1965, mission feasibility studies will be initiated on direct broadcast satellites capable of broadcasting voice to FM home radios, and advanced mission studies on TV broadcast satellites will follow in FY 1966.

In the measurements area, investigations initiated on the effect of scattering of electromagnetic waves by localized weather conditions are nearing completion. The results have made important contributions to the International Telecommunications Union Conference on Space Communications. 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 1966, these techniques will be used to make measurements on small segments of new and improved passive satellite materials and structures and on advanced antenna designs to determine their characteristics.

Echo II

	1964	1965	1966
Spacecraft.....	$660,000	---	---
Ground operations and support.....	1,015,000	$220,000	---
Total Spacecraft and Support.....	$1,675,000	$220,000	---
Thor-Agena (Launch Vehicle Procurement Program).....	(805,000)	(---)	(---)
Total (including launch vehicles).....	($2,480,000)	($220,000)	(---)

The Echo II project consisted of design, development, launch and evaluation of a 135 foot large inflatable passive communication satellite. Other than a low level effort in experiments on Echo II, the project was completed in FY 1964. FY 1963 and prior year funding, including launch vehicles, amounted to $15.1 million. FY 1965 funds are being utilized to support post launch communications experiments and data analysis. No funds for FY 1966 are required.

Relay

	1964	1965	1966
Spacecraft	$130,000	---	---
Ground operations and support	2,460,000	$525,000	$200,000
Total	$2,590,000	$525,000	$200,000

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

Relay I was successfully launched in December 1962, and Relay II in January 1964. Ground stations participating in Relay experiments were located in the U. S., Europe, Japan, and Brazil.

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 were Radio Corporation of America for spacecraft development; Space Technology Laboratories for satellite preliminary design, systems coordination and planning, test station operation, and experimental review and analysis; Philco Corporation for West Coast ground station; American Telephone and Telegraph, and International Telephone and Telegraph for ground station operation.

The FY 1963 and prior years funding for the two launches including launch vehicles amounted to $37.4 million. FY 1965 funds are being used for ground station operational support, spare parts, and data reduction and analysis. FY 1966 funds are required for continued data reduction and analysis. Subsequent fiscal year funding requirements will be minimal and determined by the utility and lifetime of the two satellites in orbit.

Syncom

	1964	1965	1966
Spacecraft	$725,000	$50,000	---
Ground operation and support	1,786,000	160,000	$100,000
Total Spacecraft and Support	$2,511,000	$210,000	$100,000
Delta (Launch Vehicle Procurement Program)	(3,201,000)	(---)	(---)
Total (including launch vehicles)	($5,712,000)	($210,000)	($100,000)

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

Three Syncom spacecraft have been launched: Syncom I in February 1963 was unsuccessful; Syncom II in July 1963 was successful in achieving the desired inclined synchronous orbit; and Syncom III was successfully launched into an equatorial synchronous (stationary) orbit. Syncoms II and III continue to function satisfactorily.

The Office of Space Science and Applications, NASA Headquarters, is responsible for overall management. Responsibility for project management is assigned to Goddard Space Flight Center. The major contractors for the Syncom project are Hughes Aircraft Company for spacecraft development and telemetry and command equipment, and Space Technology Laboratories for range and range-rate equipment.

The FY 1963 and prior years fundings for this 3 flight program including launch vehicles amounted to $25.4 million. FY 1965 funds are being used for ground station logistics support and maintenance; operational support; and data reduction and analysis. A reduction in the FY 1965 funding was made due to the elimination of a fourth Syncom flight and due to transfer of operational support of Syncom II and Syncom III to the Department of Defense (DOD) in 1965. FY 1966 funds are required for continued data reduction and analysis. Subsequent fiscal year funding requirements will be minimal and determined by the utility and lifetime of the two satellites in orbit.

Early Gravity Gradient Experiment

	1964	1965	1966
Spacecraft.....	---	$5,000,000	---

The Early Gravity Gradient project consists of the design, development, and flight testing of a gravity gradient stabilization system. The primary objective of this effort is to demonstrate a gravity gradient stabilization subsystem in support of the advanced Defense Communication Satellite Program in the near synchronous altitude region, provide data to support the selection of design parameters, and assess the feasibility of gravity gradient stabilization for advanced space systems.

NASA and DOD entered into an agreement whereby the Air Force Space Systems Command will be responsible for the procurement of flight hardware, and will flight test the gravity gradient system as an integral part of the initial Defense Communications Satellite flights. NASA will continue to monitor this effort and provide technical assistance to the Air Force. FY 1965 funds of $5,000,000 will be made available to the Air Force to cover the costs of the spacecraft. No FY 1966 funds are required for this project.

A flight test is scheduled for the second quarter of 1966.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1966 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS — APPLICATIONS TECHNOLOGY SATELLITES PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The title of this program has been changed since the FY 1965 budget from Advanced Technological Satellites to Applications Technology Satellites. The objectives however remain the same. These objectives are: (1) to develop spacecraft technology particularly suited for space applications, (2) to provide capability for experimental testing of techniques and devices from various engineering and technological disciplines in the space environment, particularly in the higher altitude orbits, and (3) to provide basic technological and scientific data on gravity gradient stabilization in a 6,500 mile orbit which may be extrapolated to the more difficult synchronous orbits. There is a need in the Department of Defense and in the National Aeronautics and Space Administration for improved spacecraft technology in the areas of stabilization, orientation, and station keeping in the synchronous orbit. There is a requirement for obtaining engineering data on the stationary orbit (equatorial synchronous orbit) for use in designing systems for that discrete orbit with its unique features and also a requirement in both the Department of Defense and the National Aeronautics and Space Administration for basic information to validate theoretical concepts of the physical parameters effecting gravity gradient stabilization. This information is required in such detail as to be amenable to extrapolation to other altitudes and be convertible to engineering handbook type data for use in systems design. It is the purpose of the Applications Technology Satellites program to meet these requirements.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Supporting research and technology.....	$2,162,000	$1,700,000	$2,000,000
Applications technology satellites.....	15,377,000	21,695,000	26,700,000
Total.....	$17,539,000	$23,395,000	$28,700,000

Distribution of Program Amount by Installation:

Goddard Space Flight Center.....	$16,478,000	$22,699,000	$28,182,000
Jet Propulsion Laboratory.....	1,061,000	396,000	518,000
NASA Headquarters.....	---	300,000	---

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1964	1965	1966
Spacecraft parts and subsystem elements	$976,000	$750,000	$1,000,000
Control	1,011,000	650,000	400,000
Wave propagation	175,000	300,000	600,000
Total	$2,162,000	$1,700,000	$2,000,000

The objective of the Applications Technology Satellites Supporting research and technology is to sponsor a continuing effort of spacecraft component and materials investigations and development; advanced instrumentation, stabilization and control systems development; technology experiment feasibility and design; and advanced system studies. The work is being performed by various industrial companies, universities and NASA Installations.

Spacecraft Parts and Subsystem Elements

In FY 1966 development efforts currently underway on advanced spacecraft components and materials will be continued. The effort to investigate multiple beam forming, electronically steerable, spacecraft antenna array techniques previously initiated has begun to yield very promising results. In FY 1966, laboratory models of the most promising arrays will be developed for experimental purposes to determine their potential for space applications such as: multiple access communications with small mobile terminals, and direct broadcast satellites. Efforts will also be continued on millimeter-wave component investigation and development for higher frequency communications systems.

Control

In the spacecraft controls area, passively damped gravity-gradient stabilization attitude control system parametric studies have been rigorously pursued in prior fiscal years. These efforts have provided the basis for conceptual designs of satellites in intermediate altitude and synchronous orbits. In fiscal years 1964-1965, development efforts were initiated on stabilization components, such as passive dampers, extendable booms and boom deployment mechanisms, and on associated instrumentation required to determine the attitude of a gravity gradient stabilized spacecraft. Efforts will be continued in FY 1966 to optimize designs and assess the performance of improved stabilization components. These efforts directly support the flight project.

In FY 1965, mission feasibility studies were initiated in-house on advanced applications technology satellite concepts. This effort will be augmented with contractual support. The study efforts are directed toward a long-lived, fully stabilized spacecraft having a large space erectible antenna which can be pointed precisely to selected geographic areas on earth. Active stabilization control systems, as well as hybrid gravity gradient systems will be considered. Technology requirements and optimum approaches will be determined in these studies.

Wave Propagation

In the millimeter wave propagation and technology experiment areas, feasibility design studies are being pursued. In FY 1966, effort will be continued on the design and preliminary development of a spaceborne millimeter propagation experiment for ATS. The frequency range, 10 to 100 Gigacycles per second (Gc/s, equal to a billion cycles per second), is of great interest because the lower frequency bands are very crowded as compared with frequency bands of 10 to 100 Gc/s. However, little is known the propagation anomalies in this frequency range.

Applications Technology Satellites

	1964	1965	1966
Spacecraft.....	$9,832,000	$18,831,000	$24,100,000
Operational support.....	5,545,000	2,864,000	2,600,000
Total Spacecraft and Support.	$15,377,000	$21,695,000	$26,700,000
Atlas Agena (Launch Vehicle Procurement Program).....	(---)	(3,057,000)	(14,200,000)
Total (including launch vehicle).....	($15,377,000)	($24,752,000)	($40,900,000)

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

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

Funding for this project commenced in FY 1964. FY 1965 funds are being utilized for partial funding for spacecraft and the gravity gradient system development, communication transmitters and receivers and for scientific and technological experiments. FY 1966 funds will be utilized to continue funding for spacecraft and the gravity gradient system, communication test equipment and for scientific and technological experiments hardware. The major portion of the ground station system development and modifications costs are included in the Office of Tracking and Data Acquisition fund requirements. Funding requirements including launch vehicle procurement for FY 1967 and to completion of this 5-flight program are estimated to be $69 million.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1966 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — BASIC RESEARCH PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

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

Engineers today must frequently use materials which are inadequate to meet the special requirements of particular applications. As a result they must "over design", adding more weight to assure adequate performance. Thus the goal in materials research is to obtain construction materials which are safer, lighter in weight, more temperature resistant, and allow cheaper construction.

In the electrophysics area, superconductivity, characterized by zero electrical resistance of some metals at temperatures near absolute zero, is being studied to learn more about the mechanisms of the electron movement within the crystal structure and to discover in this way new materials which exhibit these same characteristics at somewhat higher temperatures. Many applications are awaiting results of this research; for example, superconducting devices such as a cryogenic gyroscope which will rotate for long periods of time with no power requirements, using extremely small but very powerful magnets.

In fluid physics, refinements in magnetohydrodynamic accelerators may lead to a laboratory facility which, as a wind tunnel of extreme speed, will permit more realistic simulation of reentry conditions prevailing around space vehicles returning to the Earth or entering the atmosphere of other planets. Research in this field is also leading to an understanding of the principles of electric propulsion devices, plasma flows in atomic power generators, and such fundamental phenomena as the interaction of the solar wind with the Earth's magnetosphere.

In applied mathematics, another important part of the Basic Research Program, new and improved mathematical techniques are being developed which will enable complex physical phenomena to be represented more easily and more accurately and to be studied with greater accuracy and speed on electronic computers. These techniques will, in time, lead to the solution of many important physical and mechanical problems of the kind that now are extremely time consuming or even impossible to solve with present analytical and numerical methods.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Supporting research and technology	$22,653,000	$21,231,000	$22,000,000
Total	$22,653,000	$21,231,000	$22,000,000

Distribution of Program Amount by Installation:

Marshall Space Flight Center	$986,000	$916,000	$920,000
Goddard Space Flight Center	235,000	257,000	260,000
Jet Propulsion Laboratory	6,443,000	5,792,000	5,800,000
Ames Research Center	1,692,000	1,881,000	1,900,000
Electronics Research Center	---	---	200,000
Flight Research Center	---	30,000	30,000
Langley Research Center	1,466,000	1,861,000	1,920,000
Lewis Research Center	3,464,000	2,234,000	2,750,000
NASA Headquarters	7,831,000	8,260,000	8,220,000
Western Operations Office	536,000	---	---

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1964	1965	1966
Fluid physics	$7,887,000	$7,830,000	$8,000,000
Electrophysics	3,986,000	3,940,000	4,100,000
Materials research	9,582,000	8,156,000	8,600,000
Applied mathematics	1,198,000	1,305,000	1,300,000
Total	$22,653,000	$21,231,000	$22,000,000

Fluid Physics

The objective of basic research in fluid physics is an understanding of the fundamental processes determining the behavior of liquids and gases. Emphasis is placed on the study of processes related directly or indirectly to problems anticipated in the development of future spacecraft and aircraft. For example, problems of fluid physics are involved in the erosion of electrodes

and insulators in magnetogasdynamic propulsion devices where gas temperatures reach 50,000 degrees Fahrenheit. At these temperatures gas mixtures react chemically, interact with structural materials, and undergo molecular and atomic decompositions, causing significant alterations of the flow field and of the thermal and mechanical stresses in exposed structures. Similar problems are encountered in the hot gas cap surrounding space vehicles during atmosphere entry and result in dangerous structural stresses and severe control and communications problems. The successful solution to these and similar problems which stand in the way of minimum weight, long life spacecraft systems depends in large measure on a productive fluid physics research program.

During FY 1966 research will continue on the high temperature properties of the gases known to make up the Earth's atmosphere and of others believed to be present in the atmospheres of Mars and Venus. These properties, which will be obtained at the Ames Research Center and under contract, are essential to the prediction of flow conditions about a vehicle and hence to the structural and aerodynamic design of interplanetary spacecraft. For example, the thermal radiative properties of air and carbon dioxide nitrogen mixtures, simulating the composition of the Venusian and Martian atmospheres, show large variations at certain wave lengths in electromagnetic spectrum. Much must be learned about the characteristics, particularly in the ultraviolet wave lengths, before spacecraft designers can proceed with confidence with the design of planetary landers.

Another important high temperature characteristic of certain gases is their tendency to become ionized. Gases in this state are called plasmas and research on plasma phenomena has become an important field of fluid physics. To understand the principles involved is essential, for example, to the design of electromagnetic gas accelerators and certain energy converters. In FY 1966, plasma physics research will be focused on fundamental problems of plasma stability which are impeding the development of a number of plasma propulsive devices. Successful solution of these problems may also lead to the design and construction of a hypervelocity plasma tunnel for model testing under reentry conditions. This is the only technique so far discovered that has the potential of complete simulation of these conditions in a continuous stream. Such a facility would become a powerful tool for materials and structural research. The Langley, Lewis and Ames Research Centers, assisted by some outside contracts, are conducting the plasma physics research program.

Another important objective in fluid physics research during FY 1966 is an understanding of turbulent boundary layer behavior on hypersonic aircraft. Accurate predictions of boundary layer behavior are essential to reliable predictions of airplane performance. The present uncertainty in understanding of hypersonic boundary layers must be overcome before the feasibility of hypersonic cruise aircraft can be assessed with confidence. Hypersonic turbulent boundary layers will be studied at the Langley and Lewis Research Centers, especially under the high heat transfer conditions expected on airplane surfaces and in engine inlets and nozzles.

761-133 O-65-16

Electrophysics

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

Research is under way to determine and explain the mechanisms of energy transfer within the atomic levels of solids and gases. This will lead to new sources for the stimulated emission of coherent electromagnetic waves (lasers) in the region from gamma ray to millimeter wave lengths. The availability of such signal sources would substantially advance our capabilities in electronic communication and navigation for spacecraft. This research is being conducted at the Massachusetts Institute of Technology, Stanford University, University of Michigan and Johns Hopkins University, under NASA contracts.

Theoretical and experimental research in superconductivity research is being conducted to increase the critical temperature and magnetic field strength of superconductors. Superconducting coils offer a superior method with respect to weight, volume and power requirements for obtaining strong magnetic fields. These fields may conceivably be used to shield spacecraft from harmful solar particle radiation and also to confine properly the flow of ionized gases in magnetohydrodynamic and controlled thermonuclear electric power generators. Other potential uses of superconductors are for electric power transmission lines, for computers, and for rotating electrical motors and generators. The research is being carried out by the Lewis Research Center, the Jet Propulsion Laboratory, and the University of Chicago.

One outstanding accomplishment in the Basic Research Program during FY 1965 was the generation of acoustic energy in solids and liquids by high intensity pulsed light from a laser. This acoustic wave has a frequency thousands of times higher than that of ultrasonic sound waves produced by previous methods. Coherent acoustic energy may become a new research tool to probe further the behavior of electrons and ions which form the structure of solid state devices such as semiconductors, transistors and lasers. It may also be possible to adapt acoustic energy to industrial nondestructive testing techniques.

In FY 1966, the existing program will be continued. Additional emphasis will be placed on exploring nuclear reactions to obtain a better understanding of the forces binding the nuclei. Such knowledge not only will explain better the reactions of primary solar radiations impinging on spacecraft structures, but also provide new information about the secondary radiations arising from the primary reactions. This information may be helpful to spacecraft designers. Also, a more intense effort will be made to explore the energy transformations in the lattice structure due to applied electric and magnetic forces. The results may lead to greatly improved electronic circuit components for space navigation and communication systems.

Materials Research

The role of basic research in materials is to gain an understanding of the basic physical and chemical nature of solids. It is only through such understanding that NASA can continue to meet its growing needs for improved materials.

The program is broad in scope and ranges from basic studies of the electronic and atomic nature of matter to its application in airplanes and space vehicles. It deals with the thermodynamics of chemical reactions involved in the production and utilization of materials, and with the physical metallurgy and chemistry of complex alloys, ceramics, and polymers from which many devices used in flight programs are constructed. The program includes studies of the basic mechanisms by which materials deteriorate in service. One example is the study at Ames Research Center on the mechanism by which ablative materials deteriorate upon reentering the Earth's atmosphere. It is this breaking down of the ablative material that provides the heat protection to spacecraft. When the ablation process is completely understood, it will be possible to utilize current ablative materials more efficiently and to develop better ablatives for future spacecraft.

Encouraging results during the past year indicate that the entire Materials Research Program will show substantial progress in FY 1966. One aspect of this program should be particularly productive: the understanding of the electrical, chemical and physical nature of surfaces. This understanding is very important in problems involving almost all phases of materials behavior, and is finding frequent application in the development of space vehicles and high speed aircraft. For example, the 20 year backlog of scientific knowledge and experience in oxidation resistant high temperature alloys will, in FY 1966, be applied to the specific problem of designing stator and turbine blades for the engines of the Mach 3 supersonic transport. These engine components will be operating at temperatures 300 to 400 degrees Fahrenheit higher than those in current engines, a temperature region where oxidation becomes a severe problem.

Another aspect of materials research which is progressing well and should find practical application in FY 1966 is that of dispersion strengthened materials. These are metals or alloys which have been strengthened through the introduction of very small hard particles that retard slipping between the metal crystals. In the past, research on these materials has resulted in an accumulation of scientific knowledge on the mechanism by which such particles strengthen metals. A clear picture is almost at hand and will result in a dispersion strengthened nickel to be evaluated in FY 1966 for the structure of the supersonic transport airplane. This material should hasten the final design of this airplane.

Applied Mathematics

Research in applied mathematics is concerned with the development of improved mathematical techniques for the solution of physical problems. The

problems which may arise in aerospace science or engineering usually require the solution of non-linear differential equations. Fast and simple solutions are desired for planning experiments and predictive evaluation of results, because this is often the most feasible and economical way.

While substantial progress has been made in this direction, there remain many problems in the physical sciences which await mathematical formulation and solution. One of these is the problem of three bodies, that is, the question of solving the mathematical equations representing motion of, say, a lunar satellite or space probe moving under the influence of gravitational fields of two or more large masses, each having relatively large effects. Since a lunar probe or satellite is thus influenced by the Earth, Moon, and Sun, while any planetary probe will be critically influenced by some planet as well as the Sun, it is clear that the three body problem will recur for many future space missions. Already special cases of the three body problem have been solved to a satisfactory degree, and it is planned in FY 1966 to expand the work into the more general cases which are involved in space flight.

Efforts will also be made to find mathematical methods, both analytical and numerical, which could be used in determining the orbits of lunar satellites to a high degree of accuracy. The mathematical methods for determining and programming such an orbit are still untested and uncertain and preliminary considerations have shown that many types of lunar orbits will be highly unstable.

Similarly, there will also be efforts to improve the mathematical analysis of spacecraft and aircraft structures. Problems in this field include those of the strength of plates and shells for such structures, and of determining the requirements or limitations of modern aircraft to fly optimum trajectories between two airports.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1966 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — SPACE VEHICLE SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objectives of the Space Vehicle Systems Program are to identify and solve the critical design problems associated with space vehicle launch and ascent through the atmosphere, flight through space, entry into the atmosphere of earth or other planets, and landing. The program seeks to advance the state-of-the-art on a broad front to permit the conception and development of advanced vehicles and at the same time to solve critical technical problems that may arise during the course of development of present generation space vehicles.

The space vehicle during launch and ascent through the atmosphere must cope successfully with a wide variety of problems which include ground-wind loads, mechanical vibration, intense acoustic noise, severe gusts and wind gradients aloft, propellant sloshing, control forces, and many others. The highest possible structural efficiency is required to achieve minimum weight while assuring no structural failure. Flight through space takes place in an environment of high energy charged particle radiations, meteoroids, high vacuum, cold space and unattenuated thermal radiation from the sun, and is further characterized by a condition of zero gravity, all of which must be understood and dealt with by proper structural and system design. Return to earth (or exploratory missions to the surfaces of other planets) is characterized by high speed atmosphere entry with its intense heating which must be well understood and accurately predicted and for which adequate thermal protective structures must be devised. Research must be carried out in aerothermodynamics, structures, and in the several disciplines associated with the space environment by means of a variety of laboratory facilities and by carefully selected flight experiments to provide the detailed technological knowledge required for the design of advanced space vehicles.

Major progress was made during the past year in a number of important areas. Significant highlights include two atmosphere entry flights; one, Project Fire which measured the heating environment at 38,000 feet per second, and the other, a Scout launched experiment which measured the behavior of an advanced ablative heat shield material in the heating environment at 28,000 feet per second. A preliminary flight program at the Flight Research Center of a simplified light weight test vehicle of the M-2 lifting body configuration was successfully completed and an extension of this program was implemented by a contract for the construction of two all metal M-2 and HL-10 test vehicles with higher and more realistic planform loadings. The Explorer XXIII meteoroid satellite was successfully orbited. An important secondary experiment to measure launch vehicle structural response to severe wind gradients aloft was successfully carried out during the Explorer XIII launch.

Substantial progress was also made in ground based research and included the generation of new structural and aerodynamic concepts for planetary entry probes and techniques for use in determining the properties and composition of the atmosphere of Mars, new high velocity particle impact results contributing to our knowledge of the meteoroid hazard, and large scale measurements of the acoustic noise field generated by the high velocity hydrogen exhaust from a nuclear rocket.

During the coming year emphasis will be placed on further advancing the technology of lifting entry flight through the extended M-2 and HL-10 flight test program and through augmented laboratory research on heat protection systems and in other areas. Corollary flight experiments to measure turbulent boundary layer heat transfer and to determine the performance of advanced ablative heat shield materials will be undertaken. Emphasis will continue on determination of the meteoroid hazard, and a major milestone in that program is expected within the coming year with the Saturn launchings of Pegasus spacecraft with their 2000 square feet of meteoroid detection area. Augmented effort will be given to research on the effects of high energy radiation on space vehicle materials, components, and subsystems in the Langley Research Center's new Space Radiation Effects Laboratory with its 600 million electron volt cyclotron.

Emphasis will also be placed during the coming year on accelerating progress in the development of critical design criteria for space vehicles incorporating the most recent results of ground based research and flight experiments in order to provide industry, the NASA, and other Government agencies with vitally needed technical guidelines.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Supporting research and technology..	$24,951,000	$24,559,000	$24,000,000
Project FIRE.....	7,037,000	2,811,000	500,000
Scout reentry project.....	305,000	750,000	5,000,000
Lifting body flight and landing tests.....	1,200,000	1,500,000	1,000,000
Project Pegasus (Saturn-launched meteoroid experiment).....	9,900,000	13,690,000	2,500,000
Small space vehicle flight experiments.....	1,959,000	1,010,000	2,000,000
Scout launched meteoroid experiments.....	362,000	175,000	---
Total.....	$45,714,000	$44,495,000	$35,000,000

	1964	1965	1966
Distribution of Program Amount by Installation:			
Manned Spacecraft Center.....	$629,000	$730,000	$855,000
Marshall Space Flight Center.....	13,569,000	16,744,000	4,490,000
Goddard Space Flight Center.....	878,000	956,000	930,000
Jet Propulsion Laboratory.....	4,577,000	3,438,000	3,140,000
Ames Research Center.....	1,942,000	2,922,000	2,655,000
Flight Research Center.....	1,403,000	2,020,000	1,180,000
Langley Research Center.....	15,257,000	9,659,000	13,461,000
Lewis Research Center.....	3,186,000	2,326,000	1,770,000
NASA Headquarters.....	3,282,000	5,700,000	6,519,000
Western Operations Office.....	991,000	---	---

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1964	1965	1966
Spacecraft aerothermodynamics.....	$5,452,000	$5,242,000	$5,346,000
Spacecraft loads and structures.....	4,495,000	5,209,000	5,560,000
Launch vehicle aerothermodynamics...	826,000	1,264,000	1,300,000
Launch vehicle loads and structures.	3,720,000	3,350,000	3,414,000
Space vehicle environmental factors.	7,506,000	6,745,000	7,105,000
Advanced space vehicle concepts.....	2,371,000	1,949,000	550,000
Space vehicle design criteria.....	581,000	800,000	725,000
Total.....	$24,951,000	$24,559,000	$24,000,000

Spacecraft Aerothermodynamics

The purpose of this research is to provide information on aerodynamic heating and heat protection, advanced configurations, and landing and recovery. This information supports existing vehicle development programs and provides new concepts for future space vehicles.

Two successful flight research programs added materially to the aerodynamic heating technology during the past year. One of these programs was Project FIRE which measured the atmospheric entry heating at a speed of 38,000 feet per second where radiative heating is an important problem. This experiment provided highly significant new flight data for correlation with results of ground based research and theoretical predictions which have contained considerable uncertainty. In the other flight, an ablative heat shield experiment was flown on a Scout rocket at an entry velocity of 28,000 feet per second. A large spread in the predictions of heat shield performance had been obtained from ground based facilities. These flights, by providing anchor point data, are contributing greatly to a better understanding of test data obtained in ground based facilities.

In the field of manned entry vehicles, research continues on the lifting body concept. This principle provides maneuverability during entry and the possibility of conventional horizontal landing on land. Significant progress was made in the past year at Langley and Ames Research Centers in defining controllable configurations and in solving the stability problems. During FY 1966, ground based research will emphasize high speed performance, stability and control, vehicle heat protection, and problems associated with abort and emergency landings.

A preliminary flight investigation at the Flight Research Center of a light weight test vehicle of the M-2 lifting body configuration has been successfully completed. During the coming year heavier test vehicles of both the M-2 and HL-10 designs will be constructed and flown to study approach and landing problems at weights more representative of operational vehicles.

Research has continued at the Manned Spacecraft Center over the past year in an effort to provide other safe and reliable means of recovering manned spacecraft. Landing of heavy spacecraft, in the order of 10,000 pounds, would now require the use of multiple parachutes to provide a descent speed low enough to assure the safety of spacecraft and astronauts. These systems are heavy, require large stowage volumes, and are difficult to make reliable. Research has lead to a single large parachute (capable of recovering a 10,000 pound spacecraft) with greatly increased reliability. During FY 1966 this program will emphasize further reduction in weight of the single parachute system and will continue research on other concepts, such as steerable parachutes, parachute retro-rocket systems and light weight variable drag devices.

Spacecraft Loads and Structures

The purpose of this research program is to provide new concepts and new analytical and experimental tools for the structural design of spacecraft. The program encompasses: advanced structural concepts, new applications of materials, definition of loads, techniques for analyzing and testing structural response and structural failure, protection against entry heating and the hazards of space, storage of cryogens during long periods of space flight, and protection of components against vibrational environments and landing impact.

In the area of advanced structural concepts, a number of concepts have been generated which are sufficiently promising to warrant further evaluation in FY 1966. One example is an expandable airlock system which could be used for servicing or rendezvousing operations between space stations and spacecraft. The airlock is capable of compact storage and expansion by virtue of the application of elastic foam as part of its structure. A gas-tight liner prevents loss of internal air pressure. Tensile loads due to pressure are carried by a knitted structure. Protection against the space environment is achieved by a reflective outer shield and the meteoroid protection characteristics of the foam inner layers.

During the many operations of space vehicles, electronic and structural components are subjected to high frequency vibrations. This is an important

and complex problem occasionally resulting in mission failure but more often causing serious weight penalties resulting from overdesign. Methods of predicting space vehicle loads and load transmission through structures are inadequate, as are current methods of isolating vibrations and of proof testing spacecraft to ensure against failure resulting from vibrations. Research at the Goddard Space Flight Center and Langley Research Center will concentrate on these problems in FY 1966.

The importance of hydrogen as a fuel for future space missions is well recognized. The current program to meet the requirements for storage of hydrogen and other cryogens in space for periods greater than a few weeks will be continued in FY 1966. This research, under way at the Lewis Research Center and Marshall Space Flight Center, is emphasizing the important problems of thermal and meteoroid protection, selection of materials, and the design and fabrication of cryogenic tanks.

Launch Vehicle Aerothermodynamics

The Launch Vehicle Aerothermodynamics program is concerned with the study of new launch vehicle concepts and with the solution of heating, aerodynamic, and related problems of current and future launch vehicles. Among the important specific problems are base heating from rocket exhaust and the generation and propagation of intense acoustic noise.

One objective of this program is to develop feasible concepts for recoverable launch vehicles. Attention will be given to methods for recovery of present types of vehicles using auxiliary devices and to advanced types of vehicles designed to have flight characteristics appropriate to recovery.

Another current objective of the program is to find solutions to the base heating problems of large multi-engine launch vehicles. Research has shown that a contributing cause of these problems is the burning of the fuel-rich exhaust gases from the turbopumps in the base region. This will be explored further in the coming year. Research will also continue on theoretical and experimental methods of predicting the amount of radiative and convective base heating contributed by the rocket jets, the recirculation and burning of unburned gases from these jets, and the burning of entrained waste gases. The work includes the development of inexpensive experimental methods of determining base heating on models and the establishment of appropriate scaling laws.

In the area of research on noise generation and propagation, comprehensive measurements were made for the first time during the past year of the acoustic-noise field generated by the high velocity hydrogen jet exhaust from a nuclear rocket (KIWI). These, and similar experiments, will provide important information for the structural design of nuclear powered space vehicle systems and components and of test stands and surrounding buildings. Research on rocket noise generation will continue in FY 1966 with emphasis on providing improved understanding of the mechanism of noise production in high velocity jets.

In a related field, the effects of atmospheric conditions on the propaga-

761-133 O-65-17

tion of noise are under study. It has been found that temperature inversions and local winds cause focusing of sound waves from rocket test stands which can result in structural damage at distances from the test site normally considered safe. Research is continuing on sound propagation under a variety of atmospheric conditions quickly and accurately so that static tests of large boosters can be scheduled with less fear of building damage or disturbances to communities.

Launch Vehicles Loads and Structures

The purpose of this program is to derive and evaluate advanced structural concepts and new materials applications for launch vehicles; to define the loading to which the structures will be subjected; to improve analytical and experimental methods of determining structural response to loads; and to develop means of proof testing launch vehicles to ensure against failure.

Ground winds to which large launch vehicles are subjected on the launch pad constitute a major design load for these structures. Experimental research with scaled models in low speed wind tunnels, conducted by the Langley and Ames Research Centers, and related research at Marshall Space Flight Center, has produced important information on the nature of these loads and the structural response of launch vehicles. Approximate methods for predicting loads on full scale vehicles have been developed. During the coming year these analytical methods, and the scaled model results, will be evaluated and compared with full scale tests.

A second important objective of this program is an understanding of the dynamic loads imposed on launch vehicles during powered flight. These loads, caused by wind shear, thrust vectoring, fuel slosh, and aerodynamic flow instabilities, have caused structural failure in launch vehicles. Research on launch vehicle structural dynamics will continue at the Langley and Ames Research Centers and the Marshall Space Flight Center in FY 1966. Typical of the problems considered is that of reducing the structural loads caused by sloshing of rocket fuel in tanks during launch. Promising results are being obtained with a technique utilizing flexible baffles which inhibit sloshing.

Space Vehicle Environmental Factors

The objective of this research program is to provide understanding and detailed technical knowledge of the space environment and its effects on spacecraft and their systems to insure proper and efficient design and operation. The research includes high energy space radiation effects and shielding, the meteoroid hazard, hard vacuum, thermal radiation effects and temperature control, and the behavior and control of fluids in zero gravity.

The high energy radiation environment is detrimental to equipment and hazardous to man. A major research program is therefore being conducted to determine the effects of charged particle radiation on space vehicle equipment, to understand the damage mechanisms involved, and to develop radiation shielding techniques. The completion in FY 1966 of the Langley Research Center's new Space Radiation Effects Laboratory will greatly enhance the capability for

research on radiation effects in materials, components, and subsystems. Investigations under way to determine the shielding effectiveness of various materials against space radiation will continue. Experimental radiation penetration results recently obtained by researchers in industry and at the Oak Ridge National Laboratory under contract have compared favorably with theoretical calculations, leading to greater confidence in these methods. Theoretical and experimental laboratory research is being pursued to develop new shielding concepts involving electrostatic and electromagnetic phenomena which may result in appreciable savings in weight for future space vehicles.

Meteoroid penetration of pressurized cabins, propellant tanks, or the radiators of nuclear power systems could be catastrophic. Erosion of surface coatings by the smaller particles could have serious effects such as creating undesirable changes in the temperature balance. Current information on the meteoroid environment and on the mechanism of hypervelocity impact by meteoritic particles is seriously limited, and therefore a broad research program including both laboratory and flight experiments is under way. In the program to define the meteoroid hazard, a second satellite of the S-55 class, Explorer XXIII, was successfully orbited during the past year. A major milestone is expected during the coming year with the Saturn launchings of Pegasus spacecraft, with their 2,000 square feet of meteoroid detection area. In addition to flight experiments, meteors entering the Earth's atmosphere are being studied using radio reflection techniques by Harvard College Observatory under contract. Laboratory studies will be continued to obtain an understanding of the physics of hypervelocity impact. Preliminary data on particle size effects have been obtained by the Ames Research Center which may explain existing discrepancies found in flight between impact experiments using microphones and penetration experiments using thin wall detectors such as pressurized cells. Laboratory testing, however, is still limited by the inability to simulate meteoroid particles sizes and velocities in the most critical ranges of these quantities. Emphasis will consequently be given to the development of promising techniques for achieving better simulation.

The zero-gravity fluid behavior program involves research on the effect of weightlessness on the static and dynamic behavior and heat transfer phenomena of liquids and vapor. Problems of separating and positioning of liquids and vapors, liquid pumping, and venting of vapors are common to spacecraft systems such as propellant tanks and water supply tanks. Drop tower tests at the Lewis Research Center have produced a good understanding of the behavior of fluids and vapors in static equilibrium conditions of weightlessness. Efforts to understand the dynamics of fluids under low accelerations and to improve the capability for extrapolating small scale results to full scale systems are continuing. Flight experiments of fluids under weightless conditions are being conducted to study behavior which takes place more slowly than can be studied in the short test times provided by our drop tower research facilities.

Current evidence shows that spacecraft material properties can undergo serious detrimental changes when exposed to the extreme vacuum of space. In

the high vacuum technology area, the over-all objective is to advance our laboratory capability to simulate, maintain, and measure the very low pressure or density associated with space vacuum and thus achieve a more definitive research and development capability for testing space vehicle materials, components and systems. Research will be focused on producing cleaner deep vacuum conditions in chambers by capture of most gas molecules, and on improving of vacuum instrumentation.

An important and complex spacecraft design consideration is that of maintaining component and cabin temperatures within narrow limits. Where the solar heat input remains constant or is cyclic, passive thermal coatings can be used effectively. Where this is not the case, such as in interplanetary flight, active systems which are able to alter the thermal characteristics of the vehicle are required. Research is being carried out on thermal coatings which change their absorption or heat emmission characteristics automatically with changes in temperature, or which vary their characteristics through application of electric or magnetic fields. Major advances have been made in passive coatings which are stable in the ultraviolet space environment. The resistance of these coatings to high energy radiation is still questionable and will require further research. The ability to ground test thermal performance of spacecraft is hampered by our inability to simulate adequately the solar spectrum in laboratory facilities. The program to improve this capability includes the development of improved calibration and spectral intensity monitoring techniques, as well as improved methods of thermal balance measurement and computation.

Advanced Space-Vehicle Concepts

This program looks beyond the present generation of spaceflight projects and attempts to define problems of the next generation of spacecraft. Potentially attractive missions for future NASA spaceflight programs are analyzed with the objective of identifying those where major advances in technology will be required or where feasibility will depend upon new innovations.

During the past year studies of this type have been made in a number of important areas. These have included, for example, recoverable launch vehicles and alternate approaches to recovery which emphasize simplification to reduce booster costs, advanced logistic spacecraft of the lifting entry type, large orbiting telescopes in association with manned orbiting laboratories, new probe and probe lander concepts for determining the atmosphere of Mars, and vehicles and techniques for manned Mars exploration missions.

The studies of launch vehicle simplification have produced a potentially attractive concept involving the placement of the more complex and costly elements, such as steering controls and high energy, liquid fuel, upper stage rockets, in the spacecraft itself, which would be recovered, and reducing the lower vehicle stages to the simplest possible configuration which could be economically discarded after use.

The studies of unmanned planetary probes have produced several promising

new concepts of spacecraft and techniques for the direct measurement of the structure and composition of the atmosphere of Mars, which will be a prerequisite to the confident design of more complex unmanned spacecraft intended for soft landing on the surface of Mars.

The manned Mars mission studies resulted in the discovery of a dramatic technique for reducing markedly the total propulsive requirements for the Mars trip. The technique involves selection of a particular Earth-Mars trajectory which passes close enough to the planet Venus that the spacecraft trajectory is bent sharply by the planet's gravitational field as it passes by. This "swing-by" maneuver alters the spacecraft's direction of approach to either Mars or the Earth in such a way that the spacecraft is moving more nearly in the same direction as the target planet at the approach. The result is a much reduced relative approach velocity and hence a much lower deceleration requirement for the Mars or Earth landing.

In FY 1966 research in this program will examine in considerably greater depth the vehicle and systems design problems to identify further the technological needs and research requirements in specific problem areas such as landing systems, heat protection, communications, and aerodynamics. Particular emphasis will be given to unmanned Mars atmosphere probe technology, advanced maneuverable entry vehicles for near earth flight application, and recoverable launch vehicles.

Space Vehicle Design Criteria

Several failures of space vehicles resulting from inadequate design and testing procedures have clearly indicated the need for engineering design criteria for the guidance of the designers of future space vehicles. The basic objective of this program is to develop and disseminate such criteria, and thus to improve reliability of space vehicles and reduce costs of future space programs through the uniform application to design of up-to-date technical knowledge.

The products of this program are design criteria monographs for use by NASA and industry in the engineering design of future space vehicles. These monographs provide an important means of ensuring the availability to engineers of an appropriate formulation of the latest knowledge, based on both operating experience and research. It is expected that these design criteria documents will have an important effect in reducing or eliminating many causes of potential failure of future vehicles.

The program encompasses preparation of criteria in several areas of design, including structures, propulsion, and guidance and control; and in the terrestrial and space environments which give rise to design problems. The work is presently being carried out at six Installations; at the Jet Propulsion Laboratory; and, through contracts, at the U.S. Weather Bureau, six aerospace companies, and one university. FY 1966 funds will provide for continuing and expanding the contract program necessary to accelerate completion of urgently needed criteria.

Several criteria monographs pertaining to the structural dynamic design problems of buffeting and flutter were disseminated to industry and other Federal agencies in FY 1965. Currently about forty additional criteria monographs, dealing with other design problems and with the natural environment, are in various stages of preparation.

Project FIRE

	1964	1965	1966
Spacecraft and support services...	$7,037,000	$2,811,000	$500,000
Atlas (Launch vehicle Procurement Program).....	(1,786,000)	(972,000)	(---)
Total (including launch vehicles).....	($8,823,000)	($3,783,000)	($500,000)

This project investigates the heating environment around an Apollo shaped spacecraft during reentry at speeds near 37,000 feet per second. Flight tests are required to provide critical anchor point data for validating results from laboratory test facilities and to provide guidance for application of theoretical as well as experimental reentry data.

The FIRE I spacecraft was successfully flown on April 14, 1964. It provided the first flight measurements of total heating and radiative heating at a velocity of 38,000 feet per second on a large size body. The data defined the gross heating levels in this severe environment and provided a necessary interpretation of results from ground based facilities and theoretical predictions.

A second reentry (FIRE II) is planned near the end of FY 1965. In view of the success of the first flight, the reentry sequence has been altered to provide additional information to complement the results in hand, including measurements at maximum heating. The trajectory has also been shifted slightly to favor measuring important sources of gas radiation with a special high resolution, ground based tracking spectrograph to aid in a more complete understanding of the reentry heating environment.

FY 1966 funds are required to complete operations for FIRE II and to analyze and publish the results. Under the management of the Langley Research Center, this project employs Republic Aviation Corporation as a prime contractor for the reentry package, Ling-Temco-Vought as contractor for the velocity package, and General Dynamics/Astronautics as systems integration contractor and launch vehicle supplier.

Scout Reentry Project

	1964	1965	1966
Spacecraft and support.....	$305,000	$750,000	$5,000,000
Scout (Launch vehicle Procurement Program).....	(1,000,000)	(1,000,000)	(---)
Total (including launch vehicles).....	($1,305,000)	($1,750,000)	($5,000,000)

The performance of a reentry heat protection system is determined by a complex interaction of the physical and chemical properties of materials at high temperatures and the characteristics of the heated air surrounding the spacecraft. It is not presently possible to reproduce simultaneously, in any existing ground based facility, the proper combination of all parameters known to be of importance in the performance of a heat protection system during atmosphere reentry. This project is designed to provide a series of flight experiments, utilizing the Scout launch vehicle, which will obtain data essential to current major flight projects and will lead to more reliable interpretations of test results from ground based facilities.

The Scout reentry materials payload "Reentry D", was successfully flown in August 1964. The material flown was a candidate material for the Apollo heat shield. Ground based facilities varied in their predictions of the performance of the heat shield and none of the facilities accurately predicted the actual performance of the material. The flight provided an important anchor point for the ground based facilities and a large ground based program is now under way to determine why the material behaves as it does and why the facilities do not predict the material performance more accurately.

Scout experiment "Reentry E" will be flown early in FY 1966 with a phenolic nylon heat shield material. Phenolic nylon is probably the best understood heat shield material based on laboratory experiments, but has not been flown. The material shows great promise for certain types of flights such as the ballistic or near ballistic atmospheric entry.

Next, two different payloads plus back-up payloads will be built, using different elastomeric materials. Elastomeric materials appear promising for the long flight time of the lifting body entry and for the low density payload required for Mars missions. The payloads will be blunted cones and one payload may carry simulated flaps in order to study the region around the flap.

Another critical problem to be investigated in this series is the determination of transition Reynolds number and turbulent heating rates. The Reynolds number of transition from laminar to turbulent flow decreases with increased speed up to low hypersonic speeds, and then increases rapidly at

higher speeds. At these higher flight speeds (20,000 feet per second) there is great uncertainty as to the Reynolds number at which transition occurs. Few flight data on turbulent heating rates exist. A flight experiment will be made to provide a check of the semi-empirical turbulent heating theories at high velocities. A slender cone will be flown at 20,000 feet per second. Two payloads and one back-up are required.

Lifting Body Flight and Landing Tests

	1964	1965	1966
Flight vehicle and support services.	$1,200,000	$1,500,000	$1,000,000

The lifting body configuration as a future spacecraft promises better maneuverability on Earth reentry than Apollo and Gemini and has the capability of conventional airplane type horizontal landing.

During the past year, the light weight lifting body glider flight program was completed. This lifting body test vehicle has been built at an approximate cost of $20,000 by the Flight Research Center. The flights demonstrated that a light weight vehicle could be landed successfully.

Also during FY 1965, a fixed price contract was signed with Norair Division of Northrop Corporation to build two metal, lifting body glider configurations: one, the Langley HL-10 and the other the Ames M-2. These vehicles will be carried to an altitude of 40,000 feet and a speed of about Mach number 0.8 then released to glide back to Earth. These vehicles, which represent different concepts of lifting bodies, are being built to study the problems associated with flying at high subsonic speeds and landing a vehicle which has planform loading equivalent to what could be expected from an actual space vehicle. During FY 1966, the flight test program will begin with flights of the M-2 scheduled in the Fall of calendar year 1965. First flight of the HL-10 will be about six months later.

The funds in FY 1966 will provide for flights that will include pilot familiarization with the vehicle, and studies of effects of center of gravity change and variable planform loadings.

Project Pegasus (Saturn-Launched Meteoroid Experiments)

	1964	1965	1966
Spacecraft and support.....	$9,900,000	$13,690,000	$2,500,000

To determine the severity of the meteoroid hazard to spacecraft, direct measurements are required in the space environment to obtain actual penetration rates in spacecraft materials. The Explorer XVI (Scout launched experiment) has provided the first statistically significant penetration rates in thin materials.

These experiments, to be launched into near Earth orbits on development flights of Saturn I launch vehicles, will expose to meteoroid penetration an area almost 100 times that of the Scout launched experiments. This will permit measurements of the frequency of penetration of metal surfaces as thick as 0.016 inches, approaching nominal vehicle wall thicknesses used in propellant tanks for Apollo and other projects. FY 1966 funds will permit the launching of the third spacecraft.

The Pegasus spacecraft, operating a few hundred miles from the Earth, will provide a good measure of the penetration power of meteoroids in the near-Earth environment. While it is generally assumed that the meteoroid hazard decreases in severity with increasing distance from the Earth, not enough is known about the variation in meteoroid flux with distance from the Earth to permit taking this factor into account in spacecraft design. Some theories also indicate that there may be focusing factors, and thus points of severely increased hazard, between the Earth and the Moon. The assumptions in these theories are sufficiently uncertain that it is not possible to say whether or not these areas of increased hazard actually exist.

Upon analysis of the flight data from the Earth orbiting Pegasus spacecraft, it is planned to proceed with the study of the systems requirement for conducting similar experiments in a highly elliptical orbit to define the meteoroid penetration hazard in the region of space between the Earth and the Moon. Funds provided in FY 1966 will be used for project definition studies and preliminary design of the experiment.

Small Space Vehicle Flight Experiments

	1964	1965	1966
Behavior and handling of cryogenic propellants at zero G.	$1,050,000	$255,000	---
Wind-shear measurements	117,000	25,000	$95,000
Meteor simulation	640,000	650,000	325,000
Reentry detection	63,000	80,000	---
Materials correlation and structures tests	---	---	1,580,000
Meteoroid penetration probe	89,000	---	---
Total	$1,959,000	$1,010,000	$2,000,000

The objective of this continuing project is to provide for selected flight experiments using small rocket launch vehicles to verify results obtained in ground based facilities and to investigate problems which can only be studied under environmental conditions which occur in actual flight. Current and recently completed experiments include the following:

Behavior and Handling of Cryogenic Propellants at Zero G

Work on the handling of fuels and other fluids under weightless conditions is being pursued in flight experiments to study behavior which takes place more slowly than can be provided for in drop towers or other ground based facilities. Data from previous experiments in this project have established the rate at which heat will be transferred from the tank walls to the cold fluid, causing boil-off and resultant waste of fuel. In FY 1966 flight experiments will be conducted to extend this initial understanding to more complex problems of dynamic behavior of fluids such as fluid pumping, tank spinning or tumbling, and dynamics at engine restart.

Wind Shear Measurements

Measurements of the statistical distribution of wind velocities in the vicinity of major rocket launching bases (to provide criteria for design of launch vehicles to withstand the loads resulting from wind shear forces) are being obtained for altitudes up to 70,000 feet using Nike boosters with smoke producing nose cones.

Meteor Simulation

Experiments are being conducted to provide data at velocities up to 90,000 feet per second on the luminous efficiency, heat transfer, ablation rate, and ionization efficiency of simulated meteors of known mass, composition, material, shape and size. From the results of these tests, the gross heating experienced by natural meteors can be determined and meteoric entry phenomena can be established.

Materials Correlation and Structures Tests

The factors known to affect the performance of ablation materials are heating rate, shear stress, stream composition, duration, enthalpy and size. It is possible in existing ground based facilities to simulate simultaneously some but not all of these factors. Results of flight experiments in the past year have indicated a strong need for better comparison between results of flight test and results from ground based facilities for validation of the ground based data.

The planned flight experiments will require two payloads plus a back-up payload. The materials flown would be strong elastomeric materials suitable for Mars entry. The planned flight experiments have been formulated in such a way as to complement and extend information gained from the ground based facilities and other flight experiments.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1966 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — ELECTRONIC SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objective of this program is to provide the necessary advances in technology to assure the availability of reliable and efficient electronic components for future aeronautical and space flight missions. Research is conducted in the laboratory on the problems of guidance, control, communications, tracking, instrumentation, and data processing systems. Small flight experiments are used to confirm results of laboratory research and, in some cases, to obtain solutions to problems which cannot be studied adequately in the laboratory.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Supporting research and technology	$26,380,000	$23,322,000	$30,000,000
Small flight projects	2,320,000	2,100,000	4,400,000
Total	$28,700,000	$25,422,000	$34,400,000

Distribution of Program Amount by Installation:

Manned Spacecraft Center	$1,079,000	$475,000	$880,000
Marshall Space Flight Center	4,644,000	3,469,000	4,525,000
Goddard Space Flight Center	3,274,000	2,797,000	3,035,000
Jet Propulsion Laboratory	2,806,000	2,727,000	3,200,000
Ames Research Center	2,399,000	3,650,000	3,390,000
Electronics Research Center	---	1,873,000	5,000,000
Flight Research Center	1,072,000	1,103,000	1,400,000
Langley Research Center	8,848,000	6,390,000	9,120,000
Lewis Research Center	463,000	445,000	580,000
NASA Headquarters	4,087,000	2,493,000	3,270,000
Western Operations Office	28,000	---	---

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1964	1965	1966
Guidance systems	$4,723,000	$4,800,000	$6,200,000
Control systems	6,596,000	5,660,000	6,000,000
Communications	5,156,000	3,960,000	5,900,000
Tracking and data acquisition	2,897,000	2,750,000	3,800,000

	1964	1965	1966
Data handling and processing.....	$3,102,000	$3,040,000	$4,100,000
Instrumentation.....	3,906,000	3,112,000	4,000,000
Total.....	$26,380,000	$23,322,000	$30,000,000

Guidance Systems

The guidance system research program is directed towards the derivation of information necessary to understand and design simple, reliable and light-weight sensors, reference elements, and associated components which make up a guidance system. The program emphasizes technique and component research in inertial, optical, and electromagnetic phenomena for application to sensing and reference functions. Digital computer technology is explored as a means for implementing guidance equations and processing navigational data. Trajectory analysis provides the framework for examining energy requirements, error analyses, and sensor and data processing trade-offs for any specified space mission.

The objective of research in inertial components is to develop longlife, high performance, low power devices for future spacecraft guidance and attitude control systems. Typical uses include flight path corrections, autopilot control, and orbit plane determination. Initial investigations in one area, for example, have demonstrated the feasibility of the "frictionless" electrostatically suspended gyro (ESG); the follow-on program by Honeywell, Inc., under the direction of Jet Propulsion Laboratory will begin the development and testing of flyable prototypes.

One objective of the research on optical devices is to improve the performance of automatic space navigation equipment, such as electro-optical star trackers and star mappers. But increasing emphasis is being placed on the search for new techniques which will make on board guidance systems, particularly of manned vehicles, less dependent on complex automatic or remotely operated systems. Thus, for example, for manned space flight, the incorporation of manually operated sextants into the navigation computation loop could significantly reduce computer complexity and the size and weight of overall navigation equipment. Research at the Ames Research Center, utilizing space flight simulation techniques, is expected to lead to the development of simple hand-held sextants and the techniques for using them.

In the field of digital computer research, emphasis is currently on the problems of developing small, light weight, high performance computers for on board applications. Some of the most promising results of this research so far are coming from exploratory work on new computer concepts at the Jet Propulsion Laboratory. Included in this program are the development of a prototype magnetic-logic computer and investigations of self-organizing computer techniques. This work will continue as part of the FY 1966 research program in guidance computers.

The derivation of guidance equations and guidance system requirements is based on the analysis of trajectories related to the various mission objectives. Past work in this area has established basic trajectories to the moon and nearby planets. Continuing studies at Marshall Space Flight Center, Ames Research Center, Jet Propulsion Laboratory, Electronics Research Center, and Langley Research Center, are now seeking simplified guidance equations for use with these trajectories, and exploring new trajectory problems such as those associated with low level, long duration thrusting systems typical of electric or nuclear propulsion.

Control Systems

Research in this program establishes the technology and design requirements for control systems of aerospace vehicles. Problems studied include those of manned and automatic flight control, spacecraft attitude stabilization, and the development of improved research techniques. Along with the applied research, a program of theoretical and basic research is carried out in related fields. Specific objectives include: improvements in displays for manned vehicles, development of adaptive automatic controls, economical methods for long life satellite stabilization and more accurate pointing techniques for optical communication devices.

Research in recent years on the problems of designing control systems intended for use by man in controlling spacecraft and high speed aircraft has emphasized the need for the application of mathematical techniques to the description of human response characteristics. Mathematical descriptions of the human operator for complex control tasks are now under development at Langley Research Center, Massachusetts Institute of Technology, and the University of Michigan.

In the field of attitude stabilization, a dominant problem during the coming year will be the development of systems for long term service satellites (e.g., communications, meteorological, and navigation satellites) which require constant, or frequent, attitude reorientation. Present active methods utilizing gas jets are not satisfactory because of fuel requirements. Passive stabilization systems, which utilize natural forces as energy sources, appear promising. Gravity gradient attitude stabilization systems for satellites have been studied extensively at Ames Research Center. This principle utilizes the Earth's gravity both to establish an attitude reference and as a source of power for aligning the vehicle in the desired attitude. An application of this principle is presently being considered for use on the Applications Technology satellite. Further development of passive schemes for control purposes will continue during FY 1966.

The investigation and design of suitable components for electronic systems is an important part of the control systems research program. Electrical, electronic, and mechanical components of a wide variety are included. For example, a brushless DC motor has been developed by the Sperry Company for the Goddard Space Flight Center. The DC motor, while optimum for application to satellite electrical power systems, has not been

used because brushes wear rapidly in the vacuum of space. The brushless design has shown high reliability when operated in a vacuum and motor electrical efficiencies of 60 percent, as much as twice that available in the conventional DC motor, are obtainable over a wide operating range.

In the continuing program to refine research techniques in the control systems field, significant progress was made during the past year on the problem of processing the large amounts of data gathered from ground based simulation experiments. NASA sponsored research by Bolt, Beranek & Newman has produced a technique of using a digital computer on line with the experiment to process data immediately and display significant results. This will allow the experimenter to modify his experiment in light of results, expand his comprehension of the problem, and effect significant reductions in cost. Efforts to apply these techniques to NASA flight control simulators will continue in Fiscal Year 1966.

Communications

The objective of the NASA research program in communications is to provide the technology for increasing the data transfer capability of spacecraft by providing advanced techniques and components applicable to space-to-ground communications. Advanced satellites and deep space probes require smaller, lighter, more powerful and more reliable equipment than is presently available in order to transmit information without unduly consuming spacecraft payload weight. Particularly critical are the requirements imposed on a communications system by manned or unmanned space probes to Venus, Mars and beyond.

To improve the ability to transmit information from a spacecraft, research is underway to improve the efficiency and power handling capabilities of microwave devices. Microwave tubes to be employed as amplifiers in the ten watt range will be available in calendar year 1966. Efficient tubes in the 20-100 watt range are currently under experimental investigation by the Langley Research Center. It is expected that results of this program will provide space qualified tubes with good efficiency by calendar year 1967. Studies will be undertaken in FY 1966 for even more powerful tubes, 500-1000 watts, to meet system requirements of the mid-seventies.

During FY 1965, studies were initiated on the propagation of submillimeter waves. Detailed data on propagation through the Earth's atmosphere in this portion of the spectrum is not available and must be obtained before deep space-to-ground communication systems operating at these frequencies can be designed. During FY 1966, work in this area will also include component development and system studies. It is expected that the weight and size of these components will be less than those of corresponding microwave components, due to the shorter wavelength involved, and that systems operating at these frequencies will have increased data handling capability. The bulk of the research will be under the program direction of the Electronics Research Center.

One of the most important developments in the optical technology field for application to communications is the laser. A program to determine the effects of the atmosphere on optical frequencies, such as attenuation, refraction, fading, phase distortion and pulse shape distortion, is underway. This program will contribute to the understanding of these effects and permit the development of more efficient techniques for propagation of energy through the atmosphere at optical frequencies.

Thin film and microelectronics research performed to date has achieved reliable thin film and semi-conductor integrated components and circuits of less size and weight than the conventional approach. Continuing efforts to enhance the reliability of electronic circuits is required as well as techniques to achieve a family of low power devices. Research on methods to achieve micropower devices through the use of selected components and revised circuit design was initiated in FY 1965 by Langley Research Center and will be continued in FY 1966. In addition to the low power requirements, emphasis will also be placed on small size, low weight, improved reliability and increased resistance to radiation.

Applications of microelectronic devices to subsystems of the Saturn V vehicle have been initiated at the Marshall Space Flight Center. Selected electronic subsystems will be constructed using microelectronic components, and flown piggy back on developmental flights to determine performance capabilities and study potential reliability improvements. This program will continue in FY 1966.

Tracking and Data Acquisition

The objective of research in this area is to improve accuracy in the determination of the orbital parameters of a spacecraft, and to enhance data acquisition capability of ground based tracking systems. Improved accuracies of orbital parameters are necessary for the understanding of geophysical characteristics and variations in the Earth's gravitational field.

Laboratory experiments were initiated in FY 1965 on the use of optical methods for the acquisition of data from a spacecraft. Since such a system would eliminate the need for a transmitter aboard the spacecraft, it would increase reliability of the overall system and decrease spacecraft weight. Results to date have demonstrated the feasibility of data transfer through the distortion of thin Mylar membrances coated with reflecting materials. This effort will be continued in FY 1966 to improve efficiency and investigate the use of other phenomena such as molecular structure as modulation mechanisms.

During FY 1965, research in the use of optical tracking techniques was concentrated largely in laser component development and system studies. Effective use of the very narrow beams characteristic of laser devices requires extremely accurate pointing and position control. Studies of techniques for electronically sensing and controlling the position of the laser beam have been initiated. This work will be continued in FY 1966.

Research on microwave antennas to achieve increased data acquisition capability is concentrated in the improvement of spacecraft antennas and the arraying of parabolic dish antennas to obtain a large effective aperture for ground based stations. The research on antenna arraying is being conducted by the Langley Research Center and the Goddard Space Flight Center. A prototype model of a nine foot diameter spacecraft antenna erected from a one foot diameter folded package has been developed by Goodyear Aircraft Corporation under the direction of the Jet Propulsion Laboratory. This research will be continued in FY 1966. In addition, feasibility studies are planned in FY 1966 of the use of large antennas placed in space as satellites of the Earth for tracking and data acquisition as well as for radio astronomy purposes.

Data Handling and Processing

The variety and number of on-board and ground based data processing applications are increasing rapidly at the present time. Concommitantly with such broadening of application, marked changes in equipment and techniques are occurring. They include improved means of direct, rapid ("real time") communication between computers and users; higher capacity, fast data storage units ("Memories"); and greater use of data processing systems to enhance man's capability to make complex logical decisions.

In FY 1966 work will continue on the "continuous ferrite" plate memory. Recently, large single planes, each containing many elements, have been fabricated successfully by Radio Corporation of America. The problems of reproducibility of perfect planes, reliable interconnections and the design of associated microelectronics require further investigation. Both aerospace and ground based data handling capabilities will be augmented significantly as these very high capacity, small, rapid, digital memories become generally available.

The research on systems and techniques for the processing of TV signals, both on-board the spacecraft and on the ground, has been concentrated in two primary areas recently: In the one, advanced equipment has evolved for ground testing of various electronic configurations and for switching TV electrical signals among various media; oscilloscopes, magnetic tapes, optical elements, and so on. In the other, theories have been evolved, and some equipment made and successfully tested, utilizing advanced concepts in the substantial reduction of the number of data that must be transmitted from spacecraft to ground to ensure accurate recreation of the scene at the viewing terminal. Flyable prototypes are being designed at Goddard Space Flight Center.

Research on techniques to improve the efficiency of computer utilization has led to the development and acquisition of equipment to enable simultaneous, direct, "real-time" operation of computers by a number of users. Some of these devices are now in use at Langley Research Center and Lewis Research Center both as operational equipment and as research tools to study problems

related to sharing of large computer facilities among a number of users. Problems associated with cooperative solution of difficult computing problems through direct communications between the computer and scientist will also be studied. Successful solution of these problems will reduce requirements for additional programming specialists and contribute to more efficient use of large computational complexes. These efforts will continue in FY 1966.

Reduction of the amount of data transmitted from space vehicles to earth is a continuing goal of research in data compression techniques. One approach, under investigation at Jet Propulsion Laboratory, is a system known as "Previous Element Coding" for use in video data processing. In this scheme, the picture taken by the spacecraft camera is divided into elements which are classified and coded according to their relative brightness ("gray level"). The elements are automatically scanned and compared with adjacent elements. The spacecraft then transmits the coded brightness levels and the number of contiguous elements which are of the same shade. For pictures with large features of similar tonal quality, this results in an appreciable saving of communications channel capacity compared to the original technique of transmitting the brightness of each individual picture element. Reductions of 2 to 1 in data bit transmission requirements by this technique are predicted. Research on this and other techniques will continue in FY 1966.

Instrumentation

Instrumentation and measurement are fundamental to successful achievement of basic scientific objectives and to the technological advancement of engineering sciences. A strong and vigorous program to insure timely availability of instruments and measurement techniques for planned and anticipated space and aeronautical missions is essential to the ultimate success of such missions.

For density measurements of the upper atmosphere, remote sensing devices have been developed at Langley Research Center, based on the backscatter of electromagnetic radiation. Flight tests using sounding rockets have successfully demonstrated the feasibility and substantiated analytical predictions. Further developments using stronger radiation sources and improved sensing methods will be tested in subsequent flights to extend the technique to higher altitudes. During FY 1966 research on radiative sensing methods will be extended to investigate the remote measurement of other atmosphere characteristics such as pressure, temperature, and wind velocity which could lead to more accurate data for weather forecasting.

Although vacuum pumping systems have advanced significantly through the introduction of ion pumping, the accuracy with which vacuum can be measured is still orders of magnitude below the desired level. Absolute measuring methods do not exist for very low pressure and are urgently needed. The development of mass spectrometer techniques for measuring gas compositions, by the National Research Corporation, has progressed to a point where the use of intense ion sources and more advanced electronic counting systems should make it possible to increase the sensitivity of these analytic devices by several orders of magnitude. Knowledge of the qualitative and quantitative composition of gas residues in evacuated chambers can then be used to

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analyze possible sources of system limitation and to investigate new techniques for measuring very low pressures. These developments will be pursued further in FY 1966.

Spacecraft subject to radiation from the sun outside the Earth's atmosphere require effective temperature control over broad portions of the electromagnetic spectrum, including the far infrared. The development of solid state physics has produced new sensing materials responding to radiation in these extended ranges. Measuring apparatus is being designed by the Naval Ordnance Laboratory at Corona, California, to enable accurate evaluation, in the far infrared, of the radiative characteristics of materials. Results of this work will lead to the development of more efficient coatings for spacecraft temperature control. This program will continue in FY 1966.

Recent progress in the design of microminiature components has produced new possibilities in electro-optical imaging concepts. Solid state image converters which do not require electron beam scanning seem feasible and may find application not only for TV but also in other fields such as horizon sensing and solid state spectral analyzing. Advances in photo multiplier design and associated electronic circuits, by Avco Corporation and the Goddard Space Flight Center, have produced improved devices for counting impinging low energy electrons. These devices will be used in the Direct Measurement Explorer Satellite. Further work will be done in FY 1966.

Bioelectronic instrumentation has benefited from the development of miniature devices and circuits for measuring cardiovascular and nerve signals through the use of implants in live subjects. Microelectronic techniques contribute to the design of these devices, but power requirements restrict applications in many cases. To alleviate this restriction, research is underway to reduce power consumption and develop alternate power sources. Efforts to replace battery power supplies by either body generated power or power radiated to the implanted sensing device from outside are under investigation at Ames Research Center and Republic Aviation Corporation.

Small Flight Projects

	1964	1965	1966
Radio attenuation measurements (RAM)	$450,000	$900,000	$3,400,000
Horizon definition research (SCANNER)	1,800,000	1,200,000	1,000,000
GEMINI optical communications experiment	70,000	---	---
Total	$2,320,000	$2,100,000	$4,400,000

Radio Attenuation Measurements (RAM)

The objective of this project is to investigate the interaction of electromagnetic waves with the plasma sheath which engulfs a spacecraft during reentry into the Earth's atmosphere and causes radio blackout. Ground simulation of reentry is not adequate to generate the type of plasma encountered by a reentering spacecraft; thus, a series of flights are being undertaken by the Langley Research Center to determine the plasma parameters and the effect of this plasma on electromagnetic radiation at frequencies from VHF to X band. These flights are examining aerodynamic shaping, magnetic fields, and material addition as means of eliminating the blackout phenomena during reentry. Preliminary results indicate that material addition may be the most effective and further experiments using this technique will be performed in FY 1966.

Data obtained to date have been in the 18,000 feet per second velocity regime. Further experiments will be concerned with reentry velocities of 28,000 feet per second and beyond.

Horizon Definition Research (SCANNER)

Passive horizon sensors are used in spacecraft stabilization and guidance as devices for determining the local vertical through accurate discrimination of the change in radiant energy between the edge of a planetary disk and the space background. The SCANNER project has the objective of making detailed measurements, from high altitudes, of the natural radiation gradients which define the Earth's horizon. These data are essential to the development of accurate horizon sensors. A secondary objective is to develop a flight proven technique for gathering statistical horizon data, possibly in Earth satellite spacecraft. The project is an extension of current laboratory research on horizon characteristics. Two experiments will be performed from suborbital ballistic trajectories using the Trailblazer II launch vehicle. Flight #1 is scheduled for August 1965 and Flight #2 is scheduled for October 1965. A backup set of payload equipment and instrumentation will be provided, permitting a possible third flight. The dual channel radiometer, operating in the 14-16 and 20-40 micron bands, will provide a spatial resolution of 2 km, a five-fold increase in resolution over that of radiometers used in earlier experiments. Star mapping techniques utilizing telescopes in the spacecraft will be used to correlate the pointing direction of the sensor with observed data. Langley Research Center has project direction.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1966 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 novel environments of space and aeronautical flight, (2) to define the essential requirements for sustaining and protecting man in these environments, (3) to provide the technology necessary to develop suitable life support and protective systems, and (4) to discover means of integrating man's capabilities with those of machines to obtain composite systems of superior performance.

The first and second objectives will help establish the limits of man's usefulness in space or on the moon: To what extent will his ability to explore, observe, and experiment be encumbered by the mechanical devices and restraints necessary to sustain his life? How will his judgment and powers of perception be affected by his environment? What limitations must be placed on his exposure time to extra-terrestrial environments to avoid both immediate and long term damage? The second and third objectives together will determine the costs in weight, and therefore in dollars, of sustaining human life in space: How much food, water, and artificial atmosphere must be provided? To what extent, and at what cost in weight, can these be manufactured on board the spacecraft from human waste products? How much natural radiation can man endure and how can the required shielding be provided at least weight? The fourth objective will determine the extent to which the presence of man, with his unique capabilities, can compensate for the costs of sustaining him: How can the machine systems required to take him to the moon be made simpler, more reliable, and lighter in weight by substituting human functions for certain mechanical functions? How can man's capabilities as an observer and recorder of information be augmented by machine systems?

Answers to all of these and many other related questions are being sought in this research program. The work is done by researchers in electronics, physics, engineering, psychology, biology, and nearly every field of medicine. Many of these are NASA scientists and engineers; many more are located in university and industrial laboratories and in other Government agencies.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Supporting research and technology.....	$13,200,000	$11,850,000	$13,000,000

	1964	1965	1966
Small biotechnology flight projects.....	---	$1,470,000	$1,900,000
Total.....	$13,200,000	$13,320,000	$14,900,000

Distribution of Program Amount by Installation:

Manned Spacecraft Center.....	$1,900,000	$445,000	$900,000
Marshall Space Flight Center.	235,000	220,000	300,000
Ames Research Center.....	3,820,300	4,113,000	4,680,000
Flight Research Center.....	1,342,000	2,000,000	1,500,000
Langley Research Center.....	1,834,400	3,204,000	4,450,000
Lewis Research Center.....	137,000	230,000	200,000
NASA Headquarters.....	3,931,300	3,108,000	2,870,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1964	1965	1966
Human research and performance.	$4,128,000	$3,570,000	$5,000,000
Life support and protective systems.....	5,841,000	5,400,000	4,750,000
Man systems integration.....	2,827,000	2,230,000	2,850,000
Advanced concepts.....	404,000	650,000	400,000
Total	$13,200,000	$11,850,000	$13,000,000

Human Research and Performance

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

During the past year notable progress has been made in several areas of investigation. In the field of radiobiology, research at the University of California and the Ames Research Center has produced the first meaningful information on the biological effects of the proton component in radiation likely to be encountered in space flight. These results, obtained from animal experiments in the University of California cyclotron, showed that at the lethal-dose level the biological damage mechanism of proton radiation for small animals is similar to that of gamma radiation. If these preliminary

results are confirmed with other species, the extensive knowledge of gamma radiation effects already available may become directly applicable to the problems of radiation hazards in space flight.

During the coming year, this work will be expanded to investigate the effects of lower levels of radiation over prolonged exposure periods, and to determine whether these effects are altered by variations in temperature, humidity, or vibration.

In the field of acceleration research, Ames Research Center has continued to exploit a laboratory technique which may compensate for our inability to simulate directly the effects of long term reduced gravity on physiological systems. Each of several groups of test animals is subjected to a different level of acceleration in centrifuges for a prolonged period. Resultant physiological differences among groups are then analyzed for correlation with acceleration (or gravitational) level. If significant relationships can be established between physiological phenomena and gravitational stress at acceleration levels greater than 1-G, it may be possible to predict, by extrapolation, corresponding effects at acceleration levels less than 1-G.

In the study of the effect of altered gravity environment on small animals, preliminary results, which cannot be fully interpreted at this time, indicate certain changes in growth size and body chemistry. Rats centrifuged for periods as long as one year at G loads ranging from 2.5 to 4.7 above normal, gravity did not grow to normal size. In the coming year researchers will try to verify these trends and to discover the biological mechanisms producing them.

Life Support and Protective Systems

Life support and protective systems are those systems necessary to sustain human life and prevent physical injury in a hostile environment such as that encountered by man in space. NASA's research in this field has as its objectives to develop and demonstrate new concepts which will lead to systems of lighter weight, longer duration, lower power consumption, and greater flexibility.

Spacecraft life support systems in current use are relatively heavy, short-duration, systems which require stored gases for artificial atmospheres, chemical waste treatment with waste storage, and stored food and water. Significant reductions in system weights, which may be essential to the economic feasibility of long duration manned space flight (e.g. to the planets), appear possible if the concept of "regenerative" systems can be proven. A regenerative life support system would produce the principal life sustaining requirements of man (food, water, and oxygen) by the reprocessing of his own waste and metabolic products.

Research on this principle at the NASA Langley Research Center in the past year has provided the basis for a partial regenerative system capable of supporting four men for ninety days at about one half the cost in weight

that current operational techniques would involve. The system would produce oxygen from carbon dioxide and fresh water from urine, cabin condensation, and wash water. Food would be stored. In the coming year a full-scale laboratory version of the system, produced by General Dynamics/Astronautics, will be evaluated in a series of experiments at the Langley Research Center in which four men will live and perform space mission tasks in a simulated space vehicle for as long as 100 days supplied entirely by stored food and regenerated water and oxygen.

Further refinements of the regenerative system concept may result from research at the Ames Research Center where the feasibility of bacterial reprocessing of metabolic products is under study. A successful system based upon this principle would produce food as well as oxygen and water.

Man Systems Integration

Research in man systems integration provides the technology for effective and reliable utilization of the human in man-machine systems. The program emphasizes (1) development of quantitative measures of human performance under conditions which are typical of those to be encountered during aerospace missions, (2) the development of systems design criteria which will assure maximum utilization of man as an element in the system, and (3) the evaluation of man-machine design concepts in the laboratory.

Typical of the problems considered in this program is that of determining what difficulties the low gravity environment may cause man in performing routine tasks onthe surface of the moon. It is not at all clear, for example, that he will be able to climb, run, or even walk on the moon with the same ease that he does on Earth. Muscles, conditioned to moving limbs of a given weight on Earth, may over control in the 1/6-gravity of the moon; the reduced friction between show and surface caused by reduced weight may make traction extremely difficult. To investigate problems of this kind the Langley Research Center has developed a technique with which the conditions of moving about in a 1/6-gravity environment can be fairly closely simulated. The device consists of a floor tilted up to an angle of 80.5° on which a subject walks supported in a nearly horizontal attitude by a series of cables attached to head, upper torso, hips, and legs. The cables, suspended from overhead trolleys, are parallel to the tilted floor and support most of the subject's weight so that relative to the tilted floor his apparent weight is approximately 1/6 of normal. During the coming year this technique will be used to examine numerous routine and nonroutine tasks man will be expected to perform on the moon and identify those that will require special training or equipment.

Advanced Concepts

Research on advanced concepts in any field is essential if man is to be ready to solve the next generation of problems in that field. In human factors research, many of these problems are likely to involve ways of further

integrating man into the operational systems of future aircraft and spacecraft. Several interesting possibilities have arisen in recent years, some showing enough promise to warrant serious study. The two related examples described below are representative of those that make up this advanced concepts program.

The precision control of high speed aircraft has, under certain circumstances, already taxed to the limit man's ability to coordinate sensory perception with motor response. The control tasks of complex spacecraft systems of the future could easily exceed his ability. Researchers have hypothesized that one limiting factor may be the necessity for sensory cues (visual or aural signals) to be transmitted to the brain, translated to a motor command, and re-transmitted to arms, hands, feet, etc., before a required function is executed. If a direct link could be established between, say, the eye and the system to be controlled, this limitation could be circumvented. A concept now under study for a device designed to track eye motions of astronauts as a means of obtaining data to improve the design of instrument displays has suggested a possible method for doing this.

The device would follow the motion of the eye by tracking a beam of light reflected from the cornea. The resultant motion of the light beam would be converted into electronic signals which, in turn, would be recorded as a time history of the astronaut's eye movements. If, instead of being recorded, the signals were used to command certain control operations, the astronaut could maneuver his spacecraft using eye movements alone. The eye tracking device will be developed during the coming year. If it proves feasible, a study of this future application will follow.

A second possibility, even more remote than the first at this time but still interesting as a future application of the developing technology, is the direct transmission of control signals from man to machine by nerve impulses. With such a technique, machine systems could be controlled by the brain and nervous system directly, in the same manner that movements of man's limbs are controlled. The basis for this technique would be the detection and transmission of the magnetic field components of nerve impulses. Neurological research at Georgetown University is currently defining the complete electromagnetic character of these impulses and, if successful, will provide a starting point for later studies of control applications.

Small Biotechnology Flight Projects

	1964	1965	1966
Small biotechnology flight projects.....	---	$1,470,000	$1,900,000

In many fields of aerospace technology there are problems that cannot be solved in the laboratory at all but must be solved in flight. Apparent solutions to many other problems can be found on the ground but must then be evaluated in flight before they can be accepted. This small-flight projects

program serves these essential purposes for the Human Factors Systems research program.

One problem that is becoming more acute to aerospace medical specialists as more experience is gained with man in his new space environment is that of establishing a new base of reference for many long established measures of physiological processes. The specialists are finding that clinical standards for "normal" heart rate, blood pressure, and respiration, applicable to humans under no-stress conditions, are not applicable "norms" for astronauts functioning for prolonged periods under conditions of stress. The lack of applicable standards obscures the significance of physiological data monitored during space flights and prevents accurate assessments of the astronaut's well being. A project begun this year by the Flight Research Center should ultimately supply the new physiological standards required.

The project involves the collection of physiological data on a large number of individuals who spend long periods of time under stressful conditions representative of those encountered in space flight. The subjects chosen for the experiment, by arrangement with the U. S. Air Force, were the students of the U. S. Air Force Aerospace Test Pilots School at Edwards Air Force Base, California. These are particularly appropriate subjects because their medical histories are well documented, they participate in identical training programs involving many hours of high stress flying, and they themselves represent one major source of future astronauts. Each subject will be instrumented with small self-contained sensing devices and a miniature tape recorder which will measure and record electrocardiograms, vibracardiograms, respiration, and voice data. Data will be obtained continuously during all periods of high stress activity throughout the flying careers of each subject. Since the project is to be a continuing one, successive classes at the School will participate and, in time, a statistically significant sample of data will become available from which to derive the new standards.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY NUCLEAR-ELECTRIC SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The purpose of this research is to provide the technology needed for long life nuclear-electric power systems so that advanced space missions which may benefit from use of these systems can be selected and undertaken with assurance of success.

Nuclear-electric power generating systems and electric propulsion systems have been considered as two complementary parts of this single overall program. For future manned deep space or interplanetary missions in which the high specific impulse attainable from electric propulsion would be uniquely advantageous, nuclear-electric power is the only feasible source of the megawatt power levels required for large electric thrustors. Research has also indicated potential applications of electric propulsion for attitude control and station keeping where power levels of only watts would be required, and for satellite orbit raising and unmanned space probes where power requirements would be in the kilowatt range. The lower power requirements for these applications of electric propulsion can again be provided by nuclear power generation systems, although the power systems described under Chemical and Solar Power may also be applicable.

Concepts for utilization of large nuclear reactor power systems include potential for stationary power plants on the moon and planets, and for advanced communication and other on board power requirements as well as for electric propulsion. Isotope power represents the nuclear energy contribution at low power, in the watt to kilowatt range.

The AEC is developing isotope powered systems, and it is proceeding with efforts in the range up to 250 watts. NASA is responsible for integrating such power supplies into spacecraft. Close coordination between the agencies is maintained to insure that the AEC work is directed to meet NASA's requirements and that the results will be suitable for effective integration into the spacecraft systems.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Supporting research and technology	$26,749,000	$23,192,000	$24,000,000
SNAP-8 development	15,465,000	17,000,000	---
Space electric rocket test (SERT)	3,467,000	2,300,000	3,000,000

	1964	1965	1966
Small nuclear electric propulsion and power flight projects	$282,000	---	---
Total.....	$45,963,000	$42,492,000	$27,000,000

Distribution of Program Amount by Installation:

Manned Spacecraft Center.....	$94,000	$100,000	$100,000
Marshall Space Flight Center.	263,000	290,000	400,000
Goddard Space Flight Center..	1,320,000	1,142,000	1,200,000
Jet Propulsion Laboratory....	1,882,000	2,336,000	1,600,000
Langley Research Center.....	---	400,000	---
Lewis Research Center.....	41,719,000	37,038,000	22,700,000
NASA Headquarters.....	685,000	1,186,000	1,000,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1964	1965	1966
Nuclear-electric power.....	$15,218,000	$13,225,000	$14,000,000
Electric propulsion.....	11,531,000	9,967,000	10,000,000
Total.....	$26,749,000	$23,192,000	$24,000,000

Nuclear-Electric Power

Development of nuclear space power systems for non-propulsive auxiliary power and for electric propulsion power is dependent upon the research of the Nuclear Electric Power Supporting Research and Technology Program. This program provides technology for conversion of nuclear energy to electrical energy by power conversion systems such as the liquid metal Rankine cycle, the gaseous Brayton cycle, thermionic direct conversion and magnetoplasmadynamic systems. Component research, liquid metal and liquid metal vapor properties, space-environment effects, advanced concepts and mission analysis represent typical areas of research.

The program funding is divided with approximately 85 percent for industrial and university contracts and 15 percent spent in support of the in-house work at the NASA centers.

Primary research emphasis has been on the liquid metal Rankine cycle in which a liquid metal, vaporized by nuclear heat, is used to drive a turbine which in turn drives an electric generator. The Rankine cycle shows great promise as a high power (kilowatts to megawatts) energy conversion system because the excellent heat transfer and high operating temperature characteristics of liquid metals can result in relatively small and lightweight

components even when coupled with large nuclear reactors.

Work is continuing on advanced technology aimed at high temperature and high power systems. Testing of potassium-vapor turbines was initiated at General Electric Company in FY 1965. Performance testing and design evaluation will be continued in FY 1965 and endurance testing will begin in FY 1966. In other Rankine-cycle-component research, a design of a high temperature lightweight electro-magnetic pump to be used as a liquid-metal boiler feed pump was completed in FY 1965. Procurement and testing of this pump will be initiated in FY 1966. Testing is continuing at Lewis Research Center on the performance of centrifugal pumps for liquid-metal working fluids. During FY 1965, three axial flow inducers were performance tested; these inducers would be used for pressure boost devices for the main condensate pump in a liquid-metal power conversion system. Testing of a full-scale centrifugal condensate pump suitable for a one-megawatt power system will be started in FY 1966.

In comparison with the liquid metal Rankine cycle, a gaseous Brayton-cycle power conversion system may eliminate many of the problems inherent in the use of high temperature liquid metals and can draw upon the years of turbojet experience in the development of high efficiency reliable turbines and compressors. Gas-cycle turbomachinery has been designed and fabricated, and initial testing has verified the anticipated high efficiency potential of the Brayton cycle. A broad program of Brayton cycle component development is now in progress, emphasizing efficiency and reliability. Attainment of maximum efficiencies will compensate for the inherent Brayton-cycle characteristic of large size and weight, resulting from the fact that gas is a poor heat transfer medium compared with liquid metal. Brayton cycle power conversion equipment is adaptable for use with either a nuclear heat source or a solar heat source, and Brayton cycle system technology is, therefore, jointly supported by the Nuclear-Electric Power and the Solar and Chemical Power programs.

Another phase of Nuclear-Electric Program research is concerned with an ultimate goal of eliminating the rotating turbomachinery of dynamic Rankine and Brayton cycles by development of methods of directly converting nuclear energy to electric energy. Direct conversion research emphasizes thermionic conversion in which nuclear energy is utilized to heat an electrode until, as in radio tubes, it gives off electrons to another electrode and thereby establishes an electric current. In this concept an easily ionized element such as cesium is introduced between the two electrodes in order to facilitate the flow of electrons and prevent electron accumulation at the emitting electrode. Two principal types of thermionic direct conversion methods are being investigated:

(1) the thermionic fuel element, i.e., where the nuclear fuel is integral with the thermionic converter;

(2) The out-of-core converter in which the thermionic converter assembly is separated from the reactor with a heat-transfer loop transporting reactor heat to the converter emitters.

Primary research emphasis is on high temperature materials development (fuels, insulators, etc.), because temperatures beyond our current capability are required to make thermionic systems operate at attractive performance levels. Inasmuch as system goals require at least a 10,000 hour life, it is necessary to determine the dimensional stability, nuclear fuel retention, performance and operating characteristics of candidate materials and concepts over the long periods of time and high temperatures consistent with ultimate system requirements.

During FY 1965 irradiation tests equivalent to 2500 hour fuel burnup were conducted on a large number of mixed carbide nuclear fuel specimens. Longer term tests equivalent to 10,000 hours operation will be conducted in the NASA-Plum Brook Test Reactor in FY 1966. Long time life tests of electrically heated fueled converters will continue at General Atomics and General Electric. These tests complement in-pile evaluation of fueled diodes conducted by the AEC.

A novel externally fueled thermionic element, designed by Republic Aviation, that may have considerable operational advantages, successfully completed out-of-pile testing in FY 1965. Additional long term tests will be performed on this concept.

Still another energy conversion process that might eliminate rotating turbomachinery is under investigation at the Jet Propulsion Laboratory In much the same manner that electricity is normally generated by the motion of an electric conductor through a magnetic field, a magnetoplasmadynamic system has been proposed in which a highly conductive liquid metal flows through the magnetic field. In order to attain the high fluid flow velocities required for appreciable power generation, JPL is attempting to use the high pressure of vaporized cesium to accelerate liquid lithium. Research, to extend through FY 1966, includes high temperature electrical insulation, high velocity liquid metal corrosion, and liquid vapor separation. A low temperature feasibility test has produced 12 kilowatts of power at 93 percent of the theoretical efficiency.

Electric Propulsion

The objective of Electric Propulsion research is to provide the advanced technology that will lead to the development of electric thrustor systems for spacecraft prime and ancillary propulsion. These thrustors, when developed and used in conjunction with lightweight power generation systems, offer the potential of substantial increases in payload and/or reduction in travel time generally proportional to the energy requirements of a contemplated space mission. The basis for these performance improvements lies in raising specific impulse from the few hundred seconds typical of chemical rocket systems to specific impulses up to 10,000 seconds and above with extremely low overall system weights. The only known practical method of accomplishing this is by an electric thrustor which converts electrical energy into kinetic energy of a propellant. However, because of the low thrust levels of such systems, a major requirement that must be attained for effective ap-

plication is a capability of thousands of hours of reliable operation. Also, for prime propulsion applications, attainment of high overall thrustor system efficiency is of major importance because the total power required for operation of the thrustor system, and thus the power plant weight and the mission payload capability, is dependent on thrustor system efficiency.

Electrostatic thrustor systems in which atoms (or heavy particles) are electrically charged and then accelerated by an electrostatic field, are receiving the major emphasis. Three types of electrostatic thrustors are under active investigation. Two of these, the electron bombardment and contact ion engines, differ basically in the propellant charge or ionization technique employed, whereas the third type, the colloidal engine, accelerates charged agglomerates instead of ions.

Work will continue on the ion systems to determine the performance capability, durability, clustering and scaling relations required to proceed from the present 3 to 30 Kilowatt (KW) range to the hundreds of kilowatts and into the megawatt range that will ultimately be required for interplanetary electric propulsion systems. Both clustering of 3KW ion engines and scaling in size up to 30 KW level have been demonstrated this year at the Lewis Research Center with no major difficulties indicated. Efficiencies of 60 to 80 percent have been achieved in the impulse range of 4,000 seconds to 10,000 seconds. Further scaling into the hundred kilowatt range will be continued in FY 1966.

The principal effort in the development of the electron bombardment ion thrustor has been devoted this past year to cathode life improvement. The cathode in this type of thrustor charges the propellant by bombarding it with electrons. A cesium electron bombardment thrustor, by using cesium as the propellant, employs a promising cathode design concept called the autocathode. From limited test data, it appears that this cathode may have a 10,000 hour lifetime capability. The autocathode avoids the erosion and subsequent failure of the cathode caused by ion bombardment by continuously replenishing the cathode surface with cesium. In FY 1966, both the autocathode and new coated filament cathodes will be further evaluated for durability and performance. Another promising cathode design that would eliminate cathode erosion by using a mercury pool as the cathode, is also under investigation.

Contact ion thrustor research during this past year has concentrated heavily on the ionizer. In these engines the propellant atoms are ionized (charged) by passing them through a hot porous tungsten material called an ionizer. The ionizer must be capable of remaining porous throughout the required operating lifetime, and must be capable of ionizing or charging over 99 percent of the propellant atoms. In order to produce such an efficient long life porous ionizer, porous tungsten technology must be further advanced. The Electro-Optical Systems, Space Technology Laboratory and Hughes Research Laboratory Companies are presently investigating this problem area under NASA contracts. Further efforts will continue into FY 1966.

The colloidal or heavy particle electrostatic accelerator is still in the early research phase. This concept is of interest because it offers promise of greater thrust and because the large number of electrons that can be removed from each molecule could make it possible to vary the charge-to-mass ratio and thereby optimize specific impulse in accordance with mission requirements.

In another broad category of thrustors, called electrothermal thrustors, three types are again under investigation. The resistojet and arc jet accelerate an electrically heated propellant by thermal expansion through a nozzle. The third type is an arc-jet like device whose performance depends upon electromagnetic as well as thermal effects. The principal problem areas are in achieving high performance and long life. Specific research tasks include electrode effects, materials and fabrication, propellant selection, storage and feed, understanding of basic energy transfer mechanisms, cooling techniques and configuration effects.

Space Electric Rocket Test (SERT)

	1964	1965	1966
Development and flight project..	$3,467,000	$2,300,000	$3,000,000
Scout (Launch vehicle Procurement Program).....	(500,000)	(400,000)	(---)
Total (including launch vehicles).....	($3,967,000)	($2,700,000)	($3,000,000)

The objective of the Space Electric Rocket Test (SERT) flights is to provide information on electric thrustor systems that cannot be obtained in ground based facilities and to flight qualify electric propulsion systems for mission application.

On July 20, 1964, the SERT I flight was successfully completed. The Lewis Research Center mercury electron bombardment engine operated perfectly and demonstrated conclusively that the positively-charged ion beam can be neutralized in space. The Hughes cesium contact engine failed to operate during the flight because of a high voltage breakdown. This failure did not influence the validity of the flight results, but did emphasize the need for the continued research in high voltage power conditioning included in the Nuclear Electric Systems budget. Flight test data correlated well with ground based vacuum facility results thus also confirming the validity of established ground based laboratory practice. The success of this first electric rocket engine flight obviated the need for further SERT I type tests.

The objective of the current phase of the SERT program is the evaluation and development of advanced thrustors for satellite attitude control and station keeping, which appear to be the first potential applications for electric thrustors. Analysis has indicated that for attitude control of long lived satellites, particularly those requiring very accurate attitude stabilization, the low propellant consumption inherently characteristic of electric propulsion would result in considerable weight savings as compared with the chemical propellants presently in use. Vacuum tank test of several experimental thrustor systems are being conducted and compared with chemical systems in order to permit selection of the more promising systems for further development. These systems will be further tested to determine thrust and impulse reproducibility, reliability and operating life. It is anticipated that this laboratory evaluation program will be completed in FY 1966 and that a flight verification (SERT III) of the most promising systems will be initiated.

The SERT II flight test program has been postponed indefinitely, pending definition of a primary electric propulsion application that would require flight validation of a specific electric propulsion system.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — NUCLEAR ROCKETS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

This program provides the research, design and engineering data, test hardware, and general technology required to assure that nuclear rocket systems can be developed at the power levels, operating times, restart conditions, and specific impulse values that will be required in advanced space exploration missions. In these systems, a nuclear reactor heats hydrogen to high temperature. The high temperature hydrogen gas is then accelerated through a jet nozzle producing thrust at high specific impulse.

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

Nuclear rocket propulsion provides significant performance advantages for potential missions beyond Apollo such as lunar base logistics operations, very heavy deep space instrumented probes, and manned exploration of the planets. Manned planetary expeditions is considered among the major applications for nuclear rockets; a nuclear rocket propelled Mars spacecraft could be one third to one fifth the weight of a chemically propelled spacecraft.

A major part of the nuclear rockets program is the research and engineering on the nuclear reactor itself since this entire field is relatively new. In addition, emphasis is placed on the solution of problems associated with non-reactor components whose operating requirements tax the available technology and on the study of the fundamental heat transfer, fluid flow, structural design, and nuclear phenomena involved. An essential part of this program is investigation of experimental ground test engine systems required to develop a full understanding of the interaction of components in nuclear rocket engines and of the system performance characteristics. These data form a basis for eventual flight system development and provide information required by mission planners to incorporate nuclear rocket capabilities in advanced missions.

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

761-133 O-65-21

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Supporting research and technology	$21,261,000	$21,731,000	$22,000,000
KIWI	1,700,000	---	---
NERVA	48,820,000	34,261,000	35,000,000
RIFT	6,645,000	---	---
Nuclear Rocket Development Station	750,000	739,000	1,000,000
Total	$79,176,000	$56,731,000	$58,000,000

Distribution of Program Amount by Installation:

Marshall Space Flight Center	$7,153,000	$1,280,000	$1,300,000
Jet Propulsion Laboratory	338,000	6,000	---
Lewis Research Center	11,330,000	10,450,000	7,800,000
Space Nuclear Propulsion Office	60,355,000	44,995,000	48,900,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1964	1965	1966
Rocket reactor research	$13,615,000	$13,356,000	$15,850,000
Nuclear rocket engine component research	6,935,000	6,775,000	4,550,000
Safety	470,000	500,000	500,000
Vehicle technology	241,000	1,100,000	1,100,000
Total	$21,261,000	$21,731,000	$22,000,000

The supporting research and technology program satisfies four basic needs: (1) supporting data for current projects (NERVA); (2) technology for the development of future generations of nuclear rocket engines and vehicles; (3) feasibility investigation of advanced nuclear propulsion concepts, and, (4) studies of special flight safety considerations of nuclear rockets.

Rocket Reactor Research

The major effort in rocket reactor research is supported by the AEC. It consists principally of the advanced graphite reactor technology program (PHOEBUS) at the Los Alamos Scientific Laboratory aimed at increased reactor performance. Also included is preliminary work on fast tungsten based reactors and more advanced concepts. The NASA program in this area is applied research directed primarily towards the development and procurement of the jet nozzles and hydrogen turbopump systems required for ground testing with the PHOEBUS reactors, and the evaluation of new and advanced nuclear rocket propulsion concepts which offer potential performance advantages for future space missions.

The KIWI reactor development project (first graphite based rocket reactor) was completed by the Los Alamos Scientific Laboratory with the successful ground testing of the KIWI-B4E reactor in August and September of 1964. The technology developed in that project serves as the basis for the NERVA reactor (NRX-A), the first power test of which was successfully run in September, 1964. The KIWI reactor technology is also the basis for the advanced graphite (PHOEBUS) reactor program.

The PHOEBUS program will provide improved, high power reactors (to 5,000 megawatts nominal power) for nuclear rockets. Mission studies indicate that clustered engines of this power level would offer the propulsion capability for manned planetary expeditions.

The first test of the PHOEBUS project will be conducted by Los Alamos at the Nuclear Rocket Development Station in calendar year 1965 using KIWI sized reactors. These tests will be run using jet nozzles developed for the KIWI program and modified KIWI hydrogen turbopumps. However, pumps and jet nozzles of increased capability will be required for later tests of the large diameter, high power PHOEBUS reactor which will begin during calendar year 1967. Development of these nozzles and pumps is being initiated in FY 1965 and will be continued in FY 1966. Included as part of the Rocket Reactor Research budget is the cost of hydrogen necessary for two KIWI sized PHOEBUS reactor experiments in FY 1966, and for development tests of the pumps and nozzles mentioned above.

The NASA program in FY 1966 will also continue evaluation of the performance potential of thermal, water moderated reactors using tungsten uranium dioxide fuel. Preliminary results of this work have indicated that extremely long operating times may be attainable with this fuel. High temperature environmental testing of fuel elements in flowing hydrogen, beginning in the second half of FY 1965, will be an important step in determining performance limitations of this fuel material and will be continued in FY 1966. It is anticipated that the work to be carried out in FY 1966 and 1967 will allow an assessment of the real performance potential of tungsten-uranium-dioxide reactors in the Nuclear Rockets Program.

Research will continue in FY 1966 on advanced nuclear propulsion concepts such as the gas core nuclear rocket propulsion concept in which the uranium fissionable material is in a gaseous rather than a solid form. The objective of this work is primarily to establish feasibility and performance potential. Emphasis will be on evaluation of promising approaches for containment of the gaseous nuclear fuel within the reactor. The approach will include experimental studies of the basic fluid mechanics of two concepts using simulated propellants and nuclear fuel. Supporting research on fundamental problems, such as the effects of temperature on fluid mechanics and on heat transfer characteristics, is being sponsored in several universities (Catholic University, Princeton, Case Institute, and Georgia Institute of Technology), industrial laboratories, and NASA Centers.

Nuclear Rocket Engine Component and System Research

The objective of this program is to establish the technology required for the development of non-reactor components for nuclear rocket engines. This component research, when combined with Rocket Reactor Research, will establish the characteristics of future generations of nuclear rocket engines and, in addition, will establish design techniques and operating data on components and engine systems. Lewis Research Center conducts the in-house work in this area and directs other work accomplished under industry or university contracts.

Research is conducted on: hydrogen flow components and systems, turbomachinery for pumping hydrogen, instrumentation and controls, engine system analysis, radiation effects, jet nozzles, bearings and seals, and hydrogen properties.

Turbomachinery research is directed at the unique problems posed by application to a nuclear rocket engine. The program at the NASA Plum Brook Station in FY 1966 will emphasize radiation effects testing of various bearing materials and bearing configurations, study of nuclear rocket dynamics through system cold flow experimentation (B-1 and B-3 Test Stands), and turbopump performance evaluation in real feed system configurations in the B-3 test stand. The results of this experimental research should provide important data to the NERVA project and a better understanding of the behavior of nuclear rocket engine systems under all conditions of operation.

The experimental engine dynamics studies carried out in the B-1 test stand will map engine performance characteristics and system control using NERVA engine hardware. Although no fission power is generated, this test stand permits full investigation under vacuum conditions of the important low flow regime encountered during startup of nuclear engines. The first nuclear rocket engine systems dynamics tests were run in this facility near the end of FY 1964 and will continue through FY 1966. Information from these experiments will be used to design a safe operating map for the NERVA engine control system as well as to provide insight into the design of improved engine systems and their startup control.

The B-3 turbopump evaluation stand at the Plum Brook Station will be ready for use near the end of FY 1965. Its first use will be to evaluate turbopump operation, including the effect on pump performance of simulated heat addition to the inlet such as would be expected from the radiation in a nuclear rocket engine.

Reliable control is essential for nuclear rocket engine systems, and it requires that both instrumentation and control components function predictably in the anticipated environment under a wide range of operating conditions. The extent to which radiation and low temperatures will affect the reliability of these components will be explored experimentally at the Plum Brook Station in FY 1966. A reactor cryogenic test loop will become available during the year for testing of nuclear rocket diagnostic and control instrumentation

with realistic reactor radiation and temperature simulation. The most promising conventional instruments are being modified to withstand this environment and will be tested in this reactor test loop. A similar loop will be used during FY 1966 to make simulated tests of NERVA control actuators. The results of these tests will help determine what modifications must be made, if any, to assure reliable operation prior to incorporation into engine tests.

The radiation effects program, conducted as part of engine component research, is exploring the behavior of candidate materials for use in nuclear rocket propulsion systems in a combined radiation and cryogenic environment. A typical problem is that of bearings, seals, and lubricants required to operate in this environment as components of high speed rotating machinery. It has been found that, under those conditions, bearing lifetimes are significantly reduced, lubricants break down, and conventional seal material loses its resiliency and sealing properties. Testing equipment has been designed and constructed for use in the Plum Brook Station reactor which will simulate operational loads on these components while they are subjected to the appropriate radiation and temperature environment. This equipment is being installed in the reactor during FY 1965 and will be producing research information by FY 1966. Results of this research support all phases of the nuclear rockets program, and are essential to the development of current systems as well as to the planning of advanced systems. A considerable amount of data will be obtained on materials which will be used in the design of the high powered PHOEBUS reactors.

The operating conditions of the KIWI reactor and the NERVA engine have required extension of our present nozzle technology. The high powered PHOEBUS reactor will require even further improvements in nozzle design, materials, and fabrication procedures. The first test facility capable of heating hydrogen to temperatures and flow rates adequate to allow testing of reduced scale nozzle concepts in a hot hydrogen stream will begin operation at the Lewis Research Center in FY 1965. This facility will allow experimental confirmation of analytical results for a number of new nozzle materials and designs. Refractory metal nozzle and coated nozzle concepts will be studied during FY 1966 to determine their adequacy for advanced higher power, higher temperature nuclear rocket engines.

Fluid property research is conducted to provide basic data on propellants and fluids used in nuclear rockets and in high energy chemical rocket engines. For several years, NASA has supported research and engineering development work related to the use of liquid hydrogen at the National Bureau of Standards' Cryogenic Engineering Laboratory. While this program is funded by the nuclear rockets program, the research and consultation services are available to all users of liquid hydrogen. The work includes the compilation of basic thermodynamic data and the evaluation of commercially available sensors for use with liquid hydrogen. These activities will be continued in FY 1966.

Safety

Flight safety analyses of nuclear rockets are being performed under the direction of Marshall Space Flight Center. These studies include the analysis

of the orbital lifetime of nuclear rocket parts and the radiation levels of such parts after reentry. Theoretical reentry analysis will be expanded to include ground testing and flight test planning. These studies when combined with nuclear analyses performed by the AEC will be used to solve unique operational problems associated with the safety of nuclear rocket flight operations. Hydrogen safety research at the U. S. Bureau of Mines (Pittsburgh) will also continue. This work includes determination of detonation and combustion limits, activation energies, kinetic and thermal energy yields, and other data on gaseous and liquid hydrogen.

Vehicle Technology

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

Studies of modular vehicle concepts, in which each module includes a nuclear rocket engine and propellant tank, were initiated in FY 1965 and will be extended in FY 1966. Conceptual designs of modular systems of a single size that can be clustered to provide a wide range of power availability will continue to be investigated in FY 1966. Studies are also underway of specific technological problems that will need engineering solutions before nuclear rocket powered spaceflights of long duration will become feasible. Typical of these is the problem of long term storage in space of liquid hydrogen. Although the large tanks of liquid hydrogen associated with nuclear propulsion have a reduced surface-to-volume ratio, compared with chemical propulsion system propellants, minimization of hydrogen losses through evaporation may be an important factor in determining mission capabilities. Analyses are being performed to determine optimum methods of storing liquid hydrogen, taking into account the requirements for micrometeorite protection and the effects of solar radiation, high energy charged particle radiation, and nuclear radiation. Preliminary evaluations of super insulation, slush hydrogen, and on board refrigeration systems will be expanded in FY 1966.

NERVA

	1964	1965	1966
Engine systems development.....	$4,555,000	$4,340,500	$5,000,000
Component and subsystem development.....	17,330,000	12,300,000	11,000,000
Ground test and operations support.....	23,090,000	13,570,500	14,500,000
Propellants.....	3,845,000	4,050,000	4,500,000
Total.....	$48,820,000	$34,261,000	$35,000,000

The objective of the NERVA (Nuclear Engine for Rocket Vehicle Application) project is to develop nuclear rocket engine systems that can be tested in ground based facilities to provide a complete understanding of the performance and operation of these systems and their major components under

operating conditions corresponding to those of future space missions. The work is being carried out at a nominal power level of 1,000 megawatts, corresponding to a thrust of approximately 50,000 pounds with a specific impulse over 700 seconds. The emphasis is on developing for this purpose components and systems which can lead directly to the later development of operational flight engine systems with a high assurance of success. This project is conducted principally under a joint AEC-NASA contract by the Aerojet-General Corporation and Westinghouse Electric Corporation.

Specific technical objectives for the NERVA project are to provide the reactor, engine systems, facilities and component technologies. The reactor development phase of the NERVA project includes full-scale reactor testing to determine the suitability of the reactor design for continuing technology advancement, for use in obtaining an understanding of engine system operation, and for ultimate application in a flight engine system. During FY 1965, the KIWI and NERVA (NRX) reactors successfully operated near rated power. Tests planned for FY 1966 will further evaluate the operating limits of such reactors including definition of the trade-offs among power, operating temperature, operating duration, and restart characteristics.

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

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

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

Significant accomplishments to date in the KIWI and NERVA projects include: reactor startup and stable operation using liquid hydrogen as a coolant; demonstration of a satisfactory reactor design that avoids the flow induced vibration previously encountered; successful reactor operation for more than ten minutes at design conditions; restarting a reactor and achieving design power after a prior run at design power; and, automatic startup of a reactor from sub-critical conditions, thereby demonstrating the capability to start the nuclear rocket automatically as would be required in a flight system. Other progress includes improvement in fuel-element quality, and advances in nozzle and turbopump technology.

Engine System Development

The objective of this phase of the NERVA project is to perform the engineering, fabrication and testing of engine systems prior to their integration into complete experimental engines. The program includes cold flow tests in a non-nuclear engine simulator as well as hot flow tests conducted with operating reactors. Characteristics that will be evaluated in the cold flow simulator tests include the initial portion of engine startup with liquid hydrogen, flow stability, flow leakage, system pressure losses, and control response times. Cold flow testing of NERVA systems will be completed during FY 1966 and the test hardware will be modified for use in checkout of the Engine Test Stand in Nevada. Also during FY 1966 hot flow engine system tests will begin in one of the Reactor Test cells. Initial tests in this series will utilize an upward-firing NERVA reactor, not configured as a flight engine, but will incorporate a hot bleed port nozzle and a hydrogen turbopump system driven by reactor heated gases drawn from the bleed port.

Component and Subsystem Development

Development of components and subsystems includes those required for the experimental engine systems and some required for the experimental reactor. Principal objectives are the development of the hydrogen turbopump system, thrust chamber assembly, and engine controls. A radiation resistant turbine power control valve required to control turbopump speed will be developed. Nozzles, pressure vessels, turbopumps, controls, and associated components will be fabricated to support the engine test program. Acceptance and reliability testing of these components will be conducted.

Ground Test and Operations Support

This phase of the project provides remote handling equipment, checkout and test equipment, and maintenance equipment for all test operations. It also provides instrumentation for diagnostic and control purposes, for reliability and quality assurance testing, and for operational safety monitoring. During FY 1966, the equipment in the engine test and maintenance facilities will be checked out and used to support engine systems testing. Additional equipment and engine diagnostic instrumentation will also be provided. Technical guidance on ground test safety will be continued and safety reports and procedures will be issued.

Propellants

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

Nuclear Rocket Development Station Operations

	1964	1965	1966
General site support.....	$500,000	$589,000	$870,000
Capital equipment.....	250,000	150,000	130,000
Total.....	$750,000	$739,000	$1,000,000

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

Technical support, maintenance, housekeeping services, and management functions must be provided at this site. These funds provide for NASA's share of the general site operations, the major part of which is now funded by the AEC.

General Site Support

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

Capital Equipment

Capital equipment funds are used for the procurement of shop equipment, warehousing equipment, and other pieces of major equipment required for general support of Station activities.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — CHEMICAL PROPULSION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

Propulsion represents one of the greatest limitations in capability for exploring space. Until now space vehicles have been propelled by chemical rockets. New propulsion devices such as a thermo-nuclear rocket and various electrical rockets will eventually advance space capabilities significantly. When operational these new types of propulsion devices will take their own places in a broadened propulsion spectrum, but will not replace all chemical systems. It is certain that most space flight advances made in the foreseeable future will depend upon chemical rocket propulsion. The research and experimental engine programs in chemical propulsion are devoted to increasing capabilities to conduct space explorations.

The technological base for new engine developments is provided by a planned process of scientific investigation progressing from concept evaluation through the gathering of engineering data to the demonstration of experimental systems. To facilitate this progression the chemical propulsion programs in both liquid and solid propellant motors have each been divided into two principal efforts: one in research and advanced technology, and one in experimental engineering.

Research and advanced technology covers basic studies and experiments related to launch vehicle and spacecraft propulsion such as measurements of chemical and physical properties of propellants, ignition and combustion phenomena, classical and non-equilibrium thermodynamic processes, the examination of new materials, and the processes of fluid mechanics, gas dynamics, heat transfer, and solid mechanics. Analyses are made of the functions a piece of propulsion equipment must perform, the performance levels that can be met and, in the broad cycle efficiency sense, the conditions under which it might best perform. New methods and design concepts are assessed. Future requirements and new problem areas are identified for further work.

The purpose of the experimental engineering program is to bridge the technological gap between propulsion research technology and the initiation of mission oriented propulsion system developments. The work involves the design, fabrication and test of model propulsion systems and of subcomponents to demonstrate their engineering practicality to meet the anticipated requirements of launch vehicle, upper stage and spacecraft engines. From such experimental system demonstrations will evolve advanced propulsion hardware designs with clearly defined maximum operating conditions and engineering limitations. A direct result of this work will be a set of preliminary engineering specifications with design criteria and fabrication process

specifications. A byproduct is a realistic assessment of possible development costs and schedules, facilities and equipment requirements, etc. The results will facilitate initiation of engine development with minimum expenditures of funds and time during the development phase.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Supporting research and technology	$21,970,000	$24,762,000	$30,000,000
M-1 engine project	24,000,000	24,000,000	---
Large solid motor project	*	15,000,000	---
Small chemical propulsion flight projects	30,000	30,000	---
Total	$46,000,000	$63,792,000	$30,000,000

Distribution of Program Amount by Installation:

Manned Spacecraft Center	---	---	$500,000
Marshall Space Flight Center	$3,542,000	$3,592,000	5,100,000
Goddard Space Flight Center	375,000	550,000	800,000
Jet Propulsion Laboratory	4,296,000	4,183,000	4,700,000
Langley Research Center	1,144,000	1,480,000	1,980,000
Lewis Research Center	31,205,000	45,227,000	8,095,000
NASA Headquarters	3,194,000	8,760,000	8,825,000
Western Operations Office	2,244,000	---	---

* Previously U.S. Air Force program

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1964	1965	1966
Liquid rocket research and advanced technology	$10,527,000	$11,500,000	$13,000,000
Liquid rocket experimental engineering	6,640,000	6,075,000	8,500,000
Solid rocket research and advanced technology	2,760,000	4,995,000	5,000,000
Solid rocket experimental engineering	2,043,000	2,192,000	3,500,000
Total	$21,970,000	$24,762,000	$30,000,000

Liquid Rocket Research and Advanced Technology

The liquid rocket research and advanced technology program explores and extends the engineering science of propulsion for launch vehicles, upper stages, and spacecraft.

Part of the program continues to examine propulsion concepts for future launch vehicles. Two approaches to advanced launch vehicle engines have been pursued. The multi-chamber concept uses to the greater extent the technology developed in building engine equipment presently in use. The continuous chamber concept represents a greater departure from present technology but may offer a greater performance gain. The feasibility of methods for expanding combustion gases through either a forced deflection or a plug nozzle has been proven. Good engineering data required for detailed design analysis have been accumulated. Hot firing of critical components has been undertaken. Work related to cooling and pumping for engines at pressures significantly higher than current practice is in progress.

Efforts to improve spacecraft performance by use of advanced space-storable propellant combinations have been expanded. Investigations on the oxygen-difluoride/diborane combination have continued and a new project evaluating oxygen-difluoride/monomethyl hydrazine has been started.

Design guides for pressurized gas storage and propellant feed systems have been published. Work on positive expulsion technology and advanced chamber construction for use with high temperature combustion gases is being continued.

An example of propellant technology that has reached the application stage is the development of a suitable catalyst for hydrazine. This monopropellant has higher performance than hydrogen peroxide, which was used in the Mercury capsule and in other applications. This development has been cited as one of four major contributions to space technology last year

Combustion instability continues to plague engine development programs. NASA in-house and contractual work has been increased to provide more basic data and a better understanding of the phenomenon. At the same time techniques are being explored for avoiding the instability through engine design changes.

Better rocket test instrumentation is necessary and efforts along these lines are progressing. The feasibility of instrumentation to diagnose symptoms of trouble in operating engines and to initiate automatic corrective action has been demonstrated. Tests on operational engines are forthcoming.

Work on advanced construction materials for liquid rocket engines, thermal and corrosion protective coatings, static and dynamic seals, valves, the flow of gases in nozzles, and the dynamic behavior of propellants in the feed system of engines will also receive additional emphasis in the coming year.

Liquid Rocket Experimental Engineering

This program is focused presently on auxiliary and space propulsion. The project includes an experimental auxiliary engine program to support an area which has been troublesome in the mission development programs; the continuation of a program to evolve an advanced design for Earth storable space propulsion systems; and extension of the high performance propellant research intended to provide smaller, higher energy upper stages.

The program for experimentally investigating improved space propulsion systems has been focused in three principal areas; advanced Earth storable propellant systems; high energy deep cryogenic propellant systems, and high energy space storable propellant systems.

The advanced Earth storable propellant system program, using the same class of propellants as the Apollo, Gemini and Surveyor spacecraft systems, will continue evaluation of design concepts that will significantly extend operating life, minimize complexity of components, and improve component capability. Some of these propulsion concepts have been applied to the Mariner spacecraft design.

The high energy deep cryogenic propellant systems programs are focused on the use of liquid hydrogen with liquid fluorine in upper stages. Spacecraft propulsion systems of this type can be operative up to several weeks in the space environment. The current program has demonstrated the operation of a modified oxygen-hydrogen engine with fluorine as the oxidizer. Revised designs and operating techniques that will facilitate the realization of the full performance potential of the fluorine-hydrogen combination in flight type hardware will be demonstrated. Unique hydrogen tank pressurization concepts that could minimize total system weight will also be demonstrated.

The high energy space storable propellant systems program will establish the foundation for the future space propulsion systems that must remain operative in a space environment for months or possibly years. The predominant requirement is that the propellant physical properties permit long term storage in space. One of the attractive propellant combinations is oxygen-difluoride with light petroleum gases such as methane. This propellant combination is now being examined to establish component designs that will facilitate its future use.

An auxiliary propulsion system program encompassing monopropellant systems and bi-propellant systems that employ both the Earth storable and high energy propellants will be continued. Design criteria for small rockets that have application as reentry control, spacecraft attitude control, station keeping systems, etc., will be developed. The application of new materials, coatings and fabrication processes to enhance operating life and reliability is being emphasized to improve life and design margins.

The other principal activities in the program are: (1) interface analyses to evaluate the impact of integrating propulsion systems into launch vehicle stages and spacecraft; (2) definition and classification of the hazards associated with the use of advanced propellant combinations and development of appropriate safety procedures and criteria; and (3) the development of specifications for the design, manufacture, and test of advanced propulsion systems.

Solid Rocket Research and Advanced Technology

This program provides an engineering base not only for the relatively simple solid propellant motors, with are used extensively for applications requiring extreme reliability rather than extreme performance, but also for hybrid motors, which may improve performance to be competitive with liquid bi-propellant systems for some applications. Solid propellant motor problems that apply to motors of launch vehicle size include the need for nondestructive testing techniques for inspection and qualification of loaded motors, better understanding of ignition processes, a better understanding of instability and thrust vector control systems, better methods for combustion termination, and improved processing techniques.

Candidate methods for nondestructive testing include the use of infrared detector scanning, attenuation of x-rays using scintillation detectors, low frequency ultrasonic probes, and microwave probes. During FY 1966, these and other techniques will be evaluated for use in the inspection of loaded motors prior to flight.

There is currently a need to achieve more accurate command cutoff of solid motor thrust and the capability for a limited number of stop-restart cycles. Recent advances in steady state and transient combustion theory have shed considerable light on the basic mechanisms that control combustion termination phenomena. This work may lead to the development of solid motors capable of interrupted combustion and a limited number of stop-restart cycles.

NASA's first work in hybrid propellant technology was begun in FY 1965 and will continue in the coming year. The hybrid propellant rocket usually uses a solid fuel and a liquid oxidizer although the reverse combination also falls into this classification. Potential advantages of hybrid propellants are improved space storability and the possibility of variable thrust in high propellant performance systems.

Research on steady and non-steady state combustion, propellant and metal ignition, rheological properties, degradation mechanisms, thermochemistry, high energy oxidizers and chemical binders are also conducted in this part of the program. These studies are fundamental to the development of both launch vehicle and spacecraft propulsion systems and contribute to the knowledge of the basic disciplinary sciences.

Solid propellant rockets pose a special problem because of the widespread use of metallic additives in propellant formulations which yield condensed liquid and solid particles in the exhaust. The transmission of radio beam signals of certain frequencies through the exhaust products during flight must be examined. The interaction of the rocket exhaust products with the signals in producing distortion, attentuation, or spurious noise will be studied.

The thrust behavior of solid motors is very dependent on the predictability of the burning rate of the propellant. If the burning rate is lower than predicted, the pressure, thrust, and impulse will be lower than required. Vacuum storage of spacecraft engines causes some propellant degradation that increases burning rates. Radiation degrades the oxidizer, which reduces burning rates. These competing degradation effects decrease the accuracy of the predicted performance. The burning rate deviations produced by vacuum storage will be evaluated under this program and methods to assure predictable performance will be developed.

Solid Rocket Experimental Engineering

The experimental-engineering program was established principally to support the technology related to solid-motor developments. The program includes work in the areas of spacecraft-auxiliary and controllable motors. Increased emphasis will be applied to these areas in subsequent fiscal years.

Presently the majority of the solid propellant experimental motor research is directed toward development of important subsystems applicable to first stage or booster functions. One subsystem is a malfunction detection system for warning of an impending failure in the rocket motors in time to permit escape of the astronauts. The program was started in calendar year 1963. During 1964, a major advance was made in detecting overheating which can lead to burn-through of motor cases. This new concept gives a clear signal when the hot gases in the rocket motor erode the insulation to expose a special conductive liner material. During the current year, the concept is being evaluated in small scale motors and during the coming year the engineering details for introducing it into very large motors will be defined.

A system for producing steering forces in large solid rocket motors by the injection of liquid into the exit cone is under engineering investigation. During FY 1966, an engineering analysis will be made to determine which components of existing smaller motors are directly applicable to the larger motor and which need to be further developed. A detailed engineering design will be made of a complete system which can be joined to the nozzle of the rocket motor. In the coming fiscal years, the design will be transformed into hardware and a complete thrust vector control system will be tested by static firing.

Nondestructive inspection equipment and standards for testing motor cases, propellant charge and nozzles are being experimentally evaluated under this program. An instrument for finding cracks in metal cases with ultrasonic waves has been devised, and standards for interpreting its signal established. In the current year, the method is being improved and partially mechanized, so that the very large surface of a high thrust motor may be inspected efficiently. Instruments for inspecting the critical part of the propellant charge, based upon microwave technology, will be brought from the laboratory state to breadboard development status during the coming year. In future years, this instrumentation will be extended to fully mechanized systems and the specifications and standards for its use will be established.

Current vehicle systems use many solid propellant motors to provide retro-propulsion during stage separation and to cause positive acceleration during the initiation of liquid engine operation. Other solid propellant motors are used in upper stages of small launch vehicles such as Scout and Delta. This program will undertake the definition of standard classes of solid propellant motor systems. Small attitude control rockets such as the Cap Pistol units or the Subliming Solid will be advanced to the status of demonstrated readiness for application.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1966 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — SOLAR AND CHEMICAL POWER PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Solar and Chemical Power program provides research and technology necessary for the development of new and improved methods of solar and chemical power generation for space applications. The program includes research on all elements of complete systems: (a) the energy collection equipment such as a solar collector or a reactant supply; (b) the energy conversion devices including solar cells, thermionic generators, turbomachinery, fuel cells, etc.; (c) the energy storage unit such as a battery or thermal energy storage device; and (d) power conditioning and power management equipment.

All active space vehicles require electrical power for the operation of equipment, such as instruments, communication and data processing. For manned space missions, electric power is also required for additional functions such as life support and guidance for controlled reentry. Thus, this multidisciplined program makes a direct and significant contribution to a broad cross section of the national space program.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Supporting research and technology	$14,000,000	$13,745,000	$14,200,000
Total	$14,000,000	$13,745,000	$14,200,000

Distribution of Program Amount by Installation:

Marshall Space Flight Center	$1,429,000	$2,000,000	$1,000,000
Goddard Space Flight Center	2,170,000	2,425,000	3,075,000
Jet Propulsion Laboratory	2,381,000	3,121,000	3,106,000
Ames Research Center	105,000	191,000	170,000
Langley Research Center	710,000	690,000	740,000
Lewis Research Center	6,403,000	4,309,000	5,000,000
NASA Headquarters	630,000	1,009,000	1,109,000
Western Operations Office	172,000	---	---

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BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1964	1965	1966
Solar power generation.....	$9,343,000	$8,324,000	$8,919,000
Chemical power generation.....	4,657,000	5,421,000	5,281,000
Total.....	$14,000,000	$13,745,000	$14,200,000

Solar Power Generation

Solar cells are the most common energy conversion devices currently used for long duration space missions. However, such devices are limited by a susceptibility to damage by ionizing radiation (i.e., Van Allen electrons and protons, and solar protons), are relatively expensive, have an upper temperature limit of approximately 150°C and require on board electrical energy storage for vehicle operation out of direct sunlight. During the past three years, laboratory research at the Goddard Space Flight Center, the Lewis Research Center and the RCA and Space Technology Laboratories has determined the effect of reversing the polarity of solar cells and the effects of additives, impurities, resistivity, and junction depth on the solar cell's resistance to radiation damage. The research has shown that a controlled impurity, reversed polarity cell will have superior resistance to damage by radiation. As a result, significant progress has been made in increasing the resistance of the solar cell to Van Allen electrons, such that it has been increased by a factor of 30.

Until recently it was not possible to predict accurately the space performance of solar cells from measurements made at the Earth's surface. The solar cell responds differently to energy of different wave lengths and, as a consequence, the conversion efficiency is a function of the spectral distribution of the light source. Because of atmospheric absorption and scattering, sunlight at the Earth's surface has a different energy distribution than sunlight in space. Work under this program to launch solar cells to high altitude atop balloons, measure their performance above the atmosphere and recover the cells for use as standards, has made it possible to estimate solar cell space performance more accurately ($\pm$ 5%) from terrestrial measurements. These measurements of solar cell performance will be continued in order to obtain standards of new cells as they are developed.

In another application of solar energy, the direct conversion of heat energy to electricity by the thermionic process continues to show great promise. The concept of the thermionic converter is similar to the concept described under the Nuclear-Electric Program except that the electrode that emits electrons is heated by solar energy rather than by nuclear heat. During the past year, a 150-watt solar thermionic generator fabricated by the Thermal Electric Engineering Corp. was operated by the Jet Propulsion Laboratory at an efficiency of 10.5 per cent. This generator provides the highest conversion

efficiency that has been experimentally demonstrated to date. In conjunction with a suitable solar collector, a thermionic generator of this type, when developed, would weigh less and be less sensitive to radiation damage than a solar cell system. Thermionic investigations extend from basic research on materials and metallurgy, through surface physics and chemistry, to engineering development of thermionic devices and solar collectors.

For orbital missions with cyclic periods of sunlight and darkness, it is advantageous to keep the thermionic generator operating during the dark period, by supplying heat energy stored during sunlight. The heat stored by melting a substance with a high heat of fusion can be used to provide heat to the thermionic elements when the system is no longer in sunlight. The use of thermal energy storage eliminates the need for on board, high cycle, life batteries and reduces the thermal stresses on the thermionic generator by keeping it hot all the time. Although significant progress has been made toward identifying suitable thermal energy storage materials and compatible container materials, thermionic converters have not yet been operated with integral thermal energy storage. Such work is receiving emphasis during the present year and will be continued during FY 1966.

The design and performance characteristics of power systems based on thermoelectric conversion of solar energy are also under investigation. Thermoelectric conversion is an extension of thermocouple technology and is based on the principle that a current will flow between the junctions of two contacting materials when the junctions are at different temperatures. An example of research in this area is a flat panel fabricated by Melpar for the Goddard Space Flight Center with thermoelectric couples between the hot and cold surfaces. One surface is treated with a coating to produce a high equilibrium temperature when exposed to sunlight; the other surface is given a high emissivity coating and operates at a much lower temperature. This technique shows promise for space missions in toward the sun where temperatures would exceed the temperature limitations of solar cells.

In research on dynamic systems, the work on the mercury Rankine cycle (Sunflower) solar dynamic system was successfully concluded with the completion of a 4300 hour life test. While many problems remain to be solved, the design and performance characteristics of the system have been determined and the basic feasibility has been demonstrated. It is believed that sufficient technology now exists to permit system development if a mission requirement arises.

An alternate approach to dynamic power conversion is based on a gas (Brayton) cycle, which is expected to have higher efficiency, fewer problems with respect to zero-g start-up and operation, and longer life as a result of reduced corrosion problems. During the past year, a compressor and turbine were successfully operated on oil bearings at efficiencies slightly above those selected for the reference system. Work is in progress on both axial and radial turbomachinery that will operate on hot gas bearings. Successful completion of tests on these units will be a significant milestone in this work because the turbomachinery is usually the most critical set of components in a dynamic system.

Chemical Power Generation

Much progress has been made as a result of research on problems relating to batteries and fuel cells. Data have become available from Gulton Industries and General Electric Company to permit the design of electronic charge control circuitry which senses the signal from an added third electrode to regulate battery recharging rate. The third electrode also relieves the problem of oxygen gas pressure by dissociating excess oxygen so that it can recombine with the electrolyte. Life testing of third electrode cells is starting, and design ideas for multiple cell batteries are being evaluated. In another battery improvement program, modified cellulose and new plastic materials have been developed as battery separators to improve the life of silver-cadmium cells; preliminary indications point to at least a doubling of life as a result of impeding the migration of silver from cathode to anode.

A breadboard model of a capillary, low temperature H_2-O_2 fuel cell with passive moisture removal has completed more than 450 hours of operation on a Gemini type power profile at the Allis-Chalmers Company and is still on test. The basic design of this fuel cell has potential advantages over present spacecraft fuel cell designs because it combines features of high efficiency, zero-g start and restart capability, relatively low temperature and low parasitic power. Program objectives include the testing of flight type auxiliary hardware, construction of engineering evaluation models in the 2 kilowatt size for testing at the contractor's and NASA laboratories, and modification of the system to permit collection of water. Auxiliary equipment to permit further lowering of the start-up temperature is being developed on this contract, while very high performance electrodes suitable for use in this system are being developed by American Cyanamid Company. These electrodes may increase efficiency by 10 per cent, which would save chemical and tankage weight as well as reduce the size of the radiator.

In addition to the work on power generation, an important element of the program is the supporting research on conditioning, distribution, and control of electrical power throughout the spacecraft. High voltage arcs, short circuits, power surges, switching problems, etc. continue to plague space power systems, and insufficient emphasis on these problems is indicated. Continuing progress is being made in improving the reliability, efficiency, and other important performance characteristics of power converters, inverters, regulators, and protective devices.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — AERONAUTICS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The primary role of the Aeronautics program is to conduct scientific research to improve the efficiency, utility, and safety of aircraft. Continuing over-all objectives are:

1. To exercise unbiased technical leadership in the generation of advanced aircraft concepts.

2. To seek technological advances which will permit the development of improved aircraft.

3. To provide research information to industry for the design of new aircraft.

The scope of the NASA aeronautical research program includes work in aerodynamics, structures, materials, and air breathing propulsion, the operational and safety aspects associated with these disciplines and, to some extent, electronics and human factors. It is the evolutionary research in these technical disciplines that provides the fundamental knowledge needed to understand the complex problems involved in the design and construction of advanced aircraft. Understanding of these problems, in turn, aids in the determination of the likely direction of technological advances in the future. For example, the XV-5A fan-in-wing aircraft, the tilt-wing XC-142A V/STOL transport, and the variable sweep concept for the F-111 originated several years ago as promising concepts as a result of NASA research. In the years between the first indication of the value of the concept and the first flights of the vehicles, NASA aided in the detailed formulation of the concepts and in substantiating the over-all capabilities of practical vehicles based on these concepts.

In addition, NASA has conducted extensive wind tunnel tests, simulator programs, and flight investigations using appropriate testbed aircraft to substantiate predicted performance and operational characteristics of these vehicles and to aid in the solution of problems of a developmental nature. In this regard, advanced technical development in support of military and civil aircraft procurement continues to be conducted. This work is performed in cooperation with Government-sponsored contractors at the request of the cognizant Government agencies.

Research in Aeronautics in FY 1966 will include studies directed toward improvement of subsonic aircraft, for example, studies of means of improving the efficiency of transport aircraft by delaying the drag rise due to

compressibility effects at transonic speeds; 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; studies of manned hypersonic air breathing vehicles which have the potential of providing hypersonic reconnaissance capabilities, hypersonic transport, and recoverable hypersonic air breathing space boosters; and studies directed toward improving flight safety and increasing operational flexibility of present and proposed aircraft, especially under adverse or "all weather" flight conditions.

Experimental research and development aircraft and engineering test pilot proficiency aircraft considered necessary to carry out and support the aeronautics effort are included under this program.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Supporting research and technology	$9,195,000	$7,887,000	$8,300,000
X-15A research aircraft	900,000	1,425,000	900,000
Supersonic transport	8,821,000	19,953,000	16,000,000
V/STOL aircraft	2,879,000	2,850,000	2,000,000
Hypersonic ramjet experiment	---	3,125,000	5,000,000
XB-70/SST flight research project	---	---	10,000,000
Total	$21,795,000	$35,240,000	$42,200,000

Distribution of Program Amount by Installation:

Ames Research Center	$4,446,000	$4,967,000	$4,150,000
Flight Research Center	4,630,000	4,037,000	12,420,000
Langley Research Center	9,481,000	8,864,000	11,105,000
Lewis Research Center	1,852,000	13,566,000	12,700,000
NASA Headquarters	1,386,000	3,806,000	1,325,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1964	1965	1966
Aircraft aerodynamics	$1,404,000	$1,348,000	$2,000,000
Aircraft loads and structures	1,619,000	2,111,000	1,950,000
Air breathing propulsion	1,078,000	2,225,000	1,725,000
Aircraft operating problems	5,094,000	2,203,000	2,625,000
Total	$9,195,000	$7,887,000	$8,300,000

Aircraft Aerodynamics

The objective of research in aircraft aerodynamics is to improve the flight efficiency, performance, stability, and control effectiveness of aircraft. These characteristics strongly influence range, payload, economic feasibility, utility flexibility and safety of operation. In the case of very high speed flight, aerodynamic heating is an additional limitation and is a target for research.

In the subsonic speed range, particular attention will be devoted during FY 1966 to aerodynamic means for increasing the capabilities of current and future commercial and military subsonic jet transports. Theoretical and wind tunnel investigations will be made to develop new ways to increase cruising speeds which will directly increase flight efficiency, and to reduce landing speeds, to permit operation into airports which have shorter runways. Research will continue on the low speed stability and control of advanced supersonic cruise and V/STOL concepts and an investigation will be initiated of the take-off and landing characteristics of proposed configurations for hypersonic cruise vehicles.

In the supersonic speed range, refinement of theoretical analysis methods and computer programs for predicting the aerodynamic parameters used for the design of supersonic aircraft will be pursued. Basic studies of boundary layer flows on such aircraft will receive special attention with a view toward reducing the drag, flow separation, and interference effects. A better understanding of scale effects in predicting full size performance from small scale wind tunnel experimental data will be sought.

Analytical and experimental research at hypersonic speeds in FY 1966 will be directed toward refinement of the aerodynamic configurations suitable for manned sustained hypersonic cruise aircraft, reusable air breathing propelled, first-stage boosters and earth-to-orbit vehicles. Various combinations of wings, bodies, and air inlets will be evaluated in terms of lift drag ratio, stability, control, and heating rates at hypersonic Mach numbers where the high specific impulse of air breathing propulsion systems appears attractive. Concurrently, feasibility studies will be performed to help define critical basic research problems. An essential task in this regard in FY 1966 will be an assessment in depth of the need for a prototype or test bed flight vehicle in hypersonic cruise aircraft development.

The R&D funds requested will be used largely at the Ames, Flight, and Langley Research Centers for contract studies supplementing the in-house program described, and for necessary models and instrumentation used in their aerodynamic facilities. The requested funds also include those required for wind tunnel and related investigations in direct support of the Department of Defense in the development of advanced weapons systems, such as the F-111 and XV-5A aircraft which will continue in FY 1966.

Loads and Structures

Research on aircraft loads and structures is directed at improving the state of knowledge required for the design of efficient and reliable airframes for advanced flight vehicles. This includes research relating to the definition of the structural environment in terms of critical loads and temperatures, the structural characteristics and structural response under this environment, and the development and validation of better methods for design analyses for future vehicles.

Studies have been under way in FY 1965 to define more adequately the relative importance of such sources of aircraft loads as maneuvers, atmospheric turbulence, landing, etc. For example, past research on atmospheric turbulence has led to a generally adequate definition of gust loads for current subsonic aircraft, but for the safe design of future supersonic aircraft more precise information is needed on the characteristics of the atmosphere, particularly for gusts of long wave length.

As aircraft speeds increase structural fatigue is demanding increased attention. For the first time flight speeds are being reached for which the effects of temperature must be considered in the design of aircraft on a routine basis. In FY 1966 the fatigue characteristics of materials with cracks as well as simple structural specimens embodying various types of construction, such as welding and riveting, will be experimentally studied as points of stress concentrations and, therefore, sources of potential failure due to fatigue under high temperature, cyclic load conditions.

Experimental and analytical studies are being conducted of structural concepts having possible application to hypersonic cruise aircraft. Such structures must be light weight, must withstand high temperatures on the exterior, and must provide insulation to protect the low temperature, internally stored, liquid hydrogen fuel. To withstand the high temperatures associated with hypersonic flight, refractory materials are used which are inherently dense and, therefore, must be employed in an extremely efficient manner. Structural test specimens of two promising concepts are being constructed with completion expected during FY 1965. These structures will be intensively tested under realistic heating and loading conditions during FY 1966 to evaluate their strength and reliability under these conditions.

Air Breathing Propulsion

The major part of this program in FY 1966 will be directed toward the solution of problems associated with the Supersonic Transport and the Hypersonic Ramjet Experiment Projects.

The remainder of the research in this field during FY 1966 will be devoted to obtaining a better understanding of the basic phenomena involved in the complex systems required for future aeronautical vehicles. Inlets and nozzles for hypersonic propulsion systems will be investigated both theoretically and experimentally, particularly at off-design conditions.

Supersonic mixing of hydrogen and air and the resulting combustion of these gases will be studied. A program to investigate power plant structures and thermal protection systems associated with high speed propulsion systems will receive increased emphasis. Facilities capable of true simulation of all flight conditions of interest at hypersonic speeds and promising methods for modifying existing tunnels to obtain a more realistic testing environment will be investigated.

Specific military programs will continue to receive wind tunnel test support. Research leading to the improvement of existing systems will be conducted on a continuing basis. Typical of these is the testing, documentation, and possible modification of the F-111 induction and exhaust systems, and the study of the X-22A full scale ducted fan.

Aircraft Operating Problems

Research in this area is directed toward improving flight safety and increasing operational flexibility of present and proposed aircraft. Objectives of the research program are to obtain improvements in aircraft flying and handling qualities, in operational techniques during landing and take-off under all weather conditions, and in instrumentation directly related to the safety of flight. Research programs in the fields of sonic boom and aircraft noise are also included.

Experimental and analytical studies started in FY 1965 to obtain fundamental information on the generation and propagation of noise from the exhaust jets and the compressor and fan components of turbojet and turbofan engines will be continued during FY 1966. Theoretical studies show that small noise reductions in each engine component can be made, giving a total significant noise reduction. Experimental engine component studies will be made in the Noise Research Facility at the Langley Research Center to establish the effects of number of blades, blade loading, stage separation, etc., on noise generation. Inlet noise suppression and noise propagation in ducts will also be studied.

The techniques and procedures required to insure safe operation of commercial transport aircraft in turbulence or rough air are being investigated. The research program covers four major activities: analysis wind tunnel tests, flight tests, and piloted simulator tests. The program is designed to isolate the causes of aircraft upsets due to turbulence and establish adequate corrective measures. Flight and laboratory research will be carried out on airborne techniques, laser and others, for detecting regions of clear air turbulence.

The handling qualities of high performance executive type aircraft are being determined in a flight test program initiated during FY 1965. The primary objective of this research program is to formulate handling qualities

criteria which, if met, will ensure safe instrument flight operations with general aviation aircraft. Both single and twin engine aircraft representative of current production models by different manufacturers will be used in the flight program during FY 1966.

X-15 Research Aircraft

	1964	1965	1966
Aerodynamics.....	$130,000	$78,000	$40,000
Loads and structures.....	---	13,000	120,000
Operating problems.....	770,000	1,334,000	740,000
Total.....	$900,000	$1,425,000	$900,000

The X-15 Research Program, conducted in cooperation with the Department of Defense, is designed to provide data on manned, maneuverable hypersonic flight. During the course of the flight test program, through calendar year 1964, more than 100 flights have been made, including more than 75 flights at speeds greater than a Mach number of 4. Of these flights, more than 50 have been made at Mach numbers above 5.

The X-15 remains the only research facility in the world capable of studying hypersonic flight in its true environment. Experimental results to date have given basic insight into problems of aerodynamics, structures, propulsion and operations during hypersonic flight. Of major importance, the X-15 results have given, and will continue to give, confidence and guidance to research in ground based hypersonic research facilities enabling exploration in depth of many hypersonic flight problems. These ground facility studies in turn are defining probable hypersonic flight vehicles whose projected operation defines new research problems to be explored by the X-15.

In the light of the progress made in this research program, advantage was taken of a repair program initiated in X-15-2, as a consequence of damage sustained in an emergency landing, to increase its performance. As rebuilt, the aircraft can provide longer sustained flight at Mach 6.0 and can attain Mach 8.0 for short periods. The longer sustained flight expands greatly the capability in hot structures research, enabling near equilibrium temperature to be reached. The higher speed enables studies of hypersonic propulsion systems in a true environment which cannot yet be accomplished by any ground research techniques; this makes possible the Hypersonic Ramjet Experiment described elsewhere.

Past success in using the jettisonable lower ventral fin for structural research at hypersonic speeds lead to rebuilding the damaged wing tip of X-15-2 as a removable section, thus providing a valuable extension of the earlier techniques, particularly insofar as enabling structural research on lifting surfaces. Results from these 42" span instrumented wing tips will be unique as basic design data for sustained hypersonic flight vehicles.

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 has been undertaken and information on stellar ultraviolet radiation has been gathered using the X-15 as a carrier vehicle.

In five and one-half years of flight test, from 1959 to December 1964, the X-15 program not only has contributed to the increased confidence of designers of current high performance aircraft, such as the YF-12A and SR-71, but has focused attention on the areas which required additional research, noted above. The future program will be directed toward these areas, to provide information for the next logical step in our flight research program--manned, maneuverable hypersonic cruise flight.

Supersonic Transport

	1964	1965	1966
Aerodynamics	$1,202,000	$1,514,000	$1,000,000
Loads and structures	308,000	157,000	700,000
Propulsion	1,605,000	16,177,000	13,300,000
Operating problems	5,706,000	2,105,000	1,000,000
Total	$8,821,000	$19,953,000	$16,000,000

The NASA role in the national supersonic transport program is to provide the necessary research information on a timely basis. During the past year the NASA program on supersonic transport configurations, for example, has provided information that shows how substantial improvements in payload or range can be achieved over what was considered possible a year ago. The contractor proposals to the Federal Aviation Agency in Phase II A of its program reflect this work. Research in FY 1966 will be an extension of work in progress last year in the areas of propulsion, aerodynamic efficiency, dynamic stability, noise, sonic boom, and structural materials.

Funding for FY 1966, for example, includes a substantial sum to continue the accelerated research program initiated in FY 1965 to provide the technology required for the design of advanced power plants needed for future operational supersonic transports and for follow-on vehicles. The work in this field in FY 1966 will be directed toward improving engine component performance, raising the present limit on turbine inlet temperatures as a means of improving engine thrust for a given engine size, and reducing engine weight. The program will concentrate on the key components of gas turbine engines, namely compressors, combustors, turbines, materials, bearings, seals, lubricants, and fuels. This research, in time, will lead to more reliable and more efficient turbine engines having thrust-to-weight ratios considerably above those of today's engines.

In the supersonic transport operating problems area, the joint NASA-FAA simulation program on supersonic transport air traffic control will be continued to determine the effects of the air traffic control systems on design requirements for the aircraft and on operating techniques. The studies will utilize various proposed supersonic transport designs in a real time, air traffic control, environment and investigate priority requirements, new air traffic control concepts, aircraft instrumentation, and possible navigation improvements. The critical nature of the fuel reserve problem and the potentially severe air traffic control requirements are expected to place heavy demands on the navigation system for precise control of flight path over the ground.

Emphasis during FY 1966 will also be placed on simulator studies to aid in defining the aerodynamic characteristics of the supersonic transport necessary to meet the handling quality requirements at high speeds. Piloted simulator studies using fixed based and three degrees of freedom motion simulators will be made to define the handling qualities of representative supersonic transport designs at or near cruising speed under normal and emergency flight conditions.

In addition to the ground based simulator studies of supersonic transport operating problems, flight tests will be conducted utilizing specially modified large jet transports to validate and extend simulation results, to define the height control requirements in flare and landing, and to evaluate the requirements for airworthiness test procedures. These programs will utilize aircraft already owned by the NASA or obtained on short term lease for this purpose.

V/STOL Aircraft

	1964	1965	1966
Aerodynamics	$509,000	$990,000	$900,000
Loads and structures	560,000	180,000	100,000
Propulsion	950,000	750,000	200,000
Operating problems	860,000	930,000	800,000
Total	$2,879,000	$2,850,000	$2,000,000

In FY 1966, greater attention will be given to the potential use of V/STOL aircraft for civil applications. Initial studies of the small STOL aircraft will be extended to additional wind tunnel investigations and to a flight evaluation of a configuration considered suitable for short-haul commercial operation into relatively small unprepared areas. Special emphasis will be given to providing research and operational information required in the development of more sophisticated, larger, V/STOL short-haul aircraft required to satisfy increasing transportation needs in congested, highly developed areas.

Continued high priority will be given to wind tunnel and, if feasible, flight investigations of high speed jet V/STOL types. For example, special study will be made of interference and engine hot-gas reingestion problems, of particular concern for jet V/STOL designs.

Investigation of the problems of all weather landing for V/STOL aircraft will be continued. Included will be a study using a high performance NASA research helicopter as a test bed to investigate basic pilot display requirements during simulated zero-zero landings. An increase in the understanding of the factors affecting minimum and optimum requirements for V/STOL handling qualities and control, under Visual Flight Rules as well as Instrument Flight Rules conditions, will also be obtained through continuing flight studies with two NASA variable-stability V/STOL aircraft and with the six-degree-of-freedom simulator; related information will be obtained through NASA participation in specific military flight evaluations (e.g. on the XC-142A tilt-wing, X-19A tilt-prop, and XV-5A lift-fan vehicles).

Flight and wind tunnel studies to investigate the characteristics of several new rotor concepts having the potential of greatly improved performance for future helicopters will continue; particular attention will be given to the non-articulated rotor, studied in flight with the NASA XH-51N helicopter.

Hypersonic Ramjet Experiment

	1964	1965	1966
Propulsion.....	---	$3,125,000	$5,000,000
Total.....	---	$3,125,000	$5,000,000

Hypersonic lifting vehicles have been studied extensively for application to various earth-to-earth and earth-to-orbit missions. Propulsion for such vehicles could be by rocket, air breathing engine, or a combination of the two. The much better specific impulse (fuel economy) of the air breathing engine, however, is an especially attractive feature of this type of engine. There is a substantial background of fundamental knowledge applicable to air breathing hypersonic propulsion concepts which indicates a theoretical capability for positive, useful thrust to orbital speeds. The next essential step is an experimental demonstration of the feasibility of these concepts for application to practical future propulsion systems.

Until very recently the design and construction of such an experimental propulsion system would not have been possible, because of the existence of large gaps in essential knowledge, such as the necessary understanding of supersonic combustion. Now, however, these gaps have been narrowed sufficiently to make such an undertaking feasible and to permit selective increases in emphasis on the study of component interaction and over-all engine functioning. Also, until very recently, the testing of such a propulsion system was impossible due to the technical inability to build an adequate

ground based research facility and the lack of a flight vehicle capable of sustained flight at the required speeds. The X-15-2, rebuilt after its landing accident, now incorporates modifications enabling sustained flight at speeds in excess of Mach number 6; although these modifications were made specifically for other research purposes, this increased performance gives NASA the opportunity of using the X-15-2 as a carrier vehicle for hypersonic propulsion systems and of accomplishing the required research on these systems. The development and flight test of such a research engine would both advance the technology and provide key information on which to base the planning of future research. This project seeks the eventual construction of a ramjet research engine for this purpose.

The ramjet principle has been selected for this study because it promises to be particularly applicable to future hypersonic transport aircraft and recoverable launch vehicles. Great advantages in reduced weight and improved flight efficiency are foreseen with the ramjet at hypersonic speeds.

The research engine to be developed will use hydrogen as a fuel and will employ supersonic as well as subsonic burning. It will provide information on ramjets operating in a speed range from Mach 3 upward into the hypersonic range.

During the first phase of the program, which was started in FY 1965 and will continue during FY 1966, selected contractors are performing independent studies to establish technical concepts and accomplish preliminary designs. These studies consist primarily of analyses such as engine cycle, inlet aerodynamics, and combustor and nozzle aerodynamics, with some small substantiating laboratory research. Based on his own selected concept, each contractor will propose complete plans, including schedules and resource requirements, for the construction and ground test of the selected propulsion system.

Evaluation of these proposals will provide the basis for a decision on the continuation of the project through construction and for selection of a single contractor.

XB-70/SST Flight Research Project

	1964	1965	1966
Aerodynamics.....	---	---	$3,000,000
Loads and structures.....	---	---	3,000,000
Operating problems.....	---	---	4,000,000
Total.....	---	---	$10,000,000

Proposed designs for supersonic transports and hypersonic vehicles center around vehicles whose operating environment (speed, altitude, duration) are significantly far removed from that which can be reproduced in a ground based facility and whose sheer size introduces wholly new problems. The B-70 as a research tool provides NASA with the ability to validate its basic aerodynamic theories and experimental results obtained in ground facilities to account for, as examples, effects of scale on skin friction and heat transfer, effects of elastic structure deformation on aerodynamics and the effect of heat soak on this deformation, effects of vehicle inertia combined with low damping (high altitude) on vehicle control requirements, effects of vehicle size on sonic boom generation and propagation, inlet control system requirements and many others. All of these problems have been and will continue to be the subject of major research efforts in analysis and ground based facilities; the B-70 program will provide vital guidance and assessment of the soundness of these programs, assuring that major programs such as the Supersonic Transport are proceeding on a sound basis.

The program is being conducted in two distinct phases. The first phase, which began in FY 1963, consisted of installation of instrumentation in the two XB-70A aircraft during manufacture and the acquisition of certain data of interest to NASA during the USAF flight test program. The second phase, beginning in FY 1966, will consist of continuation and expansion of the initial program and the initiation of research which could not be accommodated during the USAF flight program. In the first phase of this program, NASA funded only the costs associated with the instrumentation and data acquisition required for those measurements of interest to NASA. The major cost, that of operating the aircraft, was funded by the United States Air Force. In the second phase, NASA will fund all of the costs associated with the NASA XB-70/SST Flight Research Program, including the cost of operating one XB-70 aircraft.

This program is obtaining results which are useful to the Federal Aviation Agency in its role as manager of the United States Supersonic Transport program; the FAA is kept informed on the progress of the program on a continuing basis.

OFFICE OF TRACKING AND DATA ACQUISITION

TRACKING AND DATA ACQUISITION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The purpose of this Program is to provide tracking and data acquisition support to meet the requirements of flight projects. Responsive and efficient support is provided for all projects, and as mutually agreed, for projects of the Department of Defense, other government agencies, universities, private corporations, international organizations, and other countries engaged in mutual research endeavors.

Support is provided for manned and unmanned flights; for spacecraft, launch vehicles, sounding rockets, and research aircraft; for Earth orbital and sub-orbital missions, lunar and planetary missions, and space probes.

Types of support provided include tracking to determine the position and trajectory of vehicles in space, acquisition of data from scientific experiments and on the engineering performance of spacecraft and launch vehicle systems, transmission of commands from ground stations to spacecraft, communication of information between various ground facilities and mission control centers, and processing of the data acquired from the space vehicles. Without this vital support, the space research program would not be possible.

Tracking and data acquisition support is provided by a world-wide network of ground stations (including Department of Defense stations and instrumented ships), and by general purpose facilities in launch areas. These stations are linked together by a network of ground communications which provides the real-time information necessary for critical decisions. Facilities also are provided to process into meaningful form the large amounts of data which are collected from flight projects.

Tracking and data acquisition facilities are used for support of current missions. At the same time, they must be augmented to meet the requirements of missions in the immediate future. Concurrently, planning must proceed for projects which are even further in the future, and equipment and techniques must be developed to assure a sound technological approach for the support of the more complex mission requirements of the next generation.

The Research and Development Appropriation provides funds for: (a) the operation and maintenance of the world-wide facilities, (b) the procurement of equipment and modifications to adapt the facilities for new and changing flight project requirements, and (c) the development of advanced tracking and data acquisition equipment and techniques. The subsequent sections detail plans and related funding requirements to continue the Tracking and Data

Acquisition Program in each of these areas during FY 1966.

In FY 1965, the Congress authorized $261,900,000 for the Tracking and Data Acquisition Program. As indicated below, NASA has allocated an amount of $274,750,000 for the program. This is due to the transfer of general tracking and data acquisition functions and related funding authority from certain flight projects in the Space Science and Applications Program to the Tracking and Data Acquisition Program.

Responsibility for the Space Flight Operations Facility (SFOF) at the Jet Propulsion Laboratory, Pasadena, California, was transferred from the Lunar and Planetary Program. This facility provides for the performance of control functions associated with missions supported by the Deep Space Network.

Also transferred to the Tracking and Data Acquisition Program was responsibility for providing ground station support for the Applications Technology Satellite. Funds for this function were formerly included in the Applications Technology Satellites Program.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Operations	$78,131,000	$102,819,000	$129,300,000
Equipment	103,326,000	157,248,000	102,400,000
Supporting research and technology	12,890,000	14,683,000	14,500,000
Total	$194,347,000	$274,750,000	$246,200,000

Distribution of Program Amount by Installation:

Marshall Space Flight Center	$2,900,000	$2,000,000	$1,500,000
Goddard Space Flight Center	132,817,000	195,201,000	173,400,000
Jet Propulsion Laboratory	42,070,000	59,799,000	53,000,000
Wallops Station	5,100,000	5,450,000	5,900,000
Flight Research Center	1,800,000	2,200,000	2,000,000
Langley Research Center	2,450,000	2,200,000	2,500,000
NASA Headquarters	7,210,000	7,900,000	7,900,000

BASIS OF FUNDING REQUIREMENTS:

Operations

	1964	1965	1966
Manned space flight network	$18,795,000	$24,258,000	$35,100,000
Satellite network	23,464,000	27,340,000	32,300,000
Deep Space Network	11,833,000	19,394,000	23,700,000
Other instrumentation	5,736,000	6,100,000	6,300,000
Communications	12,026,000	18,627,000	23,800,000
Data processing	6,277,000	7,100,000	8,100,000
Total	$78,131,000	$102,819,000	$129,300,000

761-133 O-65-25

Manned Space Flight Network

1964	1965	1966
$18,795,000	$24,258,000	$35,100,000

The Manned Space Flight Network was ready to support the Gemini Program on schedule. The various required equipments were installed at the stations and checked out. Training of operating staffs was completed and mission simulations were conducted to verify operating procedures and to integrate the stations into a cohesive network. Operational readiness is assured for support of the remaining Gemini launches.

The Manned Space Flight Network for support of Gemini consists of seven primary land stations at Cape Kennedy, Florida; Bermuda Islands; Grand Canary Islands; Carnarvon, Australia; Hawaii; Guaymas, Mexico; and Corpus Christi, Texas; two ships, the Rose Knot Victory and the Coastal Sentry Quebec; and six secondary land stations at Kano, Nigeria; Madagascar; Canton Island; Point Arguello, California; White Sands, New Mexico; and Eglin Air Force Base, Florida. The Madagascar station replaces the station which was removed from Zanzibar as a result of the revolution.

Bringing this world-wide network of stations to the required state of readiness for the Gemini Program has had, and is continuing to have, a direct impact upon operations costs due to required training and increases in manning levels, logistics, and general network support. This impact is causing increases in FY 1965, and additional increases will be required in FY 1966 to maintain the capability of the network during a full year of Gemini operations.

Concurrently with providing full operational support for the Gemini Program, the Manned Space Flight Network is being augmented for the Apollo Program. Not only are significant equipment additions being made to existing stations, but several new land stations, ships and instrumented aircraft are being added to the network.

The Manned Space Flight Network, as presently planned for Apollo, will consist of ten 30-foot antenna stations, three 85-foot antenna stations, two portable stations with 16-foot antennas, five ships, and instrumented aircraft. Of these facilities, the three 85-foot antenna stations, three of the 30-foot antenna stations, all of the ships, and the aircraft will be new. All of the facilities, including the Gemini stations which will be modified for Apollo, are scheduled to become operational during the period from mid-1966 through mid-1967. Staffing and training of operating personnel must begin nine to twelve months in advance of the operational dates to assure that the stations will be ready to support Apollo missions. In order to meet this schedule, significant operations costs for the Apollo Program must occur in FY 1966.

Satellite Network

1964	1965	1966
$23,464,000	$27,340,000	$32,300,000

The Satellite Network includes 13 electronic stations of the Space Tracking and Data Acquisition Network (STADAN) managed by the Goddard Space Flight Center, and 12 optical camera tracking stations operated by the Smithsonian Astrophysical Observatory (SAO). The STADAN stations provide a tracking and data acquisition ground system which tracks, determines the status of each satellite, commands the satellite functions and acquires stored or real-time data from the satellite. The optical camera tracking stations provide specialized services in precision orbital determination on certain satellites of scientific interest as well as backup support to STADAN during launch and early orbit tracking of all satellites.

Operation of the STADAN stations is accomplished through various arrangements. Stations located in the United States and certain foreign countries are operated under commercial contracts. Others are operated by foreign government agencies in close liaison with NASA.

During the first-half of FY 1965, the Satellite Network supported 31 satellites using the electronic stations of STADAN and 30 satellites using the optical capability of the SAO network. In the case of STADAN, this comprised 21 NASA projects, 3 international cooperative, 1 industrial, and 6 projects in direct support of the Department of Defense (DoD). In the case of the optical network of SAO, this included 14 satellites in support of the SAO's scientific investigations, 14 satellites to provide operational data to NASA, and 2 satellites in response to DoD requests for support on specific satellites.

In FY 1966, the Satellite Network will continue to support many of the same satellites which will still be in orbit. Several of these satellites have exceeded their estimated lifetimes and the originally planned levels of support. Adding to the workload will be launchings of new satellites, including initial flights of the Orbiting Astronomical Observatory and the Biosatellite projects, and additional flights of the Orbiting Geophysical Observatory project.

Increased operational costs in FY 1966 are caused by the need to fund the operations costs of the 85-foot antenna facility at Canberra, the second such facility at Rosman, North Carolina, and the Range and Range Rate facilities at Alaska. All of these facilities are scheduled to become operational at the beginning of FY 1966. A small, but general increase of staffing is required to meet increased workloads in support of scientific satellites at most stations.

Deep Space Network

1964	1965	1966
$11,833,000	$19,394,000	$23,700,000

The Deep Space Network provides tracking and data acquisition support for unmanned lunar and planetary space flights. The network provides tracking data which are used to determine, and make mid-course corrections to, spacecraft trajectories; acquires engineering telemetry data concerning performance of the spacecraft systems so that appropriate corrections can be made to spacecraft operations as required, transmits commands to spacecraft to execute the above functions; and records the scientific data which are acquired from the spacecraft.

Associated with the Deep Space Network is the Space Flight Operations Facility (SFOF) which is located at the Jet Propulsion Laboratory, Pasadena, California. The SFOF receives information transmitted via ground communications from stations of the Deep Space Network, processes the data, and displays the resulting information so that mission directors and associated project personnel can analyze real-time mission performance, make critical decisions concerning functions which must be executed by the spacecraft, and transmit instructions to the stations for commands that must be sent to the spacecraft.

The SFOF was established and initially operated by the Office of Space Science and Applications as part of the Lunar and Planetary Program. In recognition of the close relationship between the Deep Space Network and the SFOF during actual operations, management responsibility for the SFOF, on December 1, 1964, was transferred to the Office of Tracking and Data Acquisition. Coincident with this change, all FY 1965 funds, which were allocated for mission-independent functions of the SFOF in the Lunar and Planetary Program, were moved to the Tracking and Data Acquisition Program. The FY 1966 request includes funds for continuation of these functions.

During FY 1966, the initial flights of the Lunar Orbiter, Surveyor, and Pioneer projects will occur. To meet the flight schedule, the Deep Space Network and the SFOF for the first time must be prepared to support more than one mission at the same time.

At the beginning of FY 1966, the Deep Space Network will consist of two operational 85-foot antenna facilities at each of the three longitudinal locations required to maintain continuous surveillance of a lunar or planetary mission. Two of these facilities (Madrid, Spain and Canberra, Australia) will become fully operational in the second half of FY 1965 so that full operational costs will occur for the first time in FY 1966. Additional operations funds will be required in FY 1966 to provide early operations personnel for the prototype 210-foot antenna facility nearing completion at Goldstone, California, and the spacecraft checkout facility which will become operational at Cape Kennedy.

Other Instrumentation

1964	1965	1966
$5,736,000	$6,100,000	$6,300,000

This category provides funds for operating instrumentation systems used for support of sounding rocket programs conducted by Fort Churchill, Canada, and Wallops Station, Virginia, and for the flight research programs at the Flight Research Center, California. General purpose tracking, telemetry, data acquisition, recording, timing, plotting, and communications systems are used as well as special purpose optical and sound ranging (acoustical) equipment for specific missions.

The instrumentation required for support of missions launched from Wallops Station is operated by NASA contractors and by other government agencies such as the Weather Bureau, the National Bureau of Standards, the U. S. Navy, the U. S. Air Force, and the Military Sea Transportation Service. Increased operations costs for FY 1966 are due primarily to the ship operation costs of a ship borne sounding rocket expedition to the broad ocean areas of the southern hemisphere. At Fort Churchill, the instrumentation is contractor operated and is funded jointly by the Department of Defense and NASA as a cooperative effort. Activity will continue in FY 1966 at about the same rate as in the current year.

The Flight Research Center's Aerodynamic Test Range includes three sites located in the Nevada and Eastern California area. The site at Edwards Air Force Base is staffed by NASA personnel augmented by some contractor personnel. The Ely and Beatty sites in Nevada are contractor operated. Among the programs to be supported in FY 1966 will be the Lunar Lander Research Vehicle, the Lifting Reentry Research Vehicle, and the space sciences experiment program using the X-15.

Communications

1964	1965	1966
$12.026.000	$18,627,000	$23,800,000

The tracking networks are dependent upon reliable and rapid communications between the stations and their control centers. Acquisition, command, and control data must be sent from the centers to the stations and the stations must relay tracking and telemetry data back to the control centers for rapid analysis of spacecraft performance so that corrective measures can be taken quickly if problems develop aboard the spacecraft.

As spacecraft have become larger and have been designed to perform many additional and alternative functions, realtime monitoring and control of the spacecraft by the mission control centers has become an increasingly important requirement. To support these advanced missions, the requirements for volume and reliability of communications between mission control centers and network stations have been steadily increasing.

In order to minimize the actual growth of communications lines and facilities, the operational communications system has been consolidated into a single system to support all networks. Communications switching centers have been established at major locations such as Goddard Space Flight Center; London; and Australia to provide the maximum capability of sharing circuits. Maximum use is being made of alternate voice and data sharing of circuits. However, still further increases in communications capacity are required.

In the case of Apollo, additional voice-grade circuits and nine teletype circuits to overseas tracking locations will be needed over the present Gemini requirements. The major portion of these circuits will be installed during FY 1966. To further support Apollo, two wide-band data links must be installed during FY 1966 between Cape Kennedy and Houston to provide near real-time telemetry. Initial communications arrangements will be started in FY 1966 to meet ship-to-shore requirements for project Apollo.

Also during FY 1966, additional wide-band data circuits will become operational from Goddard Space Flight Center to Rosman (North Carolina) to support the Orbiting Geophysical Observatory and the Orbiting Astronomical Observatory; and between Cape Kennedy and Huntsville in support of the Launch Information Exchange Facility which will operate as a subcontrol center to the Mission Control Center at Houston to analyze and recommend actions for the Saturn IB and Saturn V launch vehicles.

Data Processing

1964	1965	1966
$6,277,000	$7.100,000	$8,100,000

Information received in the form of tracking and telemetry from satellites and space probes must be processed into a form that is useful to both those performing the real-time control of the space vehicle and those responsible for analyzing the scientific data acquired by the spacecraft.

Tracking data are processed to provide orbital elements which are used to supply stations with predictions on future passes of the spacecraft and to provide position information that can be used by the scientific experimenters to determine where in the trajectory the scientific measurements were made.

Telemetry data must be processed to separate the information from the various scientific experiments aboard the spacecraft, to consolidate information from each experiment, to apply the necessary scaling factors and calibrations of the measuring instruments, and to correlate these measurements with the position data mentioned above. Processed data presented to the experimenters is the primary objective of the spacecraft missions which are undertaken to explore and understand space.

During FY 1964, data were processed at an average of 8,000,000 data points per day. Based upon the first half of the year, it is expected that additional launches will occur during FY 1965 which will increase the data processing workload to an average of 70,000,000 data points per day.

During FY 1966, the data processing workload is expected to increase to 200,000,000 data points per day. This additional data processing workload will result primarily from the increase in observatory satellites, the Eccentric Geophysical Observatory (EGO), Polar Orbiting Geophysical Observatory (POGO), and Orbiting Astronomical Observatory (OAO), plus the normal launching of Explorer type satellites whose reliability has increased over the years so that they continue to supply useful scientific data for several years.

Equipment

	1964	1965	1966
Manned space flight network..	$56,234,000	$114,217,000	$64,000,000
Satellite network.....	15,297,000	17,250,000	14,700,000
Deep space network.....	12,004,000	11,520,000	9,800,000
Other instrumentation.....	4,690,000	5,300,000	5,500,000
Communications.....	4,036,000	4,110,000	4,400,000
Data processing.....	11,065,000	4,851,000	4,000,000
Total.....	$103,326,000	$157,248,000	$102,400,000

Manned Space Flight Network

	1964	1965	1966
Receiving systems.....	$8,613,000	$8,388,000	$10,700,000
Transmitting systems.....	3,142,000	444,000	1,500,000
Ranging systems.....	3,811,000	7,530,000	2,000,000
Antenna systems.....	7,915,000	2,115,000	4,200,000
Command systems.....	585,000	5,645,000	6,600,000
Data handling systems.....	8,339,000	12,675,000	10,300,000
Demodulation systems.....	7,123,000	8,800,000	10,100,000
Communications equipment.....	165,000	---	3,200,000
Ship modifications.....	4,452,000	37,700,000	---
Aircraft modifications.....	---	21,700,000	---
Control centers.....	2,395,000	---	4,200,000
General network support.....	6,405,000	5,949,000	5,400,000
Maintenance, spares, and repairs.....	3,289,000	3,271,000	5,800,000
Total.....	$56,234,000	$114,217,000	$64,000,000

Originally implemented as the Mercury Network, the Manned Space Flight Network has now been augmented for support of the Gemini Program in the areas

of tracking, telemetry, command, and communication. Additional augmentation of the network to meet the vastly increased requirements for support of the Apollo Saturn IB and Saturn V programs was initiated in FY 1964 and is continuing in fiscal years 1965 and 1966.

Apollo mission requirements encompass instrumentation to provide: (1) from the early ballistic and earth orbital missions, the engineering data needed for the efficient development of the lunar landing capability, and (2) for the later lunar missions, information for making the complex mission decisions in real-time and to provide data for subsequent analysis of systems behavior.

The planned augmentation of the Manned Space Flight Network for Apollo will result in ten 30-foot antenna stations, three 85-foot antenna stations, two transportable stations with 16-foot antennas, five ships, and eight instrumented aircraft. This network configuration will provide the ground instrumentation support necessary to fulfill the presently defined Apollo Program requirements; however, specific mission definition and associated tracking and data acquisition requirements definition is a continuing effort and additions may be necessary in future fiscal years.

During calendar year 1964, Apollo mission planning has been continued in greater detail as the various spacecraft and launch vehicle characteristics have become better defined. As a result, additional support requirements have been identified. For example, communications and tracking coverage requirements during the period immediately after launch have been evaluated for compatibility with newly available spacecraft and launch vehicle antenna patterns. Transportable command and telemetry stations must be added at Grand Bahama and Grand Turk Islands to close gaps in coverage and thus provide the needed flight control capability during this important mission phase.

As another example, a review of command and display requirements for mission flight control at the network stations has indicated that the meter type displays currently used for similar functions in support of the Gemini Program will not be adequate for the increased amount of data from the Apollo spacecraft and launch vehicles. At remote stations with limited capability for communication with the Integrated Mission Control Center, it will be necessary to provide data processors and numeric presentation of critical control parameters so the flight controllers can rapidly select and assimilate the large amounts of data they need to make the decisions on which the success of the mission depends. Similar detailed reviews of support capabilities have led to identification of other needed additions to standard network systems.

Receiving, transmitting, and ranging systems will provide the capabilities for transmission and reception of voice and telemetry signals, provide data for antenna directing, and enable measurement of the positions and velocities of the spacecraft and launch vehicles. In FY 1966, sensitive maser preamplifiers will be incorporated in the stations at Carnarvon,

Australia, and at Ascension Island to provide increased receiving sensitivity sufficient to fill gaps in instrumentation support during the critical transposition maneuver of the Command/Service Module (CSM) and the Lunar Excursion Module (LEM). Additional receiving and transmitting channels will be added at eight land stations and three ships to meet the additional requirements for instrumentation support for the SIVB stage during Apollo/Saturn V operations.

Antenna systems augmentation in FY 1966 will include UHF/VHF antennas and feed modifications for support of the SIVB stage. Two 16-foot diameter S-band antenna systems are planned for the transportable stations to be used for launch area support, and equipment is needed to augment the training and engineering facility at the Goddard Space Flight Center.

Command and data handling systems consist of digital display and computation equipment for monitoring telemetered spacecraft equipment performance and astronaut status and for coding and sequencing of commands. These systems include recorders for storage of telemetry data and station status information. The augmentation planned for FY 1966 includes provision of digital command remote terminal equipment for the transportable stations at Grand Bahama and Grand Turk Islands, additional consoles and displays needed to provide numeric displays for use by the flight controllers, and additional consoles and recorders for use in support of the SIVB stage during the Apollo Saturn V program.

Demodulation equipment extracts the telemetry, communications, and tracking information from received signals and prepares it for storage and for input to the data handling systems and communications terminal equipment. The major element of demodulation systems augmentation in FY 1966 consists of the provision of additional Pulse Code Modulation (PCM) telemetry decommutation systems for support of the SIVB stage.

Communications equipment consists of terminal equipment necessary for compatibility with common carrier facilities. Since the equipment is standard in nature and readily available, its procurement for support of Apollo was not planned for prior years. Funds are requested for the equipment needed for the various network stations in FY 1966.

The control center funds requested will provide equipment which must be added to the existing network control centers to enable operational control of the network during nonmission periods and simulations, and to provide the capability to assess network performance during mission periods. Funds are requested in FY 1966 for equipment to be installed for Apollo support in the Integrated Mission Control Center at the Manned Spacecraft Center; the Manned Space Flight Network Control Center at the Goddard Space Flight Center; and the Space Flight Operations Facility at the Jet Propulsion Laboratory.

Funds requested for general network support are those necessary to meet expenses for the systems engineering effort, for the shipment of equipment to the network stations, for the provision of network descriptive documentation, specifications, and operational manuals, and for the provision of

761-133 O-65-26

standard test equipment. Those requested for maintenance, spares, and repairs are primarily for the establishment of spare parts inventories needed to preclude long periods of station downtime during mission periods.

Satellite Network

	1964	1965	1966
Tracking systems.....	$2,333,000	$2,332,000	$2,550,000
Telemetry systems.....	3,790,000	2,721,000	2,455,000
Command and control systems...	566,000	1,081,000	781,000
Recording and display systems.	1,707,000	965,000	896,000
Test, calibration and checkout equipment.....	1,654,000	967,000	965,000
Timing systems.....	815,000	1,030,000	975,000
Real-time data handling systems.....	649,000	266,000	538,000
Applications technology satellite requirements.....	452,000	4,950,000	2,400,000
Control center.....	153,000	350,000	550,000
General network support.....	1,681,000	1,174,000	1,370,000
Maintenance, spares, and repairs.....	1,497,000	1,414,000	1,220,000
Total.....	$15,297,000	$17,250,000	$14,700,000

For the past three years, the Satellite Network has been enlarged and updated with new facilities and equipment to meet the support requirements of the second generation scientific and applications satellite projects. The major objectives of the equipment program are to provide the network with the capability for highly precise satellite tracking up to lunar distances, for acquiring and handling high data output rates, and for performing the more intricate command and control functions required by the more advanced satellites, particularly those of the large observatory class.

The major item in the tracking systems category in FY 1966 will be for the modification of existing Range and Range Rate Systems. These modifications are due to: (a) incorporation of greater gain capability which operating experience on the first Orbiting Geophysical Observatory has indicated is required, and (b) reassignment of the frequencies on which the system operates, directed by the international Extraordinary Administrative Radio Conference of 1963. The changes will require modification of the transmitters, antennas, and receivers of the existing Range and Range Rate Systems.

Forthcoming satellites of the observatory and Explorer class will have orbits with greater eccentricity and therefore will require longer, continuous periods of tracking and data acquisition by the viewing stations. Additionally, these satellites will transmit increased quantities of data to adequately sample the more numerous and complex experiments. It is planned to support these requirements with a network of high performance telemetry data links.

Implementation of the high performance links was initiated with FY 1963 funds and is phased to meet the operational requirements of the flight projects as they occur. FY 1966 funds will provide sufficient data links to meet the presently known requirements through calendar year 1967.

Also included in the FY 1966 request are funds for an air transportable telemetry station. Transportable stations are employed to provide support for unanticipated requirements or when total requirements do not justify establishment of a permanent station.

The modernization program for command and control equipment will continue in the next fiscal year. FY 1966 funding will provide sufficient command links to meet the workload anticipated during calendar year 1967.

In FY 1966, additional recording units are required to complement the increased data link capability. Also, additional magnetic tape evaluators and display units will be purchased to monitor station telemetry performance.

Calibration equipment for maintaining the accuracy of network stations and major equipment subsystems will be required in FY 1966. Along with the calibration function, test and monitoring are continuing programs. Prior to acceptance and installation of new or replacement equipment in the network, it is necessary to thoroughly evaluate the units for field use. Specialized spacecraft checkout equipment is required for telemetry, communications, and command subsystems to verify performance at the Eastern and Western Test Ranges of the Department of Defense to ensure compatibility between the spacecraft and the ground systems.

Continuously available, accurate timing signals at each station are of critical importance for experiment analysis and orbit determination. In FY 1966, improved and more reliable transistorized time standards will be procured for five sites as part of a program to improve time standards throughout the network.

With the augmentation of the network with equipment to receive pulse code modulation telemetry from spacecraft, a program is being initiated in FY 1966 to outfit selected stations with general purpose on-site data handling equipment. These general purpose units will be capable of data compiling and formatting for real-time transmission to the central control facility as well as to the spacecraft itself.

During FY 1965, the function of providing ground station support for the Applications Technology Satellite project was transferred from the Applications Technology Satellites Program to the Tracking and Data Acquisition Program. Related funding authority also was transferred. The purpose of this transfer is to assure maximum coordination and integration of equipment and facilities required for support of the Applications Technology Satellite project with other NASA tracking and data acquisition facilities. FY 1966 funds are required to continue efforts initiated with prior year funds. These efforts include procurement of the transportable communications

station and the telemetry and command stations, augmentation of the second 85-foot antenna facility at Rosman, North Carolina, and modification of the Satellite Network facility at Mojave, California, to support the Applications Technology Satellite project.

FY 1966 funds are required to continue implementation of a multi-purpose control center at Goddard Space Flight Center to handle the numerous scientific satellite projects. It will contain equipment to provide real-time control of spacecraft and will eliminate the need for separate control centers now being used.

General network support is a continuing effort. Minor station augmentations such as antenna hardstands, improved intra-site cabling for power distribution, and increases in the station air conditioning and heating equipment to accommodate new equipments are necessary in FY 1966.

In a similar manner, maintenance, spares, and repairs is a continuing program. Funds in this category provide for spares, modifications, and repairs to network equipment.

Deep Space Network

	1964	1965	1966
Transmitters	$409,000	$78,000	---
Receivers	4,815,000	2,146,000	$165,000
Station monitoring and control equipment	1,328,000	2,338,000	3,885,000
Antennas	1,495,000	1,830,000	914,000
Tracking data handling systems	342,000	690,000	---
Recording and display systems	489,000	223,000	---
Timing systems	225,000	320,000	490,000
Control center	---	838,000	1,758,000
General network support	1,276,000	948,000	782,000
Maintenance, spares, and repairs	1,625,000	2,109,000	1,806,000
Total	$12,004,000	$11,520,000	$9,800,000

Use of the L-band frequency for support of lunar and planetary missions will be discontinued after the last Ranger flights which are scheduled for the first six months of calendar year 1965. Conversion to full S-band capability will be accomplished at that time. The Pioneer, Surveyor, and Lunar Orbiter programs all employ S-band systems and are scheduled to be supported by the Deep Space Network beginning in FY 1966. The Mariner 1964 operation is being supported by three Deep Space Network stations previously converted to an interim S-band configuration.

Procurement of equipment for S-band transmitters has been funded in prior years and no funds for this purpose are required in FY 1966. Similarly, S-band receiver procurement requires no funding except for minor modifications at each of the six main stations and the purchase of an additional "suitcase" telemetry receiver.

The major item of FY 1966 Deep Space Network equipment cost is for station monitoring and control equipment. This equipment is necessary to provide the required reliability, flexibility, and operational readiness to support multiple lunar and planetary missions. The present schedule indicates a distinct possibility that Pioneer, Lunar Orbiter, and Surveyor will all be in flight at the same time, and will require simultaneous coverage by the network to meet mission requirements.

This new equipment will provide continous, semi-automatic monitoring of the performance of each station, enabling immediate identification of components which are approaching marginal performance with respect to predetermined limits. Status of station operations will be reported in real-time to the network director at the Space Flight Operations Facility (SFOF) so that he can make necessary decisions and initiate corrective actions promptly. Further, stations may be directed to quickly switch coverage from one spacecraft to another without loss of significant data.

In a two-phase program which was initiated in FY 1964, station monitoring consoles, on-site data processors, and associated equipment are being installed at all stations. FY 1966 funds are required to complete equipping the stations at Goldstone, Woomera, Canberra, and Madrid with a full capability for network support of multiple flight operations. The other stations of the network will be partially equipped this year but funding required for completion will be deferred until FY 1967 since the support by these stations will not be necessary until calendar year 1967.

An antenna pointing system will be installed at Johannesburg, Woomera, and Canberra to meet the more stringent requirements of the Lunar Orbiter and Surveyor projects. Previously evaluated at Goldstone, this system provides for automatic antenna positioning from a pre-computed tape.

Antenna structural modifications are required to complete conversion to standard S-band configuration. These consist of additional electronic component housings, improved bearings, and new structural members for increased strength and stiffness. A spare Cassegrain cone, which is a major antenna subsystem containing the low noise maser and transmitter, will be procured and maintained at Goldstone as a network emergency standby.

The timing system at each Deep Space Network station will be replaced by a more reliable and accurate clock to function as the master Greenwich Mean Time (GMT) clock at the site. In addition, frequency synchronizer units will be provided to each of the stations. These improvements will make possible the more accurate tracking data required by later Surveyor and Lunar Orbiter flights.

The Space Flight Operations Facility (SFOF) was used in support of Ranger VII, and also in support of the 1964 Mariner operation. Some changes in control center equipment are necessary as a result of these operational experiences. Further, for the planned combined Pioneer, Lunar Orbiter, and Surveyor operations, additional equipments will be required which were not previously anticipated. Display consoles and communications end-instruments are required to provide for the simultaneous support of multiple missions. In addition, expansion of the data handling system is necessary to accommodate the simultaneous support requirement.

Funds requested for general network support include those necessary to meet interface requirements of the Surveyor, Lunar Orbiter, and Pioneer mission-unique equipment. Among these are such miscellaneous items as cables, junction boxes, and line amplifiers. In addition, a secondary standards laboratory will be established at each of the four overseas sites for purposes of maintaining adequate calibration of test equipment to assure readiness of the equipments for support of scheduled operations. The calibration standards at the secondary laboratories will be checked periodically against the primary standards maintained at Goldstone.

Maintenance, spares, and repairs are required for all technical systems and facilities at the Deep Space Network stations, as well as the SFOF, in order to maintain the equipment in a proper operational status.

Other Instrumentation

1964	1965	1966
$4,690,000	$5,300,000	$5,500,000

A wide variety of fixed and mobile equipment is used to provide instrumentation support at Wallops Station and points off the main station, and at the Flight Research Center. This equipment is under a continuous preventive maintenance program to assure the necessary reliability for mission support. In addition, an improvement program is undertaken whereby individual subassemblies or components of major systems are modified or replaced to improve the range, speed, accuracy, and flexibility of the systems. The requirement for these improvements is generated by the large number and types of rockets in the current and planned flight schedules of Wallops Station and by the high performance characteristics of the flight projects supported by the Flight Research Center.

The major effort at the Flight Research Center during FY 1966 will be to continue the program initiated in FY 1964 to update the telemetry system by modifying the Pulse Code Modulation (PCM) ground equipment to handle several data formats through the use of programs stored in the core memory. In addition, pre-detection recording will be utilized to allow for increased data recovery by the application of various demodulation schemes. These conversions are necessitated by the requirement for higher performance telemetry systems to meet the data output requirements of the advanced test programs which must be supported.

At Wallops Station, a considerable quantity of non-recoverable flight hardware is required in support of the missions. These include not only the small meteorological rockets launched in association with other primary flights to obtain last minute wind profiles used for launch azimuth and elevation angle corrections, but also the radar beacons, transponders, antennas, and command-destruct receivers installed in launch vehicles.

Communications

1964	1965	1966
$4,036,000	$4,110,000	$4,400,000

The major project in the communications equipment program has been the conversion from manual to automatic, solid state switches at the Goddard Communications Center and secondary locations (London, England, and Canberra, Australia) which are the focal points for incoming communications. This conversion, which was started in FY 1964, will provide faster and more reliable transmission at a lower unit cost for the incoming data than was previously possible. In addition to removing the manual phase of the operation, these switching units are capable of handling upcoming flight project requirements for high speed, large volume data transmission from overseas locations. Funds requested in FY 1966 will provide for a switching unit at Hawaii and for additions to the existing switching center at Goddard.

In conjunction with the conversion program, certain data terminal equipments are required primarily for Apollo support to permit high speed data to be transmitted between stations, secondary switching centers, and the Goddard Communications Center. Included in the FY 1966 request are funds for the purchase of signal simulators, high speed data modulation/demodulation devices, error detection and correction units, data quality monitors, and distortion measuring sets.

The funds requested in FY1966 also will provide for needed improvements in teletype and voice equipment. Examples of such improvements are: (1) the present wire line between Carnarvon and Geraldton, Australia, which barely meets minimum reliability requirements, must be expanded to meet Apollo requirements; (2) voice digitizing equipment is necessary for installation on four radio circuits to improve the intelligibility of voice communications; and (3) the voice network is being updated to provide selective signaling, circuit supervision, and assurance information to overseas stations.

Data Processing

1964	1965	1966
$11,065,000	$4,851,000	$4,000,000

With FY 1964 and FY 1965 funding, the procurement of major equipments required for processing large amounts of data and for the conversion from an analog to a digital system will be essentially completed. While the

purchase of some peripheral equipment associated with the computers will be necessary in FY 1966, the major portion of the FY 1966 program consists of the modification and expansion of existing systems to meet the increasing data processing workload.

The operational data processing equipment will continuously require minor redesign, modifications, and improvements as well as normal maintenance and repair. Funds requested in FY 1966 will allow such modifications and improvements, including a maintenance test laboratory, standardized display devices, and evaluators and analyzers to decrease downtime of present equipment.

Signal recovery equipment is required for the processing of data which would otherwise be lost through weak signals. Much of this data is obtained when the spacecraft is in the apogee phase of its orbit and is scientifically very important. With recently developed signal recovery equipment, the retrieval process involving the reprocessing and refining of data is considerably shortened. Funds requested in FY 1966 will provide eight Pulse Frequency Modulation (PFM) and Pulse Code Modulation (PCM) signal recovery units in this program.

Special purpose data processing and display equipment is necessary for unusual or unique data from individual flight projects. The data requirements vary considerably between flight projects such as Orbiting Astronomical Observatory (OAO), Orbiting Solar Observatory (OSO), Interplanetary Monitoring Probe (IMP), and Nimbus, resulting in the need for special data and video processors in both FY 1965 and FY 1966.

The evaluation of analog telemetry tapes is necessary to sort out improperly recorded tapes and to monitor ground station recording performance. With the increasing number of tapes to be evaluated, present equipment and facilities are inadequate. Equipment procurement for tape evaluation which was begun in FY 1965 will continue through FY 1966.

Increases in projected data processing volumes make high density storage and recording essential for both economy and accessibility to the data. Funds requested in FY 1966 will provide the necessary storage, recording, multiplexing, and formatting equipment.

Supporting Research and Technology

	1964	1965	1966
New systems	$2,610,000	$1,375,000	$1,500,000
Integrated systems analysis, development, and test	2,446,000	2,912,000	3,024,000
Antenna subsystems	2,211,000	2,534,000	2,076,000
Receiver and transmitter subsystems	2,412,000	3,301,000	2,426,000
Data handling and control subsystems	1,608,000	2,004,000	2,529,000
Data processing and display subsystems	778,000	1,060,000	1,246,000
Spacecraft subsystems	825,000	1,497,000	1,699,000
Total	$12,890,000	$14,683,000	$14,500,000

Supporting Research and Technology is the activity whereby the Office of Tracking and Data Acquisition develops a technology of advanced systems, components and techniques which are then used to implement the various networks to meet the requirements of new flight projects, both manned and unmanned. Complementary spacecraft subsystems are developed as well as new equipment for ground instrumentation support. Operation of development sites is conducted so that the performance and reliability characteristics of new components and subsystems are proven before the equipment is committed to the network. Supporting Research and Technology effort is also directed at reduction of rising operations costs by investigating techniques which lead toward eventual station automation.

New Systems

In FY 1966, one major project will be completed and two new developments initiated. The Airborne Range and Orbit Determination (AROD) system which was initiated in FY 1963 will be concluded with the purchase of one flight test and evaluation unit to demonstrate full system capability.

One new system development to be initiated during FY 1966 is an acquisition aid. Among the technical approaches to be investigated are an interferometer system and the use of over-the-horizon radar system techniques. One of these techniques will be selected for full investigation early in FY 1966. During a spacecraft's reentry into the Earth's atmosphere, a blackout of normal tracking and communications occurs. It is imperative to reacquire the spacecraft's signal immediately after this period. This equipment, when developed, will be capable of rapidly providing pointing data for the major tracking antenna once the spacecraft comes out of the blackout.

Previous re-entering vehicles were of the Earth orbiting type. As a result, they had relatively low velocities which produced short blackout periods and they had followed simple orbital paths so that their general locations after blackout could be anticipated accurately. This acquisition aid equipment is needed for future spacecraft such as Apollo which have long blackout periods because of their much higher reentry velocities and which have a capability to maneuver such that their position cannot be extrapolated.

A second new system development is concerned with spacecraft-to-spacecraft communications. As the investigation of space continues, missions such as Voyager, or lunar and Mars orbiters will be flown which will, in turn, launch probes or landers to examine the surface of the body. Direct communication between Earth and the secondary vehicle is not practical, in view of the distances involved, and the parent spacecraft must act as a relay between the two. In FY 1966, a system development will be undertaken to provide for communications between two unmanned spacecraft.

Integrated Systems Analysis, Development, and Test

Included in this category is the integration into working systems of the components, techniques, and subsystems which are developed under the

various disciplines of the supporting research and technology program. Overall problems that are unique to a network rather than a specific discipline are also included in this effort.

One objective of this area of effort is the continued development of techniques needed for future tracking capability. As the exploration of deep space expands small inaccuracies result in large absolute errors at planetary distances. For various in-flight maneuvers of single spacecraft, and for rendezvous assistance of multiple spacecraft, these errors must be reduced.

Another objective is improvement of communications with spacecraft in deep space. Present capabilities limit the rate of information transmission to eight bits per second at a Mars distance and, at greater distances, the rate is exponentially reduced. The requirement for improved systems is imperative. In FY 1966, studies will be undertaken to evaluate the relative merits and costs of improvements in several areas such as transmitter power, receiver sensitivity, etc., which contribute to the improvement of the space instrument.

Broad investigations are underway to analyze and develop corrective procedures for the growing problem of radio frequency interference (RFI) at tracking and acquisition sites. As the number of spacecraft emitting signals increases, the difficulty of receiving only the signals from the proper spacecraft increases. This situation is further compounded by the growing amount and complexity of station equipment of extremely high power which also emits extraneous signals which can interfere with reception of the desired signal. The presence of this RFI is especially severe aboard instrumentation ships where even greater concentration of equipment exists. In FY 1966, the nature and magnitude of the radio frequency interference problem at the various network facilities will be examined and corrective procedures instituted.

Antenna Subsystems

The antenna subsystems category continues to be one of the most critical areas for development. The design and construction of a prototype 210-foot diameter antenna, funded from the FY 1963 Construction of Facilities appropriation, will be completed in calendar year 1966. At present, an antenna of this diameter appears to be as large as is economical and practical to build from a mechanical standpoint. However, future missions will undoubtedly require still higher gain antenna systems.

In FY 1966, antenna design concepts, including feeds, structures, pedestals, servo drives, and interface problems with the basic foundation itself will continue to be investigated under this project. All of these techniques will be applicable to the realization of higher-gain ground antenna systems when required.

Receiver and Transmitter Subsystems

This category of effort includes development and test of prototype hardware whose performance characteristics reflect the requirements determined by the integrated systems analysis for more accurate and reliable tracking and data acquisition support.

To afford a maximum of flexibility to the spacecraft designer where weight, size, and power are of prime importance, a major effort is being made to improve ground receiving and transmitting subsystems. This is accomplished by investigating modulation techniques which better utilize transmitter power, developing components which produce more transmitter power, exploiting results of advanced efforts which reduce noise generated within receiver and preamplifiers, and improving demodulation techniques which permit better recovery of weak signals from noise.

A second objective is the realization of frequency sources which are sufficiently stable and reliable under operational conditions to meet the support requirements of prolonged space flights. Because of the infinitesimal power received from planetary-distance transmissions, ground equipment with very narrow bandwidths is required. This minimizes accompanying noise and permits recovery of the weak signals. However, the narrow bandwidths place stringent stability requirements on spacecraft frequency sources so that the signal will remain within the passband capability of the receivers.

Data Handling and Control Subsystems

The functions of telemetry, tracking and command of spacecraft all require the generation and handling of data. Two aspects of data handling are considered under this category: the development of techniques and equipment to handle the data more accurately and more rapidly, and data compression.

An effort started in FY 1965 will continue on a highly efficient, but more complex telemetry system utilizing feedback control to adapt spacecraft and ground systems conditions to changing data needs as they occur. Also, further development of the control center concept using centralized computations will continue with emphasis on economies in operations and recording and storage for support of future spacecraft. Development of "quick look" capabilities for the stations will also continue.

Data compression is being studied to determine the optimum method to realize the advantages of this technique. These advantages included reduced bandwidth with attendant greater range and decreased data quantities and accompanying reduction in cost and time of processing.

Data Processing and Display Subsystems

The volume of data requiring processing continues to increase. Data processing facilities will handle 70,000,000 data points per day during FY 1965 and this is projected to increase to 200,000,000 data points per day in FY 1966.

In FY 1966, effort will be directed toward building up the existing telemetry data reduction capability to match the increasing requirements. In order to reduce, efficiently and reliably, the tremendous amount of data from these high data-rate spacecraft, it has become necessary to develop several general purpose processing and reduction lines capable of handling a variety of projects.

In FY 1966, development and evaluation of prototype hardware for improvement to these lines will continue. In addition, techniques will continue to be developed for recovering telemetry signals when conditions of extreme range reduce the signal level from a spacecraft. New data reduction techniques will be investigated including a study of trade-offs between various concepts of deep space network operations and data systems design characteristics.

Spacecraft Subsystems

The forthcoming deep space and extended-stay-missions require high, long lived performance. Therefore, the integral associated portion of the tracking and data acquisition system which is on the spacecraft must also have the same quality and reliable performance. The numerous, independent mission functions performed on the spacecraft in support of tracking, data acquisition, command and communication disciplines are investigated and developed under this category of effort.

In FY 1966, efforts will be continued to develop second generation spacecraft transponders, one having a fraction of the weight of the current system now required for Earth satellites with highly eccentric orbits, and the other to meet the system performance requirements for planetary missions. Efforts will also be continued on the development of a family of standard on-board transmitters, receivers, data handling modules, and memory units. Associated investigations will be aimed at effecting economies through on-board data compaction and pre-processing especially for spacecraft producing a large volume of data. Development of a standard and reliable spacecraft command subsystem for Voyager and subsequent spacecraft will continue. Evaluation of launch vehicle telemetry equipment will continue, including techniques for on-board data storage, principally in support of the Saturn program.

OFFICE OF ASSISTANT ADMINISTRATOR FOR TECHNOLOGY UTILIZATION

TECHNOLOGY UTILIZATION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The primary objective of the Technology Utilization Program is to provide for the widest practical and appropriate dissemination to industry of information concerning NASA activities and their results. The NASA program offers U. S. industry unique opportunities to improve existing industrial techniques and to develop new products and methods. It is the purpose of Technology Utilization to assist in identifying quickly these many opportunities and to insure their expeditious dissemination for the benefit of American industry, and ultimately the individual U. S. citizen. Technology Utilization also includes projects to study and evaluate those factors which will improve our understanding of the implications of the space program.

SUMMARY OF RESOURCES REQUIREMENTS:

	1964	1965	1966
Identification: Technology searches and surveys.....	$1,090,000	$1,300,000	$1,400,000
Evaluation of innovations.....	580,000	700,000	700,000
Regional information dissemination projects.....	950,000	1,850,000	1,900,000
Analysis of technology transfer; research and development management; the long range implications of the space program.....	880,000	900,000	1,000,000
Total.....	$3,500,000	$4,750,000	$5,000,000

Distribution of Program Amount by Installation:

NASA Headquarters.....	$3,500,000	$4,750,000	$5,000,000

BASIS OF FUND REQUIREMENTS:

One of the important elements of the technology utilization program is the identification and reporting of new technology resulting from NASA activities. This is accomplished primarily by NASA personnel but in certain circumstances by specialists from research institutes, universities and industry. The identification and reporting of new technology also includes a state-of-the-art survey effort. This effort is organized around broad scientific

areas and disciplines. Surveys are now underway in a number of fields including inorganic coatings, tape recording and data processing, microelectronics, antennas, and membrane phenomena. To evaluate reported innovations for originality and potential value to industrial users, the technology utilization program utilizes the services of a number of industrial research institutions. Commercially oriented reports of these developments are then prepared and published in a number of formats. In FY 1966 the identification and evaluation efforts will be pursued at about the same levels as FY 1965.

In addition to the normal method of dissemination via libraries and mailing lists, seven pilot projects in regional information dissemination are being supported. These dissemination centers, in most instances, are operated by universities. Center personnel review, interpret and convert new technology to the industrial needs of participating organizations. Using the latest NASA capabilities (printed index journals, microfiche, computer tapes and programs, etc.) these centers provide pertinent technological information on a selective basis to industrial users. The Midwest Research Institute (MRI) pilot project was initiated in early FY 1962. MRI has employed a broad approach to dissemination serving more than 1000 firms. From this experience, MRI is now developing more intensive working relationships with selected firms using back-up computer support from the Aerospace Research Applications Center (ARAC) at Indiana University. The Aerospace Research Applications Center is now nearing the end of its second year of operation. This center charges companies a membership fee for the services the center offers. The three primary services are the Retrospective Search Service, the Selective Dissemination Service, and the Industrial Applications Service. All but two of the original 29 member companies have renewed their memberships and the center has considerably expanded its enrollment in the second year. During FY 1964, five centers in addition to MRI and ARAC were established. These are at Wayne State University (Detroit), the University of Pittsburgh, University of Maryland, the North Carolina Science and Technology Research Center and Southeastern State College (Durant, Oklahoma). All seven centers are pilot programs designed to implement those elements appropriate to the industrial needs of their respective areas. In addition to these seven centers, it is planned that several new pilot programs will be started with FY 1966 funds.

Beginning in fiscal years 1962 and 1963, a number of universities received grants for research in the management of research and development. At the University of California (Berkeley) an attempt is underway to establish a computer simulation of the process of scientific inquiry including literature search, information retrieval and analogous reasoning. At the Massachusetts Institute of Technology studies on complex problem solving, interpersonal conflict, multiple task assignments and decision making have been initiated. Other studies underway include research in contracting systems and procedures, project management, cost estimation and budgeting.

The impact of the space program upon the national economy particularly with respect to its effect upon the different geographic, industrial, and civilian sectors of the economy; upon national economic growth; and upon the alloca-

tion of scientific and engineering manpower has been studied within the Technology Utilization Program. A study recently started at the University of California (Los Angeles) is attempting to analyze the shifting geographic patterns of primary first-tier and second-tier contracting. Another study funded at Washington University (St. Louis) attempts to analyze the national impact of alternative assumptions concerning the level and composition of governmental spending streams with particular emphasis being laid upon the nature of the expenditures.

NASA expenditures have had a major impact on the economy of the Cape Kennedy area, especially on the functioning and development of local governmental units, school boards, planning boards, and utility services. This impact is being studied in both an empirical and a qualitative sense to learn the types and magnitude of the problems created by the space center build-up. In another case, NASA expenditures have stimulated rapid growth of a major scientific laboratory in Boulder, Colorado. Many changes in the economic base of the community, population, and local attitudes have resulted. A study now underway at the University of Colorado will analyze these changes in considerable depth throughout the community.

It is to be emphasized that the Technology Utilization Program at its present stage is still very much an experimental program. Future plans, therefore, call for careful review of every phase of the present Technology Utilization Program in order to determine the effectiveness of the current approaches which are being pursued. Future plans also call for feasibility studies of the numerous additional ideas generated by the Program, ideas which offer promising new avenues whereby new science and technology emanating from the space program can be more readily transferred to the non-space community.

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