National Aeronautics and Space Administration

N.A.S.A. PERMANENT
HISTORICAL FILE
NO.

BUDGET ESTIMATES

FISCAL YEAR 1962

RESEARCH AND DEVELOPMENT

REVISED

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

APPROPRIATION SUMMARY

	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1961 Supplemental	Fiscal Year 1962
SALARIES AND EXPENSES.....	$91,400,000	$170,760,000	---	$196,686,000
RESEARCH AND DEVELOPMENT....	347,550,000	621,453,000	$49,000,000	919,539,000
CONSTRUCTION OF FACILITIES..	84,625,000	122,787,000	---	119,075,000
TOTAL.....	$523,575,000	$915,000,000	$49,000,000	$1,235,300,000

N.A.S.A. PERMANENT
HISTORICAL FILE
No.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

APPROPRIATION SUMMARY

	Salaries and Expenses	Research and Development	Construction of Facilities	Total
FISCAL YEAR 1960:				
Supplemental Appropriation Act 1960; P.L. 86 213...	$91,400,000	$347,550,000	$84,625,000	$523,575,000
Appropriation transfers; P.L. 86-213.....	-550,000	-14,450,000	+15,000,000	---
Total.....	$90,850,000	$333,100,000	$99,625,000	$523,575,000
FISCAL YEAR 1961:				
Independent Offices Appropriation Act; P.L. 86-626	$170,760,000	$621,453,000	$122,787,000	$915,000,000
Appropriation transfers; P.L. 86-213.....	---	-3,538,000	+3,538,000	---
Total.....	$170,760,000	$617,915,000	$126,325,000	$915,000,000
FISCAL YEAR 1961:				
Supplemental estimates....	---	$49,000,000	---	$49,000,000
FISCAL YEAR 1962:				
Regular estimates.....	$196,686,000	$919,539,000	$119,075,000	$1,235,300,000

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

RESEARCH AND DEVELOPMENT

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RD2-1	Research grants and contracts
RD3-1	Life sciences
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RD6-1	Lunar and planetary exploration
RD7-1	Meteorological satellites
RD8-1	Communications satellites
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RD12-1	Launch operations development
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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

SUMMARY OF RESEARCH AND DEVELOPMENT PROGRAMS

Page No.	Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1961 Supplemental	Fiscal Year 1962
RD1-1	Support of NASA plant....	$27,761,897	$48,203,000		$77,110,000
RD2-1	Research grants and contracts.....	4,869,370	5,000,000		7,600,000
RD3-1	Life sciences.....	---	5,000,000		8,620,000
RD4-1	Sounding rockets.....	9,681,000	8,170,000		7,000,000
RD5-1	Scientific satellites....	20,241,114	37,942,000		64,700,000
RD6-1	Lunar and planetary exploration.....	49,995,900	77,524,000	$5,000,000	103,899,000
RD7-1	Meteorological satellites	7,930,000	18,100,000		28,200,000
RD8-1	Communications satellites	3,050,000	3,912,000	24,000,000	44,600,000
RD9-1	Mercury.....	84,328,370	109,525,000		74,245,000
RD10-1	Apollo.....	100,000	1,000,000		29,500,000
RD11-1	Launch vehicle technology	---	9,100,000		15,000,000
RD12-1	Launch operations development.....	---	100,000		1,500,000
RD13-1	Spacecraft technology....	4,019,349	7,875,000		10,360,000
RD14-1	Solid propulsion.....	1,720,000	1,300,000		3,100,000
RD15-1	Liquid propulsion.....	27,217,000	57,000,000		78,020,000
RD16-1	Electric propulsion.....	1,300,000	3,300,000		6,800,000
RD17-1	Nuclear systems technology.....	5,613,000	10,000,000	2,600,000	28,000,000
RD18-1	Space power technology...	3,514,000	4,200,000		5,500,000
RD19-1	Scout.....	3,000,000	2,150,000	1,825,000	3,675,000
RD20-1	Delta.....	12,475,797	11,800,000		2,900,000
RD21-1	Centaur.....	36,644,203	47,000,000	15,575,000	56,400,000
RD22-1	Saturn.....	9,450,000	118,058,000		224,160,000
RD23-1	Vega.....	4,000,000	---		---
RD24-1	Tracking and data acquisition.....	16,189,000	31,656,000		38,650,000
	Total.....	333,100,000	617,915,000	49,000,000	919,539,000
	Transferred to Construction of Facilities.....	15,000,000	3,538,000	---	---
	Transferred from Salaries and Expenses.....	-550,000	---	---	---
	Total appropriations...	$347,550,000	$621,453,000	$49,000,000	$919,539,000

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

FUNDING FOR TRACKING NETWORKS

Network	Research and Development			Construction of Facilities			Total		
	1960	1961	1962	1960	1961	1962	1960	1961	1962
Satellite (Minitrack) Stations:									
Construction	---	---	---	$1,561,000	$1,750,000	$721,000	$1,561,000	$1,750,000	$721,000
Equipment	---	---	---	2,744,000	3,000,000	5,539,000	2,744,000	3,000,000	5,539,000
Operations	$3,675,400	$5,283,000	$5,287,000	---	---	---	3,675,400	5,283,000	5,287,000
Advanced research	190,600	2,355,000	1,906,400	---	---	---	190,600	2,355,000	1,906,400
Advanced development	1,137,600	3,062,400	4,096,800	---	---	---	1,137,600	3,062,400	4,096,800
Data transmission and reduction	2,461,640	1,823,900	2,684,800	---	---	---	2,461,640	1,823,900	2,684,800
Total	7,465,240	12,524,300	13,975,000	4,305,000	4,750,000	6,260,000	11,770,240	17,274,300	20,235,000
Facilities for Communications Satellites:									
Construction	---	---	---	---	1,588,000	---	---	1,588,000	---
Equipment	---	---	1,670,000	---	---	---	---	---	1,670,000
Total	---	---	1,670,000	---	1,588,000	---	---	1,588,000	1,670,000
Deep Space Stations:									
Construction	---	---	---	2,281,500	4,135,000	450,000	2,281,500	4,135,000	450,000
Equipment	---	---	---	1,100,000	3,865,000	9,051,000	1,100,000	3,865,000	9,051,000
Operations	1,341,000	2,996,900	3,322,300	---	---	---	1,341,000	2,996,900	3,322,300
Advanced research	---	880,500	956,100	---	---	---	---	880,500	956,100
Advanced development	1,437,000	3,502,500	5,436,200	---	---	---	1,437,000	3,502,500	5,436,200
Data transmission and reduction	---	371,100	838,100	---	---	---	---	371,100	838,100
Total	2,778,000	7,751,000	10,552,700	3,381,500	8,000,000	9,501,000	6,159,500	15,751,000	20,053,700
Optical Stations:									
Operations	1,450,000	2,160,000	2,250,000	---	---	---	1,450,000	2,160,000	2,250,000
Data transmission and reduction	1,519,000	1,340,000	2,450,000	---	---	---	1,519,000	1,340,000	2,450,000
Total	2,969,000	3,500,000	4,700,000	---	---	---	2,969,000	3,500,000	4,700,000
Mercury Stations:									
Construction	---	---	---	9,535,000	2,400,000	---	9,535,000	2,400,000	---
Equipment	---	---	---	26,260,000	12,600,000	---	26,260,000	12,600,000	---
Operations (including recovery)	497,800	22,792,000	27,485,000	---	---	---	497,800	22,792,000	27,485,000
Network operational implementation	2,695,200	6,734,000	750,000	---	---	---	2,695,200	6,734,000	750,000
Advanced development	1,500,000	500,000	675,000	---	---	---	1,500,000	500,000	675,000
Data transmission and reduction	---	5,035,700	5,500,000	---	---	---	---	5,035,700	5,500,000
Total	4,693,000	35,061,700	34,410,000	35,795,000	15,000,000	---	40,488,000	50,061,700	34,410,000
Non-NASA Stations:									
Construction	---	---	---	---	---	400,000	---	---	400,000
Equipment	---	---	---	---	---	100,000	---	---	100,000
Operations (including data transmission and reduction)	800,000	1,500,000	1,850,000	---	---	---	800,000	1,500,000	1,850,000
Total	800,000	1,500,000	1,850,000	---	---	500,000	800,000	1,500,000	2,350,000
All Stations:									
Operations (special services, spare parts, repairs and maintenance)	676,760	845,000	1,397,300	---	---	---	676,760	845,000	1,397,300
Summary:									
Construction	---	---	---	13,377,500	9,873,000	1,571,000	13,377,500	9,873,000	1,571,000
Equipment	---	---	1,670,000	30,104,000	19,465,000	14,690,000	30,104,000	19,465,000	16,360,000
Operations	8,440,960	35,576,900	41,591,600	---	---	---	8,440,960	35,576,900	41,591,600
Network operational implementation	2,695,200	6,734,000	750,000	---	---	---	2,695,200	6,734,000	750,000
Advanced research	190,600	3,235,500	2,862,500	---	---	---	190,600	3,235,500	2,862,500
Advanced development	4,074,600	7,064,900	10,208,000	---	---	---	4,074,600	7,064,900	10,208,000
Data transmission and reduction	3,980,640	8,570,700	11,472,900	---	---	---	3,980,640	8,570,700	11,472,900
TOTAL	$19,382,000	$61,182,000	$68,555,000	$43,481,500	$29,338,000	$16,261,000	$62,863,500	$90,520,000	$84,816,000

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

TRACKING NETWORK OPERATING COSTS

Network	Contractor or operator	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Satellite (Minitrack) Stations:				
Blossom Point, Maryland	Bendix Corporation	$276,000	$286,000	$330,000
Fort Myers, Florida	Bendix Corporation	254,000	260,000	297,000
San Diego/Goldstone	Bendix Corporation	214,000	220,000	297,000
Antigua, British West Indies	RCA/Pan American	55,000	200,000	---
Quito, Ecuador	Bendix Corporation	411,000	415,000	429,000
Lima, Peru	Bendix/Geophysical Institute, Huancayo.	325,000	325,000	325,000
Antofagasta, Chile	Bendix/University of Chile	380,000	370,000	435,000
Santiago, Chile	Bendix/University of Chile	380,000	382,000	435,000
Woomera, Australia	Australia	50,000	185,000	185,000
Esselen Park, South Africa	South Africa	50,000	175,000	175,000
East Grand Forks, Minnesota	Bendix Corporation	---	185,000	297,000
Fairbanks, Alaska	University of Alaska	---	105,000	517,000
St. John's, Newfoundland	Canada	---	70,000	121,000
Winkfield, England	England	---	234,000	234,000
Microlock Stations	Bendix Corporation	---	50,000	---
Space Control Center Operational Support	Bendix Corporation	43,000	200,000	220,000
Calibration Operations of Airplane	Bendix Corporation	320,000	450,000	450,000
Call Order Services	Bendix Corporation	200,000	206,000	220,000
Special Logistic Support	Various	90,800	150,000	150,000
Calibration of Field Stations:				
New Mexico State University calibration data reduction		60,000	55,000	50,000
Ambiguity resolving slide rules		---	5,000	---
Aircraft modifications for parabolic antenna calibrations		---	15,000	---
Calibration equipment		---	20,000	10,000
Replacement of Electronic Equipment:				
Ampex recorders		229,100	560,000	---
Sanborn recorders		---	110,000	110,000
Timing oscillators		---	25,000	---
Communications transmitter		---	25,000	---
Fixed transmitter		143,600	---	---
Tunable discriminator		71,400	---	---
Switchable antenna		122,500	---	---
	Total	$3,675,400	$5,283,000	$5,287,000
Deep Space Stations:				
Goldstone, California	Jet Propulsion Laboratory	$1,341,000	$1,371,500	$1,431,800
Woomera, Australia	Weapons Research Establishment, Australia	---	193,400	72,100
South Africa (Hartebeesthock-Krugersdorf)	Union of South Africa	---	339,400	486,700
Mobile Tracking Station	Not Selected	---	432,200	331,400
Reimbursement for Foreign Stations	Foreign Governments	---	300,000	600,000
Systems Tests & Operations	Jet Propulsion Laboratory	---	167,400	179,100
Logistic Support	Jet Propulsion Laboratory	---	193,000	221,200
	Total	$1,341,000	$2,996,900	$3,322,300
Optical Stations:				
Jupiter, Florida	Smithsonian Astrophysical Observatory			
Organ Pass, New Mexico	Smithsonian Astrophysical Observatory			
Haleakala, Maui, Hawaii	Smithsonian Astrophysical Observatory			
Curacao, North West Indies	Smithsonian Astrophysical Observatory			
Arequipa, Peru	Smithsonian Astrophysical Observatory			
Villa Dolores, Argentina	Smithsonian Astrophysical Observatory			
Olifontsfontein, South Africa	Smithsonian Astrophysical Observatory	$1,200,000	$1,910,000	$2,000,000
San Fernando, Spain	Smithsonian Astrophysical Observatory			
Shiraz, Iran	Smithsonian Astrophysical Observatory			
Woomera, Australia	Smithsonian Astrophysical Observatory, Weapons Research Establish., Australia			
Mitaka, Tokyo, Japan	Smithsonian Astrophysical Observatory, Japan			
Naini-Tal, India	Smithsonian Astrophysical Observatory, India			
Moon Watch 110 active stations	Volunteer Teams	250,000	250,000	250,000
	Total	$1,450,000	$2,160,000	$2,250,000
Mercury Stations:				
Bermuda Station	NASA contractor	---	$2,007,000	$3,109,000
Australia Stations	Weapons Research Establish., Australia.	---	1,852,000	3,004,000
Canary Islands Station	NASA contractor	---	705,000	1,276,000
Kano Station	NASA contractor	---	786,000	1,422,000
Zanzibar Station	NASA contractor	---	613,000	1,108,000
West Mexico Station	NASA contractor	---	1,460,000	2,644,000
Southern California Station	Department of Defense, Pacific Missile Range	---	119,000	215,000
Hawaiian Station	Department of Defense, Pacific Missile Range	---	110,000	200,000
Canton Island Station	Department of Defense, Pacific Missile Range (Bendix)	---	316,000	573,000
Cape Canaveral Atlantic Missile Range	Department of Defense, Atlantic Missile Range	$110,300	313,000	1,424,000
Corpus Christi White Sands Station	Department of Defense, White Sands Range	30,000	848,000	1,534,000
Air Proving Ground Station	Department of Defense, Eglin Air Force Base	4,500	18,000	35,000
Ocean range vessels	Department of Defense	---	958,000	2,608,000
Port Lewis Ship Support Station	.....	---	193,000	349,000
Training	NASA, Department of Defense	---	209,000	134,000
Lincoln Laboratory services	Massachusuetts Institute of Technology	---	1,500,000	---
IBM Space Computing Center services	I.B.M.	---	212,000	---
Recovery Operations:				
Bureau of Ships support	Navy Department	125,000	4,079,000	3,147,500
Bureau of Weapons support (Aircraft).	Navy Department	175,000	5,890,000	3,982,500
Retrieval equipment	Various	53,000	604,000	720,000
	Total	$497,800	$22,792,000	$27,485,000
Non-NASA Tracking Stations:				
Jodrell Bank Station	University of Manchester, England	$100,000	$250,000	$300,000
Port Churchill Station	Canada (Army Cognizance)	650,000	1,000,000	1,200,000
Phototrack Optical Stations	Soc. of Prof. Photo. Engrs	50,000	50,000	50,000
Reimbursement for Department of Defense stations and other agencies	Various	---	200,000	300,000
	Total	$800,000	$1,500,000	$1,850,000
Special Operations & Services for Flight Missions (Includes special items of equipment to meet ground instrumentation requirements, such as for Explorer VII, Centaur and Agena projects)	Various	$400,000	$500,000	$500,000
Spare Parts, Repairs & Maintenance for network tracking stations	Various	$276,760	$345,000	$897,300
	TOTAL	$8,440,960	$35,576,900	$41,591,600

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

SUPPORT OF NASA PLANT

SUMMARY OF REQUIREMENTS:

	1960	1961	1962	Page No.
Advanced Research Centers	$16,269,800	$23,250,000	$33,185,000	RD1-2
Space Flight Centers.....	5,107,300	8,570,000	11,700,000	RD1-4
Launch Vehicle Centers...	4,522,637	14,323,000	26,820,000	RD1-5
Program Direction and Coordination.....	1,862,160	2,060,000	5,405,000	RD1-6
Total.....	$27,761,897	$48,203,000	$77,110,000	

OBJECTIVES:

To provide funds for certain travel and transportation expenses, leased communication lines, contractual services, repairs, alterations, minor construction, supplies, materials, and equipment required in the operation of all NASA installations.

The operations covered under this caption differ somewhat between the program areas shown above. The support of plant funds for the Advanced Research Centers, together with the funds provided in the Salaries and Expenses appropriation, finance the in-house research programs carried on at these centers. The Space Flight and Launch Vehicle Centers also carry on in-house activities funded out of both appropriations to administer and support certain parts of their development programs, but the major program costs at these centers are funded under specific program headings. Program Direction and Coordination covers the supporting operating costs of the NASA Headquarters and Western Operations Office.

JUSTIFICATION:

The Advanced Research Centers provide a broad base of research which furthers the development of technology necessary for manned and unmanned exploration of space and for the advancement of aeronautical vehicles. The

requirements for increased size, speed, and complexity of vehicles can only be met by corresponding increases in fund requirements for the supplies, materials, and equipment adequate to carry on research of this nature.

The Space Flight Centers administer the major research contracts for the development of manned and unmanned earth-orbiting spacecraft, maintain world-wide tracking networks, consolidate and analyze the data obtained, and conduct some in-house activities including the launching of rocket vehicles as large as the Scout vehicle at the Wallops Station. The major increases in the fiscal year 1962 are for additional equipment for the new Goddard Space Flight Center and the expanded Wallops Station, and for costs involved in the transportation of supplies and equipment to tracking stations and of rocket components to the Wallops Station.

The Launch Vehicle Centers administer the major contracts for the development of advanced vehicles; carry out in-house work on vehicle development, testing, and technology; and assist in the operational aspects of space vehicle launchings. Their needs for supplies and equipment are closely related to these activities.

Program Direction and Coordination covers administration of the entire NASA establishment, including certain staff activities not carried on at the field level. The major increases required in this area are for such contractual services as reliability monitoring, fabrication of exhibits, and abstracting of pertinent scientific information.

More detailed justifications of the requirements for each NASA installation follow:

Advanced Research Centers

Location	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Langley Research Center.....	$5,477,180	$9,100,000	$14,580,000
Ames Research Center.....	3,497,020	4,070,000	5,000,000
Lewis Research Center.....	6,390,900	9,030,000	11,820,000
Flight Research Center.....	904,700	1,050,000	1,785,000
Total.....	$16,269,800	$23,250,000	$33,185,000

Within the broad objectives mentioned in the summary section, the Advanced Research Centers have the following specific responsibilities:

Langley Research Center: This center conducts research in the areas of materials applications, including space environment effects; structures applications; magnetogasdynamics, including fundamental study of the motion and interaction of

electrically conducting gases in the presence of magneto and electric fields; aerodynamic heating, stability, and performance of space and aeronautical vehicles; and guidance and navigation.

Ames Research Center: The research carried on at this center is conducted in the areas of hypersonic aerodynamics, including problems associated with re-entry of a vehicle into the Earth's atmosphere; orientation, stabilization, and control of space vehicles, missiles, and aircraft; and space environmental physics, including the study of techniques and instruments for detecting and analyzing interplanetary gases and plasmas, and of the effects of high-velocity input with such materials.

Lewis Research Center: The mission of this center comprises research in the areas of advanced propulsion including chemical and nuclear energy systems research and propellants and the system components required to control and transmit the energy into useful thrust, and research on electrical energy systems to generate and accelerate ions for propulsion of space vehicles; power generation for internal use in space vehicles; and basic materials research to find or synthesize new materials, especially metals, which have appropriate physical and chemical properties for special requirements of aeronautical and space vehicles.

Flight Research Center: Highly advanced research aircraft are instrumented and flown at this location. The research areas covered are flight mechanics, including navigation, automatic guidance, and control of vehicles such as the X-15; operation and environment, including manned guidance and control, and the effect of space environment on the pilot; and aerodynamic and structural effects of high velocity and high temperature on the external surfaces and supporting structural members.

To carry out the missions outlined above, each center must be provided with adequate equipment, supplies, and services, as well as with funds for the continual improvement of the research tools with which the work is accomplished. The major needs for the fiscal year 1962 are given below:

Langley Research Center: A new program to carry out re-entry studies using two Scout vehicles and payloads fabricated at Langley will require about $3,000,000 additional for the vehicles and other supplies to be used in the construction of payloads. Other major items in the total increase of $5,430,000 include facility improvements, $163,000; research contracts related to the development of materials for thermal protection systems, $300,000; new scientific instruments, $216,000; and other specialized scientific equipment, $793,000.

Ames Research Center: The increase of approximately $1,000,000 at this center is made up almost entirely of scientific equipment items such as improved model supports for the 3.5-inch wind tunnel, $230,000; an aerodynamic heating simulator, $210,000; flow visualization equipment for the mass transfer facility, $130,000; and improved instrumentation for the hypervelocity ranges, $223,000.

Lewis Research Center: Major items in the $2,820,000 increase at Lewis include operating supplies for constructing advanced test components, models, and associated instrumentation, $500,000; rocket propellants for larger scale tests on propulsion systems and components, $700,000; equipment for power generation studies, $563,000; equipment for electric propulsion research, $180,000; supplies and equipment for improvement of aeronautical research facilities and for acceleration of the supersonic transport research program, $185,000; and additional contractual supporting services at the Plum Brook facility, $125,000.

Flight Research Center: The advanced types of vehicles used in flight programs at this center require more complex instrumentation and servicing equipment as the research progresses. These needs are reflected in the increase for operational and maintenance supplies of approximately $200,000; and the inclusion of new equipment items such as a three-axis tilt simulation table, $220,000; a surface-temperature measurement system, $100,000; and an incremental computer for simulation facilities, $150,000.

Space Flight Centers

Location	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Goddard Space Flight Center.....	$4,161,800	$6,070,000	$8,500,000
Wallops Station.....	945,500	2,500,000	3,200,000
Total.....	$5,107,300	$8,570,000	$11,700,000

The two space flight centers have the following specific responsibilities:

Goddard Space Flight Center: This center is responsible for the formulation and implementation, mostly by contract with private business concerns and other Government agencies, of the following major programs: unmanned Earth-orbiting spacecraft, including sounding rockets for the investigation of the Earth's upper atmosphere and probes into near space, scientific satellites to orbit the Earth for the purpose of

obtaining data to increase man's knowledge of the space environment, and satellites designed for specific advancement of technology in such fields as weather prediction and communications; manned Earth-orbiting spacecraft for the initial steps in man's exploration of space; lunar and planetary spacecraft, first unmanned and later manned, for the further exploration of space; and the maintenance of a world-wide network for tracking of manned and unmanned space vehicles.

Wallops Station: At this site the instrumentation, launch, and data acquisition for sounding rockets and probes up to the size of Scout are carried on.

Although most of the fabrication of spacecraft for space missions and the operation of tracking stations is performed under contract, some in-house research and development must be carried on to insure incorporation of the latest advances in instrumentation and operating techniques, and to reduce and analyze the data acquired from the spacecraft. These activities, along with the administration of the programs and the launching operations at the Wallops Station, will require additional funds in the fiscal year 1962:

Goddard Space Flight Center: The increase of approximately $2,500,000 at this center is largely attributable to the requirements for instruments and scientific equipment which have become apparent since the first buildings were occupied in June, 1960. The required additional funds for this purpose total about $1,500,000. An increase of $888,000 for the transportation of supplies and equipment to the world-wide tracking station networks is necessary as additional sites become operational.

Wallops Station: The $700,000 increase at this location includes the modification and modernization of existing launchers and other minor construction, $239,000; and $320,000 for supplies required to prepare and launch the rockets and probes scheduled during the fiscal year 1962.

Launch Vehicle Centers

Location	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Marshall Space Flight Center.....	$4,522,637	$14,323,000	$26,820,000

Marshall Space Flight Center: This center, which also administers the NASA activities at the Atlantic and Pacific Missile Ranges, is responsible for the formulation and implementation of development programs for improved booster systems for spacecraft; the advancement of propulsion technology, including launch and guidance techniques; and for the supervision of launch operations at the major launch sites. A considerable proportion of the work is carried on by contract with private industrial concerns and other Government agencies, but some work requiring close supervision is carried on by the Marshall staff. The major portion of the in-house effort is directed toward the development, fabrication, and test of the Saturn booster (S-I). The center became a NASA activity on July 1, 1960, at which time certain personnel, facilities, and supplies were transferred from the Army to the NASA.

Provision was made in May of 1960 for an orderly transition of functions and contracts from the Army to the NASA, and advance funding for the fiscal year 1961 was provided in the amount of $4,500,000. Since very little of these funds were actually used prior to July 1, 1960, the amount of $14,323,000 shown for the fiscal year 1961 should be increased by about $4,500,000 for comparison purposes. In addition, due to fundamental differences between NASA and Army funding policies and procedures, many items in the original NASA fiscal year 1961 budget for Marshall were underestimated, and some needs were omitted. When the advance funding provided in the latter part of 1960 is included with the 1961 figure the proposed increase in 1962 amounts to approximately $8,000,000. Of this amount, about $2,700,000 covers supplies, and represents the amount by which the combined 1960 and 1961 funds fall short of actual yearly needs. These needs are being met in 1961 by reducing the inventory to an absolute minimum. For repairs, alterations, and minor construction, an increase of $1,000,000 is required for supporting functions associated with larger-class vehicle developments. The increase of about $3,800,000 in equipment provides for general purpose machine tools and instrumentation required to handle the larger and more complex vehicles such as Centaur and Saturn.

Program Direction and Coordination

	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
NASA Headquarters.....	$1,805,860	$2,025,000	$5,361,000
Western Operations Office.....	56,300	35,000	44,000
Total.....	$1,862,160	$2,060,000	$5,405,000

These activities are assigned the over-all administration of the NASA programs with specific responsibilities as follows:

NASA Headquarters: The responsibilities of this office include the formulation and approval of broad program objectives, and of the major policies to be followed in reaching these objectives; coordination of the programs between major areas, and with the other Government agencies working in allied fields; formulation and implementation of broad administrative policies and procedures; consolidation of information flowing in from field activities, and presentation of this information in a form useful for management purposes; and specialized staff activities (such as the Office for the United Nations Conference) that must be carried on at the Headquarters level.

Western Operations Office: This office acts as the liaison unit between NASA Headquarters and Government-owned Jet Propulsion Laboratory, which is operated under contract for NASA by the California Institute of Technology. The office also is responsible for the negotiation and administration of certain NASA contracts with West Coast companies.

As our space programs increase in size and scope, the supervisory and staff work must expand in proportion. In order to conserve personnel, as much work as possible is contracted outside the agency. The 1962 requirements for funds are summarized below:

NASA Headquarters: Most of the increase of about $3,300,000 covers contractual services for reliability monitoring, $1,000,000; abstracting, cataloguing, and microfilming, $850,000; and exhibits for national and international conferences and educational programs, $600,000. Other increases cover transportation of equipment and exhibits, auditing and contract administration by Department of Defense units, photography and film processing, additional supplies and equipment to carry on the increasing level of operations, and an increase in representation allowances and other extraordinary expenses of the Administrator.

Western Operations Office: The nominal increase of $9,000 at this activity is for office supplies and equipment required to support the increased staff requested for this activity.

FUNDING REQUIREMENTS:

Object of Expenditure	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962	Page No.
21 Travel and transportation of persons.....	$62,733	$65,000	$164,600	RD1-9
22 Transportation of things.	577,790	1,744,600	3,060,800	RD1-10
23 Communications.....	173,410	426,800	570,800	RD1-11
24 Printing and reproduction	87,000	---	---	
25 Other services:				
Repairs, alterations, and minor construction	2,027,625	5,620,800	7,318,150	RD1-12
Miscellaneous services.	3,781,384	8,172,900	13,989,600	RD1-14
Services of other agencies.....	2,057,328	4,880,900	5,497,000	RD1-16
26 Supplies and materials...	10,152,537	14,860,000	24,472,000	RD1-18
31 Equipment.....	8,842,090	12,422,000	22,017,050	RD1-20
Unvouchered.....	---	10,000	20,000	
Total, Support of NASA Plant.....	$27,761,897	$48,203,000	$77,110,000	

Supporting schedules are presented on the following pages.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

SUPPORT OF NASA PLANT

TRAVEL AND TRANSPORTATION OF PERSONS

	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Shuttle Bus Service			
Langley Center.....	$36,925	$38,000	$40,400
Wallops Station.....	25,808	27,000	30,000
	62,733	65,000	70,400
Hire of Passenger Motor Vehicles			
NASA Headquarters.....	---	---	5,000 1/
Lewis Center.....	---	---	1,000 1/
Marshall Center.....	---	---	88,200 1/
			94,200
Total.....	$62,733	$65,000	$164,600

1/ Estimates for these costs were carried in the Salaries and Expenses appropriation in prior years.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

SUPPORT OF NASA PLANT

TRANSPORTATION OF THINGS

	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Transportation of Supplies and Equipment			
NASA Headquarters	$10,000	$20,000	$100,000
Langley Center	83,900	144,000	198,000
Ames Center	18,000	22,000	27,000
Lewis Center	102,190	145,000	169,000
Flight Center	12,800	9,000	15,000
Goddard Center	240,000	912,000	1,750,000
Wallops Station	60,000	90,000	100,000
Marshall Center	15,100	233,000	497,800
Western Office	300	600	1,000
	542,290	1,575,600	2,857,800
Drayage and Other Local Transportation			
NASA Headquarters	---	---	---
Langley Center	13,500	16,000	18,000
Ames Center	2,000	3,000	3,000
Lewis Center	10,000	15,000	15,000
Flight Center	---	---	---
Goddard Center	10,000	100,000	150,000
Wallops Station	---	---	---
Marshall Center	---	35,000	17,000
Western Office	---	---	---
	35,500	169,000	203,000
Total	$577,790	$1,744,600	$3,060,800

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

SUPPORT OF NASA PLANT

COMMUNICATIONS

Leased Lines	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
NASA Headquarters:			
Washington to Langley Center.....	$6,000	$10,000	$10,000
Washington to Western Office.....	48,000	50,000	50,000
	54,000	60,000	60,000
Langley Center:			
Langley Center to Wallops Station..	5,500	5,000	5,000
Lewis Center:			
Cleveland to Plum Brook Station....	3,810	10,000	10,000
Flight Center:			
Edwards, California to Ely and Beatty, Nevada.....	107,100	108,000	108,000
Wallops Station:			
Wallops Island to Wallops Station..	3,000	8,800	8,800
Wallops Station to NASA Headquarters.....	---	8,000	8,000
Wallops Station to Goddard Center..	---	8,000	8,000
Wallops Station to FAA Air Traffic Control and Air Force Stations....	---	55,000	55,000
	3,000	79,800	79,800
Marshall Center:			
Atlantic Missile Range to NASA Headquarters.....	---	---	47,000
Atlantic Missile Range to Pacific Missile Range.....	---	---	72,000
Atlantic Missile Range to Marshall Center.....	---	89,000	114,000
Lines to microlock stations.....	---	75,000	75,000
	---	164,000	308,000
Total.....	$173,410	$426,800	$570,800

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

SUPPORT OF NASA PLANT

REPAIRS, ALTERATIONS, AND MINOR CONSTRUCTION

	Automotive equipment and aircraft	Buildings, facilities and grounds	Instruments and scientific equip.	Shop and office equipment	Utility installations and process systems	Total
Fiscal Year 1960:						
NASA Headquarters...	---	---	---	$22,000	---	$22,000
Langley Center.....	$3,800	$470,900	$30,700	25,400	$43,900	574,700
Ames Center.....	108	274,636	25,405	5,687	60,119	365,955
Lewis Center.....	2,960	202,400	119,970	12,820	62,750	400,900
Flight Center.....	4,653	101,620	10,545	2,510	6,242	125,570
Goddard Center.....	---	195,000	11,000	---	---	206,000
Wallops Station.....	---	114,500	9,000	---	---	123,500
Marshall Center.....	---	---	100,000	100,000	---	200,000
Western Office.....	---	5,000	---	4,000	---	9,000
Total.....	$11,521	$1,364,056	$306,620	$172,417	$173,011	$2,027,625
Fiscal Year 1961:						
NASA Headquarters...	---	---	---	$25,000	---	$25,000
Langley Center.....	$5,000	$667,000	$100,000	30,000	$50,000	852,000
Ames Center.....	500	420,500	20,000	7,000	92,000	540,000
Lewis Center.....	3,000	320,000	204,000	13,000	102,000	642,000
Flight Center.....	12,200	20,100	22,200	3,200	18,500	76,200
Goddard Center.....	---	356,000	8,000	---	240,000	604,000
Wallops Station.....	---	293,700	222,500	---	---	516,200
Marshall Center.....	---	1,480,000	540,000	340,000	---	2,360,000
Western Office.....	---	400	---	5,000	---	5,400
Total.....	$20,700	$3,557,700	$1,116,700	$423,200	$502,500	$5,620,800

REPAIRS, ALTERATIONS, AND MINOR CONSTRUCTION - CONTINUED

	Automotive equipment and aircraft	Buildings, facilities and grounds	Instruments and scientific equip.	Shop and office equipment	Utility installations and process systems	Total
Fiscal Year 1962:						
NASA Headquarters.....	---	---	---	$30,000	---	$30,000
Langley Center.....	$5,000	$780,000	$160,000	30,000	$50,000	1,025,000
Ames Center.....	500	494,500	25,000	8,000	62,000	590,000
Lewis Center.....	3,000	245,000	252,000	12,000	148,000	660,000
Flight Center.....	7,000	---	30,000	2,500	8,500	48,000
Goddard Center.....	---	605,000	22,000	---	---	627,000
Wallops Station.....	---	502,450	252,700	---	---	755,150
Marshall Center.....	---	2,422,000	707,000	448,000	---	3,577,000
Western Office.....	---	500	---	5,500	---	6,000
Total.....	$15,500	$5,049,450	$1,448,700	$536,000	$268,500	$7,318,150

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

SUPPORT OF NASA PLANT

MISCELLANEOUS SERVICES

	Scientific services	Management and administrative services	Maintenance services	Shop services	All other services 1/	Total
Fiscal Year 1960:						
NASA Headquarters.....	$40,000	$250,000	---	---	$440,860	$730,860
Langley Center.....	83,800	34,125	$49,000	$19,000	17,150	203,075
Ames Center.....	100,647	60,311	12,730	7,069	---	180,757
Lewis Center.....	54,665	70,980	---	259,300	30,355	415,300
Flight Center.....	---	14,033	28,010	1,557	17,100	60,700
Goddard Center.....	2,000	18,000	---	---	15,000	35,000
Wallops Station.....	4,500	---	19,000	---	50,692	74,192
Marshall Center.....	1,237,000	281,000	250,000	---	300,500	2,068,500
Western Office.....	---	---	---	---	13,000	13,000
Total.....	$1,522,612	$728,449	$358,740	$286,926	$884,657	$3,781,384
Fiscal Year 1961:						
NASA Headquarters.....	$100,000	$250,000	---	---	$675,000	$1,025,000
Langley Center.....	129,000	143,000	$75,000	$20,000	20,000	387,000
Ames Center.....	74,500	66,500	40,000	8,000	---	189,000
Lewis Center.....	83,000	446,000	22,000	274,000	28,000	853,000
Flight Center.....	---	13,000	29,400	---	29,500	71,900
Goddard Center.....	340,000	144,000	---	---	235,000	719,000
Wallops Station.....	170,900	---	162,100	2,000	128,000	463,000
Marshall Center.....	2,310,000	626,000	498,000	100,000	921,000	4,455,000
Western Office.....	---	---	---	---	10,000	10,000
Total.....	$3,207,400	$1,688,500	$826,500	$404,000	$2,046,500	$8,172,900

MISCELLANEOUS SERVICES - CONTINUED

	Scientific services	Management and administrative services	Maintenance services	Shop services	All other services 1/	Total
Fiscal Year 1962:						
NASA Headquarters...	$120,000	$1,300,000	---	---	$2,486,000	$3,906,000
Langley Center.....	449,600	248,000	$75,000	$20,000	20,000	812,600
Ames Center.....	78,000	73,000	40,000	9,000	---	200,000
Lewis Center.....	120,000	557,000	30,000	285,000	28,000	1,020,000
Flight Center.....	---	60,100	27,400	7,500	15,000	110,000
Goddard Center.....	325,000	300,000	---	---	300,000	925,000
Wallops Station.....	25,000	---	315,000	2,000	180,000	522,000
Marshall Center.....	3,493,000	1,136,000	665,000	50,000	1,140,000	6,484,000
Western Office.....	---	---	---	---	10,000	10,000
Total.....	$4,610,600	$3,674,100	$1,152,400	$373,500	$4,179,000	$13,989,600

1/ Includes abstracting, microfilming, fabrication of exhibits, photographic and film processing services, and other specialized services at NASA Headquarters; plant protection services at Goddard and Wallops; chemical cleaning and rental of motor vehicles for transportation of supplies, equipment, and space vehicle components at Marshall; and minor miscellaneous services at all locations.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

SUPPORT OF NASA PLANT

SERVICES OF OTHER AGENCIES

	Army	Navy	Air Force	Commerce and G.S.A.	Agri-culture	Others	Total
Fiscal Year 1960:							
NASA Headquarters	$10,000	$50,000	---	$174,000	---	$90,000	$324,000
Langley Center...	2,400	48,000	$4,000	---	---	9,600	64,000
Ames Center.....	---	35,138	8,000	---	---	60	43,198
Lewis Center.....	1,400	550	90	200	---	1,560	3,800
Flight Center....	---	---	330	---	---	---	330
Goddard Center...	---	1,354,000	---	---	$65,000	---	1,409,000
Wallops Station..	---	---	---	63,000	---	---	63,000
Marshall Center..	150,000	---	---	---	---	---	150,000
Western Office...	---	---	---	---	---	---	---
Total.....	$163,800	$1,487,688	$12,420	$237,200	$65,000	$101,220	$2,057,328
Fiscal Year 1961:							
NASA Headquarters	$20,000	$55,000	---	$135,000	---	$95,000	$305,000
Langley Center...	3,000	51,000	---	---	---	11,000	65,000
Ames Center.....	500	99,500	$500	---	---	500	101,000
Lewis Center.....	1,400	600	100	200	---	2,700	5,000
Flight Center....	---	---	900	---	---	---	900
Goddard Center...	---	332,000	---	---	$377,000	43,000	752,000
Wallops Station..	---	40,000	---	160,600	---	32,400	233,000
Marshall Center..	2,819,000	---	600,000	---	---	---	3,419,000
Western Office...	---	---	---	---	---	---	---
Total.....	$2,843,900	$578,100	$601,500	$295,800	$377,000	$184,600	$4,880,900

SERVICES OF OTHER AGENCIES - CONTINUED

	Army	Navy	Air Force	Commerce and G.S.A.	Agri-culture	Others	Total
Fiscal Year 1962:							
NASA Headquarters.....	$50,000	$125,000	---	$140,000	---	$195,000	$510,000
Langley Center.....	3,000	51,000	---	---	---	11,000	65,000
Ames Center.....	500	99,500	$500	---	---	500	101,000
Lewis Center.....	1,400	600	100	200	---	2,700	5,000
Flight Center.....	---	---	1,000	---	---	---	1,000
Goddard Center.....	---	230,000	---	---	$720,000	50,000	1,000,000
Wallops Station.....	---	40,000	---	240,000	---	25,000	305,000
Marshall Center.....	2,829,000	260,000	421,000	---	---	---	3,510,000
Western Office.....	---	---	---	---	---	---	---
Total.....	$2,883,900	$806,100	$422,600	$380,200	$720,000	$284,200	$5,497,000

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

SUPPORT OF NASA PLANT

SUPPLIES AND MATERIALS

	Fabrication	Plant operations	Maintenance and improvements	Office operations	Report reproduction	Medical, security and safety	Propellants, fuels, and lubricants: Missile propellants	Propellants, fuels, and lubricants: All other	Total
Fiscal Year 1960:									
NASA Headquarters	---	---	---	$283,000	---	---	---	---	$283,000
Langley Center...	$1,030,500	$440,000	$450,000	260,000	$150,000	$20,000	$500,000	$430,000	3,280,500
Ames Center.....	505,000	251,300	188,000	129,500	40,000	10,600	---	125,000	1,249,400
Lewis Center.....	877,600	947,000	146,000	85,400	35,000	17,900	500,000	159,000	2,767,900
Flight Center....	95,500	149,500	93,000	14,000	2,500	2,500	8,000	9,500	374,500
Goddard Center...	---	56,700	61,400	167,500	11,400	---	---	3,000	300,000
Wallops Station..	106,000	100,000	100,000	20,000	---	4,000	30,000	120,000	480,000
Marshall Center..	500,637	120,000	272,260	296,640	---	---	150,000	70,000	1,409,537
Western Office...	---	---	---	7,700	---	---	---	---	7,700
Total.....	$3,115,237	$2,064,500	$1,310,660	$1,263,740	$238,900	$55,000	$1,188,000	$916,500	$10,152,537
Fiscal Year 1961:									
NASA Headquarters	---	---	---	$300,000	---	---	---	---	$300,000
Langley Center...	$2,905,000	$500,000	$520,000	275,000	$155,000	$20,000	$700,000	$500,000	5,575,000
Ames Center.....	466,000	284,000	186,000	132,000	40,000	12,000	---	130,000	1,250,000
Lewis Center.....	655,000	1,000,000	200,000	90,000	35,000	20,000	1,150,000	700,000	3,850,000
Flight Center....	110,000	100,400	114,300	28,800	2,500	4,000	30,000	10,000	400,000
Goddard Center...	204,000	191,000	263,000	415,000	94,000	25,000	---	35,000	1,227,000
Wallops Station..	45,000	150,000	150,000	20,000	---	4,000	27,000	189,000	585,000
Marshall Center..	600,000	130,000	320,000	347,000	12,000	19,000	175,000	62,000	1,665,000
Western Office...	---	---	---	8,000	---	---	---	---	8,000
Total.....	$4,985,000	$2,355,400	$1,753,300	$1,615,800	$338,500	$104,000	$2,082,000	$1,626,000	$14,860,000

SUPPLIES AND MATERIALS - CONTINUED

	Fabrication	Plant operations	Maintenance and improvements	Office operations	Report reproduction	Medical, security and safety	Propellants, fuels, and lubricants: Missile propellants	Propellants, fuels, and lubricants: All other	Total
Fiscal Year 1962:									
NASA Headquarters	---	---	---	$400,000	---	---	---	---	$400,000
Langley Center...	$5,450,000	$540,000	$545,000	285,000	$155,000	$20,000	$2,000,000	$500,000	$9,495,000
Ames Center.....	475,000	300,000	195,000	142,000	40,000	13,000	---	135,000	1,300,000
Lewis Center.....	750,000	1,415,000	290,000	100,000	35,000	20,000	1,850,000	700,000	5,160,000
Flight Center....	165,000	145,000	195,000	34,500	2,500	6,000	40,000	15,000	603,000
Goddard Center...	75,000	70,000	200,000	285,000	60,000	20,000	---	60,000	770,000
Wallops Station..	200,000	250,000	180,000	20,000	---	4,000	30,000	221,000	905,000
Marshall Center..	2,411,000	435,000	1,500,000	935,000	13,000	30,000	303,000	200,000	5,827,000
Western Office...	---	---	---	12,000	---	---	---	---	12,000
Total.....	$9,526,000	$3,155,000	$3,105,000	$2,213,500	$305,500	$113,000	$4,223,000	$1,831,000	$24,472,000

Definitions of Functional Headings

Fabrication - In-house construction of models, research set-ups, test set-ups, test vehicles, temporary installations, instruments, and items of equipment.

Plant operations - Operation of all facilities, supporting shops, utility systems, motor vehicles, and aircraft.

Maintenance and improvements - Maintenance, repair, alteration, or improvements to land, buildings, structures, facilities, equipment, roads, utility systems, motor vehicles, and aircraft.

Office operations - Office activities, including drafting, library, and computing functions, and reproduction work not included under "Report reproduction".

Report reproduction - Processing, duplicating, and distributing research reports.

Medical, security, and safety - Execution of health, security, and safety programs.

Propellants, fuels, and lubricants:

Missile propellants - Solid and liquid rocket and missile propellants.

All other - Nuclear fuel elements and all fuels and lubricants other than missile propellants.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

SUPPORT OF NASA PLANT

EQUIPMENT

	Scientific instruments	Other scientific equipment	Utility systems, service, and safety equipment	Machine tools and shop equipment	Automotive and other mobile equipment	Drafting, office, and reproduction equipment	Total
Fiscal Year 1960:							
NASA Headquarters.....	---	---	---	---	$1,500	$293,500	$295,000
Langley Center.....	$280,000	$615,000	$112,000	$25,000	38,080	145,000	1,215,080
Ames Center.....	281,261	1,193,476	39,129	70,563	3,071	50,210	1,637,710
Lewis Center.....	866,300	1,548,300	45,000	57,200	76,600	93,600	2,687,000
Flight Center.....	11,500	134,600	18,610	11,970	29,000	18,020	223,700
Goddard Center.....	296,000	717,000	---	678,000	86,000	184,800	1,961,800
Wallops Station.....	18,200	34,500	14,700	5,100	9,200	34,300	116,000
Marshall Center.....	120,000	55,000	---	400,000	---	104,500	679,500
Western Office.....	---	---	---	---	---	26,300	26,300
Total.....	$1,873,261	$4,297,876	$229,439	$1,247,833	$243,451	$950,230	$8,842,090
Fiscal Year 1961:							
NASA Headquarters.....	---	---	---	---	---	$280,000	$280,000
Langley Center.....	$1,009,000	$703,000	$105,000	$60,000	$46,000	95,000	2,018,000
Ames Center.....	270,000	1,480,500	40,000	80,000	4,500	90,000	1,965,000
Lewis Center.....	875,000	2,353,780	46,000	57,500	97,720	80,000	3,510,000
Flight Center.....	10,500	321,150	25,780	5,500	8,500	12,570	384,000
Goddard Center.....	732,100	558,000	22,400	144,000	95,400	204,100	1,756,000
Wallops Station.....	115,000	123,000	170,600	9,400	77,000	11,000	506,000
Marshall Center.....	436,000	188,000	260,000	561,000	257,000	290,000	1,992,000
Western Office.....	---	---	---	---	---	11,000	11,000
Total.....	$3,447,600	$5,727,430	$669,780	$917,400	$586,120	$1,073,670	$12,422,000

EQUIPMENT - CONTINUED

	Scientific instruments	Other scientific equipment	Utility systems, service, and safety equipment	Machine tools and shop equipment	Automotive and other mobile equipment	Drafting, office, and reproduction equipment	Total
Fiscal Year 1962:							
NASA Headquarters.....	---	---	---	---	$6,000	$324,000	$330,000
Langley Center.....	$1,225,000	$1,296,000	$160,000	$65,000	75,000	100,000	2,921,000
Ames Center.....	270,000	2,128,000	248,000	68,500	4,500	60,000	2,779,000
Lewis Center.....	950,000	3,538,850	46,000	105,000	60,150	80,000	4,780,000
Flight Center.....	14,000	832,700	16,850	6,500	20,950	9,000	900,000
Goddard Center.....	1,268,000	1,242,000	70,000	277,000	25,000	396,000	3,278,000
Wallops Station.....	112,900	120,000	169,950	10,900	74,300	15,000	503,050
Marshall Center.....	2,713,000	1,490,000	266,000	1,450,000	124,000	468,000	6,511,000
Western Office.....	---	---	---	---	---	15,000	15,000
Total.....	$6,552,900	$10,647,550	$976,800	$1,982,900	$389,900	$1,467,000	$22,017,050

SUMMARY OF EQUIPMENT REQUIREMENTS

	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Replacement.....	$666,000	$1,628,100	$4,062,850
New.....	8,176,090	10,793,900	17,954,200
Total.....	$8,842,090	$12,422,000	$22,017,050

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

RESEARCH GRANTS AND CONTRACTS

SUMMARY OF REQUIREMENTS:

	1960	1961	1962	Page No.
Research Grants and Contracts..	$4,869,370	$5,000,000	$7,600,000	RD2-2

OBJECTIVES:

To utilize as effectively as possible the capabilities of nongovernment organizations in carrying out under grant or contract research fundamental to the national space and aeronautical programs; and to encourage the maintenance of the national capability to conduct research in the fields of interest to these programs.

JUSTIFICATION:

The knowledge required to form a broad fundamental program of research to support the objectives of the space exploration program encompasses almost all the scientific disciplines. Basic research is the foundation of all research endeavors, upon which applied research, advanced technology and advanced developments are strongly dependent.

In addition to basic research effort which is part of the NASA in-house research programs, there are many organizations, specifically colleges and universities, nonprofit research institutes, and industrial research laboratories, which are rich in scientific talent and unique facilities. The utilization of these sources of research capability will assure a continuing flow of fundamental knowledge vital in importance to the national space and aeronautical programs.

The importance of encouraging these organizations lies in keeping active possible sources of significant contribution. In particular the support of universities and colleges not only permits the educational system to keep up to date and maintain competence in the various scientific disciplines but, at the same time, allows our scientific strength to be focused on national programs of technological importance.

FUNDING REQUIREMENTS:

	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Physical Sciences.....	$1,185,676	$1,200,000	$1,800,000
Engineering Sciences.....	1,681,456	2,000,000	5,100,000
Propulsion Sciences.....	---	800,000	1/
Biosciences.....	916,990	1/	1/
Cosmological Sciences.....	656,845	500,000	1/
Socio-Economic and Miscellaneous Studies.....	428,403	500,000	700,000
Total.....	$4,869,370	$5,000,000	$7,600,000

1/ Funded under other programs.

Funding for this program of fundamental research is variously budgeted. Requirements associated with propulsion sciences and cosmological sciences are budgeted as subelements of the various research and development programs which such research studies are most predominantly expected to benefit. Requirements within the field of biosciences which principally affect the scientific disciplines of the Life Sciences Programs are almost totally budgeted under those programs. Requirements for the physical sciences, engineering sciences, and for the socio-economic and miscellaneous studies, all of which can broadly affect several scientific disciplines, are separately budgeted under the Research Grants and Contracts program as follows:

Physical Sciences

A broad range of sponsored research in physics, chemistry, and mathematics, relevant to space technology, has been undertaken in the recent past and will be continued in the fiscal year 1962. Subjects of investigation include research on high velocity and excited molecular and atomic species, physics of solids at high temperature, magnetohydrodynamics, fundamental cohesive forces in materials, energetic chemical reactions, heat-exchange methods in the absence of gravity, differential equations of space flight trajectories, studies of properties of liquid metals, studies of plasmas, high-energy fuels research, and gas dynamics. These represent a cross section of the areas to be investigated, and in the scientific spectrum related to aeronautical and space research.

Engineering Sciences

The knowledge provided by basic scientific research points up a wide variety of possible new techniques and approaches. To properly utilize the advances that are afforded by new theories and techniques, research is also conducted to seek means of applying the basic knowledge in the solution of advanced technical problems. These in turn provide the researcher with

the fundamental tools necessary to seek solutions to technical problems that may have practical application. The engineering sciences are thus more directly focused toward the practical applications that will formulate the bases of advanced technology and design. Programs of interest in this category include energy production and conversion, space communications and telemetry, millimeter wave length astronomical devices, boundary layer aerodynamics, heat transfer, thermal stability of materials, alloy development, structural dynamics and stability of shells and other vehicle geometrics, theory of control systems, pump cavitation, and rocket engine combustion dynamics. These examples point up the diversity of problem areas and each represents a significant challenge which must be met.

Socio-Economic and Miscellaneous Studies

The impact of space exploration on the course of civilization poses many difficult and absorbing questions. To assure sound policy determination and program planning, studies of social and economic problems that arise from the creation and utilization of space technology are required. Examples of the types of studies that must be undertaken are on the social and economic influence of communication satellites and meteorological satellites. There is an urgent need to expand the studies presently being undertaken and to initiate additional studies of similar problems that arise as our space technology broadens.

The activities of the Space Science Board of the National Academy of Sciences, and scientific symposia of direct concern to the space program of the National Aeronautics and Space Administration are examples of the other types of activities that are supported as a part of this program.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

LIFE SCIENCE PROGRAMS

SUMMARY OF REQUIREMENTS:

	1960	1961	1962	Page No.
Advanced Research.....	---	$2,419,000	$2,570,000	RD3-5
Advanced Technical Development	---	1,331,000	2,250,000	RD3-7
Flight Program.....	---	1,250,000	3,800,000	RD3-8
Total.....	---	$5,000,000	$8,620,000	

OBJECTIVES:

To assure man's contribution to the success of space flight missions and to utilize his unique capabilities as a scientific observer in space exploration in both remotely controlled and directly controlled systems; and to conduct biological investigations to determine the effects of remote environments on living organisms including the search for extra-terrestrial life. The latter effort can be expected to contribute knowledge pertaining to the origin of life and its evolution in the universe, which is one major scientific goal to be achieved in the total space program.

JUSTIFICATION:

Although significant engineering achievements in rocketry, automation, sensing, recording, programming and telemetering have been realized and considerable future development is in prospect, the indispensability of man in space exploration is well founded. Man's versatility, selectivity and ability to perceive and utilize the significance of the unexpected and to react intelligently in unanticipated situations have not been simulated by any physical device. Since the human brain is the ultimate reservoir and integrator of all human knowledge, its relationship to both remotely controlled and directly controlled systems must be a prime consideration. The use of space as a new dimension for basic biological investigations will contribute to the explanation of hitherto unexplained biological phenomena.

Under current NASA concepts, the Life Sciences program is accomplished within three principal scientific disciplines which are further discussed below. For the sake of budgetary consistency, program requirements have

been expressed by the functional classifications Advanced Research, Advanced Technical Development, and Flight Program. However, detailed funding requirements presented later in this write-up will be grouped into the following for scientific disciplines:

Flight Medicine and Biology

This field of scientific inquiry consists of biotechnology and the operational aspects of life sciences experiments.

The biotechnology research, development, test and operations program is required in order to provide the capability for manned exploration and exploitation of space and the improved utilization of remote vehicles and sampling devices. This includes: (a) the use and creation of new methods to provide information in a form readily accessible to the human brain; (b) the improvement of effectiveness of both directly-controlled and remotely-controlled vehicle systems; (c) the provision of adequate life supporting environments for extraterrestrial missions; (d) coordination with other agencies and industry in the application of NASA Life Science information to advanced aircraft; (e) providing capability for crew selection and training; and (f) providing techniques and design criteria to insure public safety.

The long-range benefits which may accrue from manned space flight are, in a large measure, unknown. It is clear, however, that instrumentation alone will not tell us as much about the moon, or the planets, as man himself will be able to report once he has visited those distant places. Man contributes observational, analytical, and decision-making ability concerning both expected and unanticipated problems. He provides a vast flexibility of action for operation, correction, and maintenance of scientific and technological instrumentation and equipment that characterize his present usefulness in aircraft and in the scientific laboratory. By means of improved physical sensors, information display, and ground control integration, man can also contribute to increased effectiveness and capability of remotely operating unmanned vehicles, sample collecting, and analyzing devices for both physical and biological scientific investigations.

The operational aspects of work in the flight medicine and biology areas are expected to: (a) provide for safety and to demonstrate the feasibility of space flight; (b) organize Life Science support programs for launch and recovery operations; (c) provide space laboratories for full scale research and development programs; (d) determine the effects on earth life forms of extraterrestrial environments including those of the earth's upper atmosphere, space, the moon and planets; (e) search for extraterrestrial life and information relative to the origin of life; and (f) plan for laboratories on the moon and planets.

The opportunity now exists to conduct fundamental life sciences research in satellites and space probes. The space environment presents a new dimension for observation of biologic phenomena. The ultimate goal is the identification and study of life, its precursors, or remains, on the

moon and planets. This accomplishment would lead to knowledge pertaining to the origin of life and its evolution.

Immediate interest centers on the conditions of the space flight environment that are irrevocably different from the terrestrial, namely, radiation and the altered gravity state. The former is qualitatively and quantitatively different from terrestrial radiation and has far-reaching implications regarding future manned space flight missions as well as offering opportunity for further delineation of the subcellular ionizing effects from a basic biological viewpoint. The weightless state presents the opportunity for determining its effects on performance in animals and men subjected to long duration removal of the constant stimulation of specialized bodily sensors by the force of gravity, and, elucidation of biological processes affected by weight or apposition of one part against another, such a cell division and morphogenesis.

The hazards of space flight are such that tests to insure survival and meaningful performance must be determined with animals prior to subjecting man to this experience involving application of combined stresses which can be expected to alter the distribution of blood flow to vital organs including the brain, heart, lungs, and kidneys as well as the neurological consequences of long-term altered sensory input as it affects internal regulating systems and the mind. In-flight tests of life support systems as regards their long-duration adequacy, efficiency, and reliability in maintaining a habitable artificial environment will precede trials with men.

Biological studies conducted at a cellular and subcellular level in the extraterrestrial environment, in addition to those concerned with radiation and weightlessness, will include observations of the effects of high vacuum, temperature extremes, and the unusual combinations of elements to be found in remote planetary atmospheres and surfaces. These investigations can be profitably extended by spectroscopic studies directed toward more precise identification of extraterrestrial life supporting substances from outside the earth's atmosphere.

Space Medical and Behavioral Sciences

Activity in this field is directed toward obtaining basic metabolic, physiologic and psychologic contributions for implementation of manned space flight. Included are observations and studies of the fundamental aspects of the reactions of animals and men related to space flight and exploration as they affect survival and performance; and studies of human ecology as it relates to advances in space science and technology.

As manned space flights become voyages of days, weeks, or months duration, there is need for a more fundamental approach to problems involving the basic medical and behavioral disciplines of radiology, metabolism, cardiovascular physiology, respiratory physiology, neurophysiology, psychology, and sociology.

Physical measurements of the radiations in space have defined the requirements for more precise evaluation of the effects of long-term, relatively low dosages of ionizing radiation and the finding of means for protection therefrom in addition to conventional shielding techniques. Altered metabolic reactions achieved through temporary lowering of body temperatures or pharmacologic means hold promise of affording varying degrees of protection from radiation or effects which may result from exposure to other sources of energy in the electromagnetic spectrum as occur in space flight.

Metabolic requirements of animals and men in terms of energy exchange, heat transfer, and nutrition under the limitations imposed by confinement in an artificial space capsule environment pose problems of a fundamental nature which require further study.

Acceleration forces and weightlessness produce a redistribution of blood flow to the heart, lungs, brain, and kidneys. The chronic effects of these physical stresses on vital organs and adaptation thereto, as well as the long-term cardiovascular effects of restricted mobility, are subjects for detailed scientific consideration as they relate to space exploration.

Long-term living in an artificial atmosphere which can be expected to deviate from optimal conditions on occasion necessitates further study of the process of diffusion of gases including toxic substances from the lungs to blood and from blood to body tissues as well as further consideration of the chemical alterations incident to pulmonary ventilation.

More detailed knowledge of nervous system sensors; visual and auditory perception; the physiologic substrate of orientation, thought, and emotion, the neural control of respiration, cardiovascular function, temperature, and metabolism; and, the neurophysiological aspects of environmental adaptation and fatigue as well as psychological reactions involved in motivation, vigilance, and social adjustment, reflect a series of important areas of concern in regard to man's performance under conditions imposed in flight.

Investigations in the medical and behavioral sciences will also contribute knowledge in these areas which will result in a better understanding of health and disease on earth.

Rapid advances in science and technology, particularly improvements in communications and rapid transportation, lend increasing emphasis to man's relationships to other men and to his total environment. The life sciences provide an appropriate-focal point for collection and dissemination of information concerning human ecology.

Radiation hazards in projected manned space flight missions to the moon and planets make radiology a primary area of effort. In addition to the ambient radiation in space, the proposed use of nuclear energy for auxiliary power and for propulsion lend more emphasis to this field.

The psychophysiological concomitants of weightlessness, isolation and confinement are high priority areas of concern included in the basic medical and behavioral sciences.

Stimulation of interest and mobilization of talent for research in the medical schools and other research institutions will be carried out in the disciplines as well as in cardiovascular physiology metabolism and respiratory physiology.

Space Biology

The objectives of this activity are: (a) studies of the effects of newly defined extraterrestrial environments on living organisms; (b) assessment of organic chemical life-supporting compounds on extraterrestrial sites; (c) development of means of remote identification and analysis of possible extraterrestrial life forms; and (d) preventing terrestrial organic chemical or microbiological contamination of extraterrestrial bodies in order to preserve them for study of life processes.

A major goal for scientific achievement in space exploration is the acquisition of further knowledge of the origin of life and its evolution. The search for extraterrestrial life bears directly on this problem and includes further investigation of extraterrestrial organic compounds which tentatively have been identified. Authorities agree that probes and vehicles flown in search of extraterrestrial life must themselves contain no life--in other words, decontaminated or sterilized.

Zero-g; ionizing radiation and other components of the electromagnetic spectrum; high vacuum; temperature extremes; and unusual combinations of substances in planetary atmospheres and surfaces as found in space environments, provide a new vantage point for observation of the biologic effects on simple organisms, including intimate details of the molecular control of life processes.

FUNDING REQUIREMENTS:

Advanced Research	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Flight Medicine and Biology.....	---	$740,000	$855,000
Space Medical and Behavioral Sciences..	---	1,000,000	1,000,000
Space Biology.....	---	679,000	715,000
Total, Advanced Research	---	$2,419,000	$2,570,000

Advanced Research	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Flight Medicine and Biology:			
Compiling existing data against known requirements for advanced manned flight systems and documenting for rapid machine access...	---	$50,000	$100,000
Conceptual definition of the integrated requirements necessary to control environment for "Apollo" and other manned flight programs...	---	145,000	145,000
Define information needed, control requirements, display requirements, computer requirements and integration requirements necessary for the man-machine linkage for the performance control of "Apollo" and generalized vehicle and sub-vehicles.....	---	425,000	425,000
Organizing data from AEC and other sources to define and provide the biotechnology needed for protection of ground and flight personnel in the coming nuclear systems.....	---	45,000	60,000
Providing requirements and methodology for real time linkage of a remote human operator to improved control of physical science experiments at a distance from the operator.....	---	75,000	125,000
	---	740,000	855,000
Space Medical and Behavioral Sciences:			
Cardiovascular physiology.....	---	147,000	80,000
Metabolism.....	---	162,000	170,000
Neurophysiology.....	---	302,000	250,000
Psychology.....	---	65,000	65,000
Radiology.....	---	164,000	295,000
Respiratory physiology.....	---	65,000	55,000
Pathology.....	---	20,000	20,000
Sociology.....	---	10,000	5,000
Information exchange.....	---	65,000	60,000
		1,000,000	1,000,000

Advanced Research	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Space Biology:			
Sterilization by radiation and heat	---	$110,000	---
Chemical analysis of meteorites	---	---	$38,000
Compendium for spectroscopic analysis of organic compounds	---	195,000	---
Extraterrestrial environmental studies	---	17,000	17,000
Microorganisms under simulated conditions	---	63,000	80,000
Effects of space environments on cellular systems	---	---	500,000
Martian and Venus simulation study	---	174,000	60,000
Study of microorganisms in the upper atmosphere	---	16,000	20,000
Experiments in prebiological chemistry	---	104,000	---
	---	679,000	715,000
Total, Advanced Research		$2,419,000	$2,570,000
Advanced Technical Development			
Flight Medicine and Biology	---	$1,010,000	$1,465,000
Space Medical and Behavioral Sciences	---	---	---
Space Biology	---	321,000	785,000
Total, Advanced Technical Development	---	$1,331,000	$2,250,000
Flight Medicine and Biology:			
Providing preliminary integrated environment control technology for "Apollo" and other manned flight programs	---	$115,000	$115,000
Providing preliminary development of advanced control and display equipment for human operators of space vehicles	---	375,000	375,000
Simulation programs for checking environment and control systems	---	250,000	350,000
Integrated control program for better linking a remote human operator with biological experiments	---	100,000	245,000
Bioelectric sensing and transmitting equipment for human control of remote vehicle systems	---	100,000	300,000

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Coordinating programs between DOD and FAA to insure that NASA developed technology is usefully integrated into advanced aircraft.			
Feasibility devices.....	---	$70,000	$80,000
		1,010,000	1,465,000
Space Biology:			
Operational techniques for space probe decontamination.....	---	30,000	30,000
Advanced development and application of decontamination techniques	---	28,000	100,000
Instruments for remote analysis of organic compounds.....	---	99,000	180,000
Remote sampling instrument for planetary microorganisms.....	---	18,000	40,000
Biochemical probe for extraterrestrial life.....	---	146,000	---
Planetary cytochemical instrumentation.....	---	---	435,000
		321,000	785,000
Total, Advanced Technical Development.....	---	$1,331,000	$2,250,000
Flight Program			
Flight Medicine and Biology.....	---	$1,250,000	$3,800,000
Space Medical and Behavioral Sciences.	---	---	---
Space Biology.....	---	---	---
Total, Flight Program.....	---	$1,250,000	$3,800,000
Flight Medicine and Biology:			
Research and development activities associated with the exposure of primates to the space environment with recovery from orbital flight..	---	$249,000	$765,000
Final design and testing integration of research instrumentation.....	---	185,000	1,205,000
Biological investigations in flight conducted at a cellular and subcellular level.....	---	336,000	555,000

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Launch and recovery support program:			
Emergency and survival equipment for escape from vehicles in space.....	---	---	$50,000
Development of methods to predict efficiency of the experimental animal through the assessment of viability and performance, and to stepwise interpret the efficiency equation for mission planning purposes.....	---	$20,000	25,000
Flight vehicles for experiments with small animals and biological payloads.....	---	150,000	500,000
Two mobile laboratory vehicles to serve at launch sites.....	---	50,000	---
Equipment for mobile laboratories such as air conditioning, heat, electricity, water, benches, chairs, and scientific equipment such as microscopes, centrifuge, chemicals, glassware, etc.....	---	20,000	10,000
Support at launch and recovery sites.....	---	60,000	150,000
Non-NASA experimenters and assistants at recovery site. Transportation and per diem for average of 7 days for 2 people for 10 flights.....	---	15,000	30,000
Special air transport of biological material.....	---	20,000	40,000
Non-NASA experimenters and assistants at launch site.....	---	10,000	60,000
Manned space laboratory programs; research and development on operational equipment in support of orbiting manned space laboratory.....	---	---	120,000
Lunar and planetary probe sampler program; development and fabrication of experimental hardware and integration of experiment and vehicle including lunar and planetary probe landings. 6 flights (Centaur - Surveyor).....	---	135,000	270,000

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Feasibility study for manned lunar and planetary laboratory.....	---	---	$20,000
Total, Flight Program.....		$1,250,000	$3,800,000

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

SOUNDING ROCKETS

SUMMARY OF REQUIREMENTS:

	1960	1961	1962	Page No.
Advanced Research.....	$418,529	$420,000	$320,000	RD4-4
Advanced Technical Development	834,671	490,000	420,000	RD4-5
Flight Program.....	8,427,800	7,260,000	6,260,000	RD4-6
Total.....	$9,681,000	$8,170,000	$7,000,000	

OBJECTIVES:

To investigate geophysical phenomena from the earth's surface through satellite altitudes, using sounding rockets and other probing techniques. To perform astronomical observations by measuring the radiation arriving from other celestial bodies from above the obscuring and distorting effects of the earth's atmosphere. To investigate the structure of the atmosphere, the ionosphere, the geomagnetic field, energetic particles, and the chemistry and solar dynamical effects of the upper atmosphere.

JUSTIFICATION:

A sounding rocket may be defined as a rocket used to carry a payload to an altitude no greater than 4,000 miles (one earth's radius) and which then falls back to the earth. These rockets have the capability of performing those experiments in the upper reaches of the ionosphere and atmosphere that cannot be accomplished by means of satellites. For instance, a rocket experiment can obtain a vertical cross section measurement of the characteristics of the atmosphere in the short time required for its climb to maximum altitude. Also, rockets carrying recoverable payloads will permit a more detailed study of energetic particles of solar origin, cosmic rays, and the lower regions of the Van Allen radiation belts. Tasks for which sounding rockets are particularly suited include:

1. Direct measurements of atmospheric conditions above the maximum obtainable balloon and airplane altitude and below the minimum useful satellite altitude; that is, 20 to 125 miles.

2. Measurements of vertical atmospheric cross-section over any altitude range.

3. Simultaneous measurements (synoptic observations) above a number of selected locations, possibly timed to coincide with some unusual event such as a solar flare.

4. Upper air measurements which require a very large payload power level for only a short period of time.

5. Experiments which require the recovery of experimental materials or devices after a short exposure at altitudes up to several thousand miles.

6. Flight testing satellite and space probe equipment at a much lesser cost than the same tests would require using space vehicles associated with such satellites and space probes.

Sounding rockets offer a comparatively inexpensive method of performing many scientific observations. They have a comparatively short lead time for procurement, and payload development time is much less than that required for the heavier, more complex, longer lived satellite payloads. Thus, the sounding rocket is an extremely flexible tool for use in space sciences. Due to the flexibility of the program, a scientist can perform an experiment, study his results, and design and build a new experiment based upon his findings in the space of approximately one year. The sounding rocket schedule is, therefore, usually defined in detail for only approximately one year in advance. This is to be contrasted with research using satellites in which lead times of two years are usual for small satellites, and three years are required for the highly complex satellite payloads.

Operationally, the sounding rocket program is divided into categories according to the nature of the experiment or investigation. These categories are as follows:

Aeronomy

This study area is concerned with investigations of the atmosphere including its composition, chemical reactions, dynamical processes, the interactions of the atmosphere with solar energy and the variations of these properties from day to night and with season of the year. Mass spectrometers and temperature, pressure and density gages are the instruments most commonly used. Sodium vapor releases and grenade experiments are techniques that are employed for the determination of winds, diffusion effects, and the dynamics of the upper atmosphere.

Energetic Particles and Fields

Included in this area are those experiments directed at achieving a better understanding of the nature, origin, and characteristics of energetic particles (electrons, atoms, neutrons and ions having large amounts of

energy and consequently possessing properties that may roughly be described as similar to the radiation from radioactive substances). Also included are those experiments studying the magnetic field of the earth and its characteristics, and the interactions that occur between energetic particles and the magnetic field and atmosphere of the earth are included. Examples of studies in this category include investigations of cosmic rays, gamma rays, auroral phenomena, energetic particles released by the sun especially during periods of enhanced activity (solar storms and flares), and the lower region of the Van Allen radiation belts surrounding the earth. The instruments used in these studies include magnetometers, Geiger counters, other types of detectors including ion and scintillation counters, and complex arrays of these that are usually referred to as "telescopes" (i.e., a gamma ray telescope). A laboratory technique that has been an extremely valuable tool for studies of cosmic rays and radioactivity can also be used when recovery of the rocket payload can be arranged. This technique involves the use of special photographic emulsions. The emulsions are sensitive to energetic particles and permit identification of the various particles through studies of the characteristics of the paths of the particles in the emulsions.

Ionospheric Physics

This area includes all investigations of the ionized (electrified) regions of the earth's atmosphere. Studies here are directed at determining the number and composition of the ions (atoms and molecules bearing an electric charge) and the concentration of the electrons in the earth's atmosphere. The path and propagation characteristics of radio waves over the surface of the earth are determined by the electrons present in the ionosphere. The more common types of instrumentation include ion spectrometers; Langmuir, ion, and electron probes; radio frequency impedance probes; and electric field meters. Other techniques for studying the ionosphere are based upon the strong influence exerted by the ionosphere on radio wave propagation. These techniques include single and multi-frequency propagation experiments and soundings from both the ground and from rockets to determine ionospheric absorption, refraction, and polarization effects.

Astronomy

Astronomy is particularly significant because the astronomical experiments included here were not possible before sounding rockets and satellites made it possible for astronomers to make observations from above the earth's atmosphere. This is important because the atmosphere actually permits the transmission to the surface of the earth of only a small amount of the total electromagnetic radiations arriving from the sun and other celestial bodies. This small amount is in the visible region and even here the atmosphere causes blurring and distorting effects. X-ray, ultraviolet, and infrared radiations are not transmitted by the earth's atmosphere. Information deduced from studies of these radiations emitted by the sun, planets, and stars will yield a much more advanced understanding of the nature, composition and phenomena of these bodies, and

eventually lead to a better understanding of the origin and nature of the solar system and perhaps of the universe. The experiments performed by means of sounding rockets usually include one or more specialized detectors and accompanying filters or spectroscopes. Typical experiments are those designed to study the nature and to measure the intensity of the X-rays or ultraviolet radiation from the sun (solar physics), a star (galactic astronomy), or other specific source. For these experiments the rocket payload usually includes special instrumentation designed to train the instruments upon the object under investigation independently of the motion or position of the rocket.

Special

This last category includes all other sounding rocket experiments that do not fall within one of the categories described above. Included here are special launches for testing rocket performance and vehavior, and highly specialized payloads such as those instrumented primarily for engineering or materials testing purposes or for micrometeorite detection.

In summary, sounding rocket investigations make it possible to study certain altitude regions otherwise inaccessible; provide a relatively inexpensive means for the development of new instruments and experiments; enable the experimenter to collect data far closer to when and where he wishes to than is possible with any other vehicle; and because of the short time required to prepare and launch experiments, make it possible to move quickly into the investigation of new and valuable study areas.

FUNDING REQUIREMENTS:

Advanced Research	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Aeronomy:			
Mass spectrometer.....	$29,494	$60,000	$50,000
Ultraviolet scattering densitometer.....	59,629	60,000	50,000
	89,123	120,000	100,000
Energetic Particles and Fields:			
Riometer measurements (Northern Hemisphere).....	---	---	35,000
Solar cosmic ray events.....	20,000	30,000	35,000
	20,000	30,000	70,000

Advanced Research	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Ionospheric Physics:			
Plasma environment measurements....	$117,500	---	---
Ionosphere propagation measurements	91,906	---	---
	209,406	---	---
Astronomy:			
Ultraviolet mapping experiment.....	100,000	---	---
International Program.....	---	$170,000	$150,000
Sounding Rocket Handbook.....	---	100,000	---
Total, Advanced Research.....	$418,529	$420,000	$320,000

In the Advanced Research area, effort leading to improved and new types of spectrometers and density gages for atmospheric research will be continued. Tiometers will be established at appropriate sites to support the sounding rocket program of investigation of phenomena associated with the arrival at the earth of energetic particles of solar origin. A riometer is a ground-based specially designed radio receiver which continuously monitors ionospheric radio wave absorption characteristics and thereby gives an immediate indication of the arrival of energetic particles from the sun. This permits the prompt launching of standby rockets, instrumented for energetic particle studies, which have been ready on the launcher. Funding of the international program will also be continued to provide for cooperative efforts with other nations in research utilizing sounding rockets.

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Aeronomy:			
Rocket instrumentation for the upper atmosphere.....	$195,550	$200,000	$180,000
Upper atmosphere sodium vapor experiments.....	256,582	---	---
	452,132	200,000	180,000
Energetic Particles and Fields:			
Magnetic field and ionospheric currents.....	---	50,000	50,000

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Ionospheric Physics:			
Langmuir ionosphere probes.....	$125,000	---	---
Ionosphere plasma studies.....	125,339	---	---
Electron density probes.....	---	100,000	70,000
	250,339	100,000	70,000
Vibration Studies.....	132,200	140,000	120,000
Total, Advanced Technical Development.....	$834,671	$490,000	$420,000

The activities under this heading are concerned with the development of advanced instrumentation intended for flights in 1963 and 1964. Included here are the development of mass spectrometers of greater dynamic range and faster response time and pressure gages capable of reporting the very low pressures encountered in the upper atmosphere. Improved electron density probes for accurately determining the electron content of the ionosphere are also being developed. Studies of the vibrations encountered in sounding rockets during engine burning and the effects of these vibrations on rocket and payload performance will continue about at the level established during the fiscal years 1960 and 1961.

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Aeronomy:			
Low-pressure flight detectors.....	$9,900	$50,000	$50,000
Gage interaction with radiation measurements.....	31,600	30,000	30,000
Flight detectors and electronics...	45,700	50,000	50,000
Gas composition detector studies...	76,200	59,000	---
Procurement and fabrication of payload components and subsystems.	92,200	270,000	230,000
Ultra-high vacuum system calibration setup.....	114,700	---	---
Rocket grenade experiments.....	375,000	300,000	280,000
Pressure gage calibration.....	---	10,000	10,000
All metal low-pressure gages.....	---	50,000	30,000
Sodium vapor experiments.....	---	250,000	200,000
Attitude control units.....	---	15,000	---
Computing facilities.....	---	50,000	---
Services, facilities, and materials for fabrication of grenades.....	---	---	100,000
	745,300	1,134,000	980,000

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Energetic Particles and Fields:			
Calibration of rocket experiment (Skyhook flights)	$258,500	$60,000	$150,000
Emulsion scanning	8,700	10,000	10,000
Nuclear emulsion	34,700	5,000	5,000
Procurement and fabrication of payload components and subsystems	45,600	103,000	110,000
Engineering services	28,800	---	20,000
Magnetic field experiments with Nike-Asp	45,600	---	---
Design and construction of payload for Nervos	213,100	---	---
Scintillation counter units	51,500	---	---
Computing services	---	10,000	10,000
Flight magnetometers	---	13,000	35,000
Magnetic aspect units	---	---	5,000
Flight programming unit	---	---	5,000
	686,500	201,000	350,000
Galactic Astronomy:			
Flight photoemissive detectors	20,000	25,000	25,000
Design and construction of rocket instrumentation for interstellar and intergalactic media	258,000	216,000	210,000
Aerobee attitude control system	250,000	50,000	50,000
Design of optical systems	20,000	30,000	20,000
Design and construction of rocket instrumentation for stellar studies	150,000	196,000	160,000
Spectrophotometer gratings	12,000	5,000	10,000
Flight photomultipliers	10,000	20,000	15,000
Flight ionization chambers	---	5,000	5,000
Computing services	---	5,000	5,000
	720,000	552,000	500,000
Solar Physics:			
Flight electrometers	14,800	25,000	---
Flight instrumentation sections	81,300	153,000	140,000
Nose shells	15,000	20,000	20,000
High resolution spectrophotometry	14,000	150,000	65,000
Flight detector development	36,700	50,000	40,000
Design and construction of optics	87,000	50,000	40,000
Procurement and fabrication of payload components and subsystems	74,600	49,000	50,000
Field services	---	30,000	30,000

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Flight electronic system engineering	---	$25,000	$25,000
Flight spectrophotometers.....	---	---	40,000
	323,400	552,000	450,000
Ionospheric Physics:			
Flight instrumentation.....	174,500	278,000	280,000
Flight support.....	48,300	15,000	15,000
Data reduction.....	20,000	20,000	20,000
Antenna development.....	40,000	30,000	25,000
Procurement and fabrication of payload components and subsystems..	52,100	74,000	60,000
Rocket-borne power amplifier.....	---	6,000	5,000
Ion spectroscopy data reduction.....	---	20,000	15,000
	334,900	443,000	420,000
Meteorite Studies:			
Design, fabrication and assembly of field support equipment.....	17,700	43,000	60,000
Ionization coincidence system.....	64,400	---	---
Flight detectors.....	---	38,000	34,000
	82,100	81,000	94,000
Sounding Rocket Support:			
Sounding rocket improvement and modification.....	395,600	---	---
Drop test for Nerv.....	65,000	---	---
Development of 20-inch sounding rocket.....	1,000,000	365,000	---
Aerobee attitude control system.....	250,000	1,000	---
Javelin D-4's.....	300,000	300,000	---
Computer services.....	22,000	50,000	50,000
Study of wind effects.....	11,500	100,000	50,000
Telemetry.....	109,200	195,000	210,000
Telemetering services.....	100,000	200,000	200,000
Antenna services.....	35,000	50,000	40,000
Dovap development.....	95,000	50,000	40,000
Cut off receivers.....	125,000	50,000	80,000
Silvercells.....	25,000	25,000	25,000
Recording tape.....	17,000	10,000	10,000
Recording paper.....	15,000	10,000	10,000
Calibrators.....	60,000	32,000	25,000
Asp rocket systems.....	181,600	138,000	150,000
Aerobee systems.....	794,600	900,000	750,000
Nike-Cajun systems.....	150,400	67,000	67,000
Journeymen systems.....	470,000	500,000	500,000

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Iris systems	$214,000	$100,000	$400,000
Nike systems	90,000	50,000	50,000
Nerv systems	1,009,700	---	90,000
Nike launcher modification	---	40,000	---
Attitude pointing calibrator	---	5,000	---
Attitude control scanner	---	20,000	---
Performance gages	---	50,000	---
Instrumentation for Nike-Asp rockets	---	40,000	---
Instrumentation for Iris rockets	---	60,000	---
Fine pointing control	---	250,000	---
Solar aspect cells	---	16,000	16,000
Aerobee bulkhead	---	10,000	10,000
Structure tests	---	20,000	20,000
Performance studies	---	70,000	50,000
Beacon and power supplies	---	20,000	40,000
Dovap operations	---	50,000	50,000
Dovap transponders	---	30,000	30,000
Transmitters	---	12,000	20,000
Timers	---	5,000	5,000
Relays	---	5,000	10,000
Commutators	---	15,000	15,000
Teleflow wire	---	5,000	5,000
Voltage control oscillators	---	64,000	60,000
Attitude control units	---	100,000	190,000
Test and evaluation	---	18,000	18,000
Procurement and fabrication of components and subsystems	---	199,000	180,000
	5,535,600	4,297,000	3,466,000
Total, Flight Program	$8,427,800	$7,260,000	$6,260,000

During the fiscal year 1960 the sounding rocket program continued to gain momentum through the launching of rockets and experiments initiated during the first year of NASA's existence. An Aerobee launching tower was completed at the Wallops Station, Virginia, in March 1960. The initial NASA launchings at Fort Churchill, Canada, had been conducted some months earlier. The number of launchings has increased gradually and will level out at approximately 85 per year. Fiscal Year 1959 and 1960 funds were used to start the build-up to this program level. The major efforts early in the fiscal year were in the procurement of rockets and the construction of payloads for launching late in the fiscal years 1960 and 1961. The data obtained from the experiments performed in the first half of the fiscal year 1960 were analyzed and follow-up experiments were being planned or constructed at year's end.

The rockets launched through the first half of the fiscal year 1961 were mostly Nike-Asp and Aerobee vehicles which were capable of attaining altitudes of about 150 miles with normal payload weights. By the middle

of the fiscal year 1961 the first launchings will be made of larger rockets (Journeyman and Javelin) capable of carrying heavy payloads to over 500 miles in altitude and light payloads to over 1,000 miles.

The funds planned for the fiscal year 1962 will continue the sounding rocket program at the 1961 level of approximately 85-rocket firings per year. Preparation of experiments, analysis of results, and continuation of supporting research activities and advanced instrumentation development will be continued at the level required to support the flight program. High-altitude investigations of the outer regions of the atmosphere and ionosphere will be increased, and recovery experiments will be of particular value in the Particles and Fields program. The exact experiments and the details of the instrumentation to be used will generally be determined by the results obtained from launchings during the fiscal year 1961.

A major portion of the fiscal year 1962 funds will be utilized to procure rockets and payload equipment. An increased level of activity in the fields and particles program is indicated by the larger amounts requested for magnetometers, engineering services and calibration work. In the other scientific disciplines, the 1962 level of activity will be about the same as the 1961 level. The amount needed for hardware and general support of the sounding rocket program has decreased since some of the development costs for rockets and specialized hardware are no longer required. The fiscal year 1962 budget provides for the procurement of approximately 25 Aerobees, 21 Nike-Asps, 12 Nike-Cajuns, 20 Iris rockets, and 4 high-altitude (over 1,000 miles) journeyman rockets.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

SCIENTIFIC SATELLITES

SUMMARY OF REQUIREMENTS:

	1960	1961	1962	Page No.
Advanced Research.....	$1,680,337	$3,327,000	$3,543,000	RD5-5
Advanced Technical Development	2,332,484	6,861,000	5,826,000	RD5-9
Flight Program.....	16,228,293	27,754,000	55,331,000	RD5-14
Total.....	$20,241,114	$37,942,000	$64,700,000	

OBJECTIVES:

The fundamental objective of the scientific satellite program is the expansion of human knowledge of phenomena in the atmosphere and space. This objective encompasses two fundamental questions of universal interest. One of these deals with the nature and origin of the universe, and the other is concerned with the major role that the sun exerts over the natural physical processes of the earth and its atmosphere. This broad fundamental objective is being pursued by means of a research program utilizing satellites designed to investigate specific problem areas in upper atmosphere and space phenomena.

This fundamental objective can be further categorized in terms of basic scientific investigations in the areas of Astronomy and Geophysics. These general objectives are as follows:

Astronomy

To investigate the electromagnetic radiations in all wavelengths, from gamma rays to radiowaves, that reach the vicinity of the earth from the planets, sun, stars, galaxies, and interstellar and intergalactic matter, and to use these observations to extend our knowledge of these bodies. More specifically, this area is subdivided into the following scientific program objectives:

Solar Astronomy: To observe the sun and the solar atmosphere in the X-ray, ultraviolet, and infrared region of the spectrum in an effort to understand the detailed behavior of a typical star.

Stellar and Galactic Astronomy: To understand the origin, present state, and evolution of the universe and its component parts. For this purpose, observations of stars, nebulae, galaxies, and planets will be made in the gamma ray, X-ray, ultraviolet, visible, and infrared region of the spectrum.

Astrophysics: To understand the physical processes occurring in the universe. In particular, attention will be devoted to the nature of gravity, to a thorough study of the gross features of the earth's gravitational field, and to the behavior of elementary particles in rapid motion as evidenced in the production of radio frequency radiation.

Geophysics

To determine and understand the structure, composition, and dynamical behavior of the earth's atmosphere and ionosphere. To investigate and determine the nature and origin of the Great Radiation Belts. To determine and understand the relations between solar activity, the earth's atmosphere, and surface meteorology. To investigate phenomena associated with photons, ions, cosmic rays, other energetic particles, magnetic, electric, and gravitational fields, micrometeorites, and other matter; their interactions; and their effects on instrumented and manned space flight. More specifically, this area is subdivided into the following scientific program objectives:

Aeronomy and Micrometeorites: To study the atmosphere by measurements of the composition, the density distribution with altitude, latitude, and longitude, the motions of atmospheric gases; and to determine daily and seasonal variations of these parameters. To determine the effects of solar energy and the physical forces controlling the chemistry and dynamics of the atmosphere. To determine the relations to other basic and applied research programs, including those relating to the ionosphere, energetic particles, meteorology, and space vehicle performance. To determine quantity, composition and impact velocities of micrometeorites entering the earth's atmosphere.

Energetic Particles and Fields: To measure the flux of energetic particle radiations in the vicinity of the earth so that it can be accurately described at any point in space and at any given time. To carry out analytical and theoretical studies to determine the origin of the particles, the mechanism by which they are accelerated, the paths which they follow in space, the effect of the solar cycle on their properties, and their interactions with the fields in space. To accurately map out the magnetic field of the earth, to determine fluctuations and interactions with charged particles and plasmas, and to carry on analytical and theoretical studies to determine the mechanisms producing the field and the interactions.

Ionospheric Studies: To study the nature, dynamical behavior, and spatial and temporal distribution of charged particles with thermal energies. Parameters investigated are the concentrations of electrons and of positive and negative ions, their energy distributions, the ion masses, the coefficients of dissociation and recombination between neutral and charged particles, the frequency of collisions, and the motions of the charged particles and belts of such particles.

JUSTIFICATION:

The new knowledge to be gained in the scientific satellite program has obvious applications. Spacecraft which are to return from orbital flight must be designed with the characteristics of the upper atmosphere in mind. These characteristics must be defined and studied in detail. The ionosphere exerts such a tremendous control over radiowave propagation that it is easy to recognize the benefits to be derived from a better understanding of the phenomena of the ionosphere, radio noise storms and blackouts. The radiation belts are of considerable interest because of the limitations this region may impose on manned space flight. Likewise, solar phenomena and the gusts of energetic particles emitted by the sun from time to time are of similar concern. The micrometeorite hazard to space vehicles has not yet been even broadly defined. These are but a few examples of known applications, and oftentimes the most important and spectacular discoveries are those which cannot be anticipated.

Satellites offer the opportunity to conduct investigations over large regions of space and for long period of time, in excess of one year if required. Satellites also make it possible to perform many astronomical observations, including studies of our own sun, which were not possible earlier from ground-based or balloon-borne observations due to the absorbing effects of the earth's atmosphere. The sun is the principal source of energy for the earth. Daily and seasonal effects of the sun on the earth and its atmosphere have been observed for centuries. Satellites now offer the opportunity of studying the energy output of the sun before it reaches and is partially absorbed by the earth's atmosphere. Likewise, satellites make it possible to perform direct observations and measurements in the region of the upper atmosphere where the sun's energy produces some of its primary effects. The surface meteorology of the earth, the propagation characteristics of radiowaves, the auroras, the radiation belts, and other geophysical phenomena are the results of interactions of the sun's energy with the earth and its atmosphere. Ultimately, the knowledge acquired through space research will lead to a better understanding of the earth and its relations to our solar system and the universe, and to a fuller understanding of the relations of man to his environment.

The following is a list of scientific satellites and near space probes included in this program. They are listed under the appropriate scientific disciplines:

Satellite or Probe	Vehicle	Fiscal Year of Launch
Solar Astronomy:		
Orbiting Solar Observatory	Delta	1961
Orbiting Solar Observatory (backup or follow-on)	Delta	1962
Orbiting Solar Observatory (follow-on)	Thor-Agena B	1964
Stellar and Galactic Astronomy:		
Gamma Ray Astronomy Satellite	Juno II	1961
Gamma Ray Astronomy Satellite (backup)	Scout	1961
Oribiting Astronomical Observatory	Atlas-Agena B	1964
Aeronomy and Micrometeorites:		
Air Density-Drag Measurements Satellite	Scout	1961
Micrometeoroid Satellite	Scout	1961
Atmospheric Structure Satellite	Delta	1962
Micrometeoroid Satellite (backup or follow-on)	Scout	1962
Energetic Particles and Fields:		
Energetic Particles Satellite	Delta	1961
Energetic Particles Satellite (backup or follow-on)	Delta	1962
Recoverable Nuclear Emulsions Probe	Scout	1963
Ionospheric Physics:		
Ionospheric Direct Measurements Satellite	Juno II	Nov.1960
Ionosphere Beacon Satellite	Juno II	1961
Ionosphere Beacon Satellite (backup)	Juno II	1961
Electron Density Profile Probe (#1)	Scout	1962
Electron Density Profile Probe (#2)	Scout	1962
Swept Frequency Topside Sounder (Canada)	Thor-Agena B	1962
Swept Frequency Topside Sounder (Canada) (backup)	Thor-Agena B	1963
Fixed-Frequency Topside Sounder (US)	Scout	1963
Geophysical Observatories:		
Eccentric Orbiting Geophysical Observatory	Atlas-Agena B	1963
Polar Orbiting Geophysical Observatory	Thor-Agena B	1964
International Programs:		
International Ionosphere Satellite (United Kingdom No. 1)	Scout	1962
International Ionosphere Satellite (United Kingdom No. 1) (backup)	Scout	1962
International Program Satellite (United Kingdom No. 2)	Scout	1964
International Program Satellite (No. 3)	Scout	1964

FUNDING REQUIREMENTS:

Advanced Research	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Solar Astronomy:			
Solar research	$97,300	---	$100,000
Theoretical research - solar activity	---	---	50,000
Studies of solar flares	---	$50,000	50,000
Development of theories of solar and stellar physics	---	60,000	60,000
	97,300	110,000	260,000
Stellar and Galactic Astronomy:			
Ultraviolet laboratory spectroscopy	150,000	75,000	50,000
Photometric standards and optical constants	24,000	---	25,000
Theoretical interpretation of ultraviolet spectra	---	---	100,000
Formation and properties of interstellar matter	---	---	25,000
Interstellar reddening and polarization	---	---	25,000
	174,000	75,000	225,000
Astrophysics:			
Relativistic deductions from satellite motions	---	10,000	20,000
Trajectory and orbit computations	---	25,000	25,000
Trajectory analysis and programs	19,100	40,000	40,000
Gravity and relativity	---	---	50,000
Astrophysical hydromagnetics	---	---	50,000
Interpretation of non-thermal radiation sources	---	---	30,000
Millimeter receiver research	---	25,000	25,000
	19,100	100,000	240,000
Aeronomy and Micrometeorites:			
Planetary atmosphere studies	170,473	180,000	30,000
Micrometeorite simulation	---	37,000	50,000
Kinetic aeronomy	---	50,000	50,000
Support of space science literature abstracts	50,000	---	---
Studies in upper atmosphere dynamics	---	100,000	100,000
Calibration of micrometeorite detectors	---	50,000	50,000
Kinetics of the atmosphere studies	---	100,000	100,000
	220,473	517,000	380,000

Advanced Research	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Energetic Particles and Fields:			
Cosmic ray monitoring.....	---	$105,000	---
Anti-particles in space.....	---	77,000	$50,000
Radiation belt studies.....	$382,000	200,000	400,000
Charged particles and fields in space	114,441	78,000	100,000
Solid state energetic particles detectors.....	---	75,000	100,000
Geohydromagnetic theory.....	---	40,000	50,000
Riometer measurements (Southern Hemisphere).....	---	50,000	50,000
	496,441	625,000	750,000
Ionospheric Physics:			
Ionospheric propagation research....	343,126	480,000	500,000
Ionospheric reaction studies.....	59,277	60,000	60,000
True height ionograms.....	100,000	100,000	100,000
Very low frequency propagation studies	122,620	125,000	125,000
Studies of low energy ionospheric reactions.....	48,000	48,000	48,000
Theoretical studies on plasma probes	---	25,000	25,000
Analysis of spectrometer designs....	---	20,000	20,000
Ionized sheath studies.....	---	20,000	20,000
Dual spacecraft propagation measurements.....	---	50,000	100,000
Propagation research methods.....	---	100,000	150,000
Ionospheric and cosmic radio noise studies.....	---	---	75,000
	673,023	1,028,000	1,223,000
General Geophysics:			
Analysis of terrestrial gravimetric data.....	---	10,000	10,000
Geodetic investigations.....	---	500,000	328,000
	---	510,000	338,000
General Support:			
Satellite payload recovery studies..	---	75,000	---
Effects of space environment on solar cells.....	---	150,000	---
Feasibility studies of advanced instrumentation.....	---	50,000	---
Mathematics and computing.....	---	87,000	127,000
	---	362,000	127,000
Total, Advanced Research.....	$1,680,337	$3,327,000	$3,543,000

A comprehensive program of advanced research in space sciences is essential to provide a sound basis for experimental investigations in scientific satellites. This research builds on data obtained through ground based observations, sounding rocket experiments, balloon flights, satellite and space probe flights, and laboratory experiments to provide guidance for planning future studies, to develop techniques for these observations and explorations, and to interpret the results of satellite experiments. Contracts and grants are placed with universities, nonprofit institutions, industry and government agencies for this research.

Solar Astronomy

Ground based monitoring of solar activity, presently being conducted, will provide a high speed, high resolution record of solar events which can be correlated with satellite observations not only of the sun itself, but also of cosmic rays, magnetic storms and other interplanetary, planetary and geophysical phenomena. Theoretical studies of the active and quiet sun, in coordination with satellite observations, should lead to an understanding of what produces solar activity and why different regions of the sun behave differently. Ultimately this should provide a means for predicting the occurrence of the flares which release the energetic particles which present a hazard to manned space flight. The program will continue beyond the fiscal year 1962.

Stellar and Galactic Astronomy

In this area the emphasis is on providing laboratory data needed to interpret ultraviolet photometry and spectrometry. This work will be continued through the fiscal year 1962 and theoretical studies will be initiated on the nature of the interstellar medium, not only for its own sake, but also because of its effect on the light observed from distant stars.

Astrophysics

Studies are being conducted of satellite orbits for use in solving problems of geodesy and relativity. Theoretical studies will be initiated in the fiscal year 1962 in geodesy and relativity to support the interpretation of satellite observations. Studies will also be conducted on the theoretical interpretation of the radiation received from radio stars and from the galactic background. Related low-frequency radio astronomy measurements are now being conducted from sounding rockets and are planned for later satellites. Research is also being conducted to provide a basis for development of components for millimeter and sub-millimeter receivers for radio astronomy.

Aeronomy and Micrometeorites

Studies in this area are being conducted on the absorption and emissivity of planetary gases; the rate coefficients for chemical interactions of atmospheric gases; and the turbulence, eddies and circulation system of the upper atmosphere. In addition, laboratory studies are being conducted to simulate micrometeorite interactions with gases and surfaces and to calibrate instrumentation for micrometeorite detection.

Energetic Particles and Fields

The stress here is on radiation belt studies to provide a basis for development for better instrumentation to be flown on the geophysical observatories. Research is also being conducted on methods of searching for and measuring the flux of anti-particles in space. Research in charged particles and field in space geohydromagnetic theory, and riometer measurements are all a part of a combined study of relationships between aurora, the outer radiation belt and the magnetic field. Research will also be conducted in furtherance of newly discovered techniques for particle detection and measurement.

Ionospheric Physics

Major emphasis in this area is being placed on a research project on ionospheric propagation being conducted by universities and the National Bureau of Standards. This project makes use of ground reception of radio signals transmitted from satellites. The ionosphere beacon satellite to be launched early in 1961 contains transmitters specifically designed for this research project. Work on true height ionograms is being conducted in support of the ionospheric propagation research. Research on ionospheric reactions, low energy reactions, plasma probes, spectrometer designs and ionized sheaths is being conducted to provide a basis for direct ionospheric measurements from satellites. Work will also be started on techniques for measuring ionospheric characteristics by studying the propagation of radio signals from one satellite to another. New efforts will be initiated in research on very low-frequency and extremely low-frequency propagation and on cosmic radio noise levels.

General Geophysics

Research will be initiated in the fiscal year 1961 and will be continued in the fiscal year 1962 in the measurement of the earth's gravitational field and geometry through accurate computation of satellite orbits

General Support

Investigation of improved methods for recovering scientific payloads will be made using fiscal year 1961 funds. Research will also be conducted with the objective of providing a basis for development of solar cells and scientific instrumentation with improved operating characteristics in a space environment. Research will also be conducted in the fiscal years 1961 and 1962 on the solution of mathematical problems and computing techniques directly related to space sciences.

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Solar Astronomy:			
X-ray astronomy optics	$98,205	---	---
Gamma ray spectrometer		$60,000	---
Solar spectroscopy	200,000	103,000	$300,000
Galactic background photometry	---	100,000	---
Ultraviolet spectrographs	140,000	125,000	---
Gamma ray detectors	46,800	---	100,000
Gamma ray data handling	86,020	---	---
Solar X-ray measurements	---	150,000	---
High-resolution spectrograph	---	40,000	---
	571,025	578,000	400,000
Stellar and Galactic Astronomy:			
Ultraviolet sky mapping	289,927	---	---
Engineering studies for orbiting astronomical observatories	55,000	75,000	75,000
Miniaturized ruggedized phototubes	---	30,000	50,000
X-ray astronomy	---	50,000	---
Ultraviolet photometry	104,992	---	---
Optical research	123,000	150,000	150,000
Astronomical image tube research	---	180,000	250,000
Far ultraviolet detector development	---	100,000	50,000
Infrared astronomical optics and detectors	---	50,000	250,000
Application of television to remote astronomy	110,000	---	---
Lightweight and specialized optics	14,980	20,000	100,000
Optical filter development	32,515	---	---
Data transmission studies	---	25,000	---
Inert atmosphere crystal growing equipment	---	15,000	---
Radiometric standards	---	25,000	---
High-altitude recoverable astronomical experiments	---	400,000	---

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Image intensifiers.....	---	$50,000	$80,000
Alkali halide photo-diodes and photo-multipliers.....	---	30,000	25,000
Ion chamber prototype production	---	15,000	25,000
Development of optical crystals	---	25,000	25,000
Procurement and fabrication of components.....	---	96,000	100,000
Crystallographic orientation devices.....	---	---	10,000
X-ray instrumentation research	---	100,000	100,000
	$730,414	1,436,000	1,290,000
Astrophysics:			
Directive antennas for radio astronomy.....	---	100,000	300,000
Millimeter wave receiver development.....	7,000	50,000	300,000
Sweep frequency receiver.....	119,140	250,000	---
Satellite clock.....	140,000	---	---
Microwave planetary spectrometer	---	100,000	200,000
Gravitation and relativity.....	---	100,000	---
	266,140	600,000	800,000
Aeronomy and Micrometeorites:			
Instrumentation, composition of the upper atmosphere.....	373,505	375,000	---
Absorption spectroscopy atmospheric analysis.....	---	100,000	250,000
Advanced mass spectrometers....	---	100,000	100,000
Planetary atmospheres instrumentation.....	---	---	50,000
Atmospheric structure detector design.....	---	50,000	50,000
Free radical sensors.....	---	95,000	30,000
Non-magnetic spectrometer.....	---	50,000	20,000
Atmospheric structure detector components.....	---	15,000	26,000
Development of improved micrometeorite detectors.....	---	50,000	50,000
Hypervelocity gun usage.....	---	75,000	75,000
Development of micrometeorite composition detector.....	---	50,000	100,000
Detector development.....	---	30,000	30,000
Detector component procurements	---	50,000	72,000
	373,505	1,040,000	853,000

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Energetic Particles and Fields:			
Primary cosmic radiation telescope..	---	$65,000	---
Primary cosmic ray instrumentation..	---	300,000	$200,000
Cosmic radiation at high altitudes..	$20,000	50,000	200,000
Cosmic ray particle detector development.....	---	90,000	75,000
Low energy particle detector development.....	---	100,000	80,000
Measurement of neutron intensity....	---	100,000	100,000
Energy and mass analyzers for energetic particles.....	---	260,000	100,000
Vector magnetometer development.....	---	50,000	75,000
Auroral and solar proton experiments	---	---	85,000
Hydromagnetic wave analyzers.....	---	---	75,000
	20,000	1,015,000	990,000
Ionospheric Studies:			
Very-low frequency propagation experiments.....	---	75,000	---
Advanced topside sounder development	---	100,000	100,000
Plasma probe development.....	---	150,000	150,000
Ionospheric noise survey.....	---	374,000	---
Development of ion spectrometer sensors	---	60,000	50,000
Development of low-power motion for flight field meters.....	---	10,000	5,000
Procurement and fabrication of components.....	---	77,000	73,000
	---	846,000	378,000
General Geophysics:			
Instrumentation for X-15 airplane...	---	100,000	50,000
Atlas tests of instrumentation.....	---	100,000	---
	---	200,000	50,000
International Program Experiments.....	---	200,000	200,000
Scientific Satellite Support:			
Temperature control devices and coatings.....	143,700	58,000	40,000
Wide-band flight recorders.....	123,800	162,000	145,000
Electrical and mechanical component development.....	24,000	112,000	139,000

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Advanced telemetry.....	$69,900	$65,000	$78,000
Advanced power supplies.....	10,000	60,000	60,000
Thermal energy conversion.....	---	36,000	50,000
Memory tube electronics and storage matrices.....	---	170,000	115,000
Bearings for vacuum operation.....	---	40,000	35,000
Precession damping and spin control devices.....	---	20,000	30,000
Spacecraft propulsion.....	---	50,000	60,000
Antenna development.....	---	30,000	40,000
Vibration measurements and technology	---	37,000	40,000
General environmental and specification data on conditions at launching sites.....	---	50,000	---
Environmental test facility services	---	56,000	33,000
	371,400	946,000	865,000
Total, Advanced Technical Development.....	$2,332,484	$6,861,000	$5,826,000

Development of instrumentation for scientific experiments must be conducted on a continuing basis to provide more advanced instrumentation in future satellite flights. Technical development efforts are also required on the electronic, thermal, mechanical and power subsystems for future satellites. Requirements in this area are for development contracts with universities, nonprofit institutions, industry and government agencies; and for components and materials for development activities at the Goddard Space Flight Center.

Solar Astronomy

In this area emphasis is on the design of more sophisticated equipment for observing the sun. Fiscal year 1962 funds will provide for continuation of work now under way in high-resolution spectroscopy and gamma ray detectors. Much of the instrumentation developed for stellar and galactic astronomy is also applicable to solar astronomy. Some work covered in this area in the fiscal years 1960 and 1961 will be conducted as a part of the orbiting solar observatories project in the fiscal year 1962.

Stellar and Galactic Astronomy

Some of the projects initiated in this area in 1960 and 1961 will become a part of the orbiting astronomical observatories project in the fiscal year 1962. Other projects are being continued in this area in preparation for future observatories. These include engineering studies of stabilization and guidance techniques, development of small ruggedized

phototubes and various types of astronomical detectors. Development must be continued on new instrumentation for the far ultraviolet and on optical equipment that can stand the strenuous environment of launch and outer space. Work also must be done on far ultraviolet detectors to increase their sensitivity and spectral resolution. Infrared astronomical instrumentation will be developed for the study of planets, cool stars and interstellar material. Much can be learned from photographs of the sky in the ultraviolet and infrared, but the use of photographic film requires techniques which have not yet been applied to astronomy. Development of photographic instrumentation for high altitude planes, balloons, and rockets will provide a capability in this area. Image intensifiers provide an alternative to the use of photographic film as they can be used in non-recoverable satellites, but further development is required before they will have the resolution and sensitivity to be competitive with photography.

Astrophysics

Development in this area in the fiscal year 1962 will be primarily in the field of radio astronomy. Work will be done on an expanding basis on millimeter wave receivers for study of the inner reaches of the atmospheres of the sun and planets and for study of interstellar material. The development of directive antennas will provide better resolution for low-frequency studies of the solar corona and the outer atmospheres of planets. Development of a microwave planetary spectrometer for satellite use will provide valuable information on planetary atmospheres which cannot be obtained from ground-based experiments, because the earth's atmosphere has many of the absorption features we wish to study in other planets.

Aeronomy and Micrometeorites

Emphasis will be placed on development of improved instrumentation for measuring atmospheric structure composition and density employing spectrometry, backscattering techniques, free radical sensors and scanning systems. Improved micrometeorite detectors will be developed. These will attempt to increase the performance of the presently used impacting satellite sensors. Work will be done to improve the stability and sensitivity of micrometeorite detector components and for the development of instrumentation for determining the composition of micrometeorites.

Energetic Particles and Fields

A substantial development program is being conducted to provide instrumentation which will yield information concerning the nature and origin of cosmic rays. Improvement of instrumentation for other energetic particles will be continued. Vector magnetometers and hydromagnetic wave analyzers will be developed for studies of the geomagnetic field.

Ionospheric Studies

In this area, the emphasis in fiscal year 1962 will be on development of improved swept frequency equipment for topside sounding, and on plasma probes and spectrometer sensors for direct ionospheric measurements from satellites.

General Geophysics

A program is being undertaken to package various types of geophysical experiments to be carried aboard the X-15 research aircraft and on Atlas ballistic missile flights. These experiments will supplement other geophysical data from sounding rocket and satellite experiments.

International Program Experiments

Funding in this area in the fiscal years 1961 and 1962 is to provide for development services in support of experiments originated by foreign scientists. This service will be provided in those cases where the experimenters need assistance to provide the prototype instrumentation for evaluation of experiments for future satellite flights.

Scientific Satellite Support

A continuing program will be conducted in this area to improve temperature control, data recording, telemetry, power supplies, data storage, and stabilization and control subsystems of satellites.

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Orbiting Solar Observatories:			
Design and fabrication of prototypes and three flight units.....	$1,498,300	$1,732,000	$1,628,000
Low-resolution X-ray spectrophotometer	175,000	28,000	---
High-resolution X-ray spectrophotometer	---	100,000	100,000
Development research on open window multiplier detectors.....	51,800	50,000	50,000
Vacuum test chamber.....	---	25,000	---
Development of laboratory soft X-ray sources.....	---	50,000	50,000
Development of image intensifiers and purchase of experimental units.....	---	50,000	50,000
Detector development and purchase...	---	25,000	25,000
Pulse height analyzers and data handling circuitry purchase.....	64,400	65,000	45,000
Proportional counter experiment.....	---	15,000	14,000
Associated electronics.....	---	10,000	10,000

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Solar constant experiment.....	---	$50,000	$60,000
Hydrogen Lyman-Alpha profile experiment.....	---	150,000	150,000
High-resolution spectrophotometry...	---	300,000	300,000
Narrow-band monitoring of selected solar radiations.....	---	125,000	125,000
Narrow-band detector and filter development.....	$13,500	10,000	25,000
Data reduction and continuation of energy X-ray experiment.....	---	150,000	165,000
Survey experiment for astronomy program.....	---	---	120,000
Other wheel experiments.....	---	300,000	100,000
Rocket pointing controls.....	60,000	---	---
Data reduction.....	---	375,000	50,000
Modification or addition to ground control equipment.....	---	50,000	100,000
Delta launch vehicles (two; funded under vehicle development program).	---	---	---
Thor-Agena B launch vehicle.....	---	---	1,000,000
	1,863,000	3,660,000	4,167,000
Gamma Ray Astronomy Satellite:			
Spectrometer design and construction	225,830	---	---
Tape recorder.....	25,800	---	---
Payload recorder.....	20,300	---	---
Flight system components.....	8,600	7,000	---
Prototype and flight models.....	1,034,000	30,000	---
Data reduction.....	---	150,000	---
Juno II launch vehicle.....	870,837	55,000	---
Scout backup vehicle (funded under vehicle development program).....	---	---	---
	2,185,367	242,000	---
Orbiting Astronomical Observatory:			
Intensifiers.....	55,500	---	---
Dielectric filters.....	25,000	---	---
Flight optical design and construction.....	38,900	70,000	50,000
Flight telescope design and construction.....	50,000	200,000	175,000
Flight detectors.....	46,100	15,000	15,000
Ultraviolet mapping experiment.....	---	640,000	1,500,000
Ultraviolet spectrophotometer.....	---	300,000	489,000

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Ultraviolet photometry.....	---	$500,000	$700,000
Planetary spectrometer.....	---	150,000	400,000
X-ray instrumentation.....	---	---	400,000
Infrared instrumentation.....	---	---	400,000
Secondary instrumentation.....	$50,000	100,000	100,000
Test and evaluation services.....	---	100,000	200,000
Monochromatic light source.....	---	20,000	10,000
Flight spectrometer grating.....	---	20,000	10,000
Subsystem components and fabrication	---	72,000	102,000
Flight systems electronics.....	10,000	10,000	100,000
Component procurement and fabrication	25,000	135,000	185,000
Jet systems and associated equipment	---	---	58,000
High-precision radiation measuring facility.....	45,900	---	---
Test and evaluation of instrumentation	---	4,000	166,000
Vacuum optical bench.....	---	190,000	---
Digital to digital converter and plotter.....	---	---	20,000
Stellar simulation equipment.....	---	---	40,000
Computing services.....	---	40,000	55,000
Design and fabrication of prototypes and flight units.....	---	4,241,000	12,000,000
Atlas-Agena B launch vehicle.....	---	---	600,000
	346,400	6,807,000	17,775,000
Air Density Drag Measurements Satellite:			
12-foot sphere.....	125,000	---	---
Data reduction.....	---	50,000	---
Scout launch vehicle (funded under vehicle development program).....	---	---	---
	125,000	50,000	---
Micrometeoroid Satellite:			
Test and evaluation.....	---	6,000	5,000
Data reduction and analysis.....	---	75,000	75,000
Design and fabrication of flight hardware.....	225,000	---	---
Scout launch vehicle (funded under vehicle development program).....	---	---	---
Scout vehicle for backup or follow-on spacecraft.....	---	750,000	---
	225,000	831,000	80,000

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Atmospheric Structures Satellite:			
Mass spectrometer and related electronics	$263,000	---	---
Redhead flight gage	---	$75,000	---
Flight detector calibration	---	50,000	---
Calibration of mass spectrometer	---	40,000	---
Components for instrumentation	31,900	50,000	$26,000
Components and assembly of flight data systems	81,600	187,000	74,000
Electronic commutators	---	30,000	---
Transmitters	---	24,000	---
Frequency and power measuring equipment	---	10,000	---
Component assemblies for flight systems	---	80,000	29,000
Batteries	11,200	40,000	---
Mechanical subsystems and assemblies	---	121,000	24,000
Satellite structural shell contract.	113,100	200,000	10,000
Javelin payload structural parts	---	50,000	---
Coating for temperature control	---	10,000	---
Assembly of thermal systems	---	10,000	---
Test and evaluation of components, prototypes and flight units	---	43,000	24,000
Leak test chamber for pressurized shell	---	10,000	---
Testing of explosive breakoff	---	---	15,000
Data processing	---	---	150,000
Hypervelocity neutral beam calculation	27,000	50,000	---
Data analysis	---	---	30,000
Ground stations for test and checkout	---	280,000	---
Recorders	---	6,000	---
Engineering and field service contracts	37,100	118,000	81,000
Delta launch vehicle (funded under vehicle development program)	---	---	---
	564,900	1,484,000	463,000
Energetic Particles Satellite:			
Low-field magnetometer	33,700	---	---
Support services	62,800	---	---
Ion electron scintillation detector.	46,300	---	---
Instrumentation for backup flight	126,600	345,000	224,000
Sliding pulse analyzer	10,700	---	---
Multi-channel analyzer and decoder	162,700	20,000	20,000
Antenna development	10,500	10,000	---
Phase lock receivers	45,000	50,000	---
Component assemblies	51,900	20,000	20,000
Radio frequency systems	72,000	51,000	31,000

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Ten active solar cell paddles plus eight dummies	$206,600	$115,000	---
Battery packs	---	20,000	$15,000
Fabrication of mechanical systems	---	152,000	26,000
Engineering and technical services	---	50,000	---
Six platforms	---	6,000	---
Components for thermal systems	---	5,000	5,000
Coating for temperature control	---	8,000	5,000
Test and evaluation	---	61,000	---
Data reduction and analysis	---	310,000	150,000
Delta launch vehicles (two funded under vehicle development program)	---	---	---
	828,800	1,223,000	496,000
Recoverable Nuclear Emulsions Probe:			
Nuclear emulsions	---	21,000	25,000
Components and fabrication of subsystems	17,900	22,000	75,000
Flight telemetry equipment	---	85,000	50,000
Engineering services	---	30,000	65,000
Environmental test	---	55,000	45,000
Quartz lamps	---	18,000	15,000
Computing services	---	25,000	25,000
Nuclear emulsion processing	---	20,000	20,000
Nuclear emulsion scanning	---	10,000	10,000
Payload package design and construction	426,700	---	---
Scout launch vehicle	---	---	1,000,000
	444,600	286,000	1,330,000
Ionosphere Direct Measurement Satellite:			
Ultra-high vacuum system	35,000	---	---
Electrometer procurement and development	71,400	---	---
Field engineering services	13,900	---	---
Detector development	29,500	---	---
Ion-trap programmer switch	10,000	---	---
Ionospheric measurements	13,400	---	---
Procurement and fabrication of components	33,000	26,000	---
Flight subassemblies	38,500	---	---
Command receiver	9,000	---	---
Flight systems measurement	44,700	5,000	---
Antenna development contract for satellite	42,000	---	---
Flight data systems measurement	47,000	30,000	---

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Test and evaluation.....	$8,200	$4,000	---
Reduction of data.....	---	20,000	---
Data reduction.....	---	150,000	$30,000
Data analysis.....	---	15,000	20,000
Design and fabrication of prototype and two flight models.....	676,000	---	---
Juno II launch vehicle.....	870,837	55,000	---
	1,942,437	305,000	50,000
Ionosphere Beacon Satellite:			
Design and fabrication of flight hardware (2 flight units).....	745,000	---	---
Data reduction.....	---	125,000	---
Juno II launch vehicles (two).....	1,741,672	109,000	---
	2,486,672	234,000	---
Electron Density Profile Probes:			
Instrumentation and fabrication of two payloads.....	77,400	125,000	95,000
Antenna design and construction.....	75,000	---	---
Payload integration and telemetry...	---	150,000	---
Nose cone.....	---	30,000	---
Test and evaluation.....	---	66,000	3,000
Data acquisition field support.....	44,700	60,000	60,000
Vertical height station.....	---	125,000	15,000
Data analysis.....	---	---	20,000
Scout launch vehicles (two; funded under vehicle development program).	---	---	---
	197,100	556,000	193,000
Swept Frequencies Topside Sounder (Canada):			
Integration of experiments and subsystems.....	---	42,000	42,000
Test and evaluation of components...	---	2,000	14,000
Thor-Agena B launch vehicles (two)..	---	4,400,000	8,300,000
	---	4,444,000	8,356,000
Fixed-Frequency Topside Sounder (U. S.):			
Subsystem and component procurement and assembly.....	---	41,000	41,000
Test and evaluation.....	---	23,000	18,000
Flight instrumentation.....	269,808	755,000	---

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Systems studies	$33,900	$87,000	$194,000
Scout launch vehicle	---	---	1,000,000
	303,708	906,000	1,253,000
Geophysical Observatories:			
Mass spectrometers	14,700	64,000	425,000
Preparation of experiments by contractors	34,400	660,000	1,500,000
Special photomultipliers	---	30,000	30,000
Phoswich development	---	20,000	20,000
Instrumentation components	---	39,000	225,000
Magnetometer development and procurement	---	56,000	100,000
Radiation belt and auroral measurements	---	9,000	23,000
Ion spectrometer experiments	---	14,000	52,000
Data storage techniques	---	20,000	50,000
Electronic assemblies for instrumentation	93,000	220,000	338,000
Fabrication and assembly of subsystems	16,000	25,000	65,000
Low-noise command receivers	---	10,000	30,000
Telemetry systems	95,000	20,000	40,000
Development of directive antenna systems	---	5,000	10,000
Encoding techniques	18,000	20,000	40,000
Low-drain telemetry	---	30,000	30,000
Jet systems and associated equipment	19,700	30,000	85,000
Control systems component development	37,300	71,000	60,000
Horizon scanners	---	---	40,000
Gyroscopes	---	---	40,000
Torque controls	---	---	15,000
Electronic units	---	---	20,000
Test and evaluation	---	15,000	435,000
Turntable discriminator	8,400	---	---
Commutators, simulator, and evaluation	58,000	---	---
Direct write recorder	6,000	---	---
Air bearing stand	---	---	12,000
High-frequency magnetic field station	---	---	70,000
Computing services	---	41,000	27,000
Engineering services	---	---	30,000
Design and fabrication of prototypes and two flight models	---	3,188,000	11,000,000
Atlas-Agena B launch vehicle	---	---	3,700,000
	400,500	4,587,000	18,512,000

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
International Ionosphere Satellite (UK No. 1):			
Recorder development.....	---	$75,000	---
Component development and assemblies	---	80,000	---
Flight data systems.....	---	195,000	$64,000
Radio frequency systems fabrication.	---	73,000	16,000
Batteries.....	---	20,000	---
Solar cells-10 paddles 8 dummies....	---	200,000	---
Components and fabrication of mechanical systems.....	---	52,000	31,000
Manufacture prototypes and two flight units.....	---	100,000	---
Engineering and design services.....	---	23,000	---
Coatings for temperature control....	---	8,000	---
Test and evaluation of components and flight units.....	---	22,000	20,000
Data processing.....	---	---	100,000
Scout launch vehicle (funded under vehicle development program).....	---	---	---
Scout launch vehicle for backup flight.....	---	---	1,000,000
	---	848,000	1,231,000
International Program Satellite (UK No. 2):			
Design and fabrication of payload...	---	250,000	1,000,000
International Program Satellite No. 3:			
Design and fabrication of payload...	---	---	420,000
Explorer VI:			
Design and fabrication of flight hardware.....	$2,027,000	---	---
Data reduction.....	239,775	---	---
	2,266,775	---	---
Explorer VII:			
Design and fabrication of flight hardware.....	1,028,080	---	---
Data reduction.....	391,450	---	---
	1,419,530	---	---

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
12-foot Sphere:			
Completion of experimental work.....	$50,863	---	---
Radiation Balance Experiment:			
Design and fabrication of flight hardware.....	565,484	---	---
Vanguard III:			
Data reduction and computing services	---	$50,000	$5,000
Jupiter Nuclear Emulsions.....	2,212	---	---
Integration of Emulsion Package:			
Air Force reentry vehicle.....	9,945	---	---
Atlas Pods.....	---	150,000	---
Modification of X-15 for Payloads.....	---	641,000	---
Systems for Payload Recovery.....	---	200,000	---
Total, Flight Program.....	$16,228,293	$27,754,000	$55,331,000

Orbiting Solar Observatories

The first major satellite with the objective of measuring the electromagnetic radiations of the sun from above the absorbing curtain of the earth's atmosphere will be launched in the 4th quarter of the fiscal year 1961. An automatic pointing control will be used to keep the scientific instruments trained on the sun during the periods of observation. The satellite will weight about 350 pounds. The design goal for the operating lifetime is one year. Funding of this satellite will be completed with 1961 funds. Work has been started on a second orbiting solar observatory spacecraft, which will carry somewhat different experiments, which will be launched in the fiscal year 1962. This spacecraft will continue the solar observations initiated with the first unit. It is also considered to be the back unit, should any difficulties be encountered with the first satellite. Funding for this second satellite will be accomplished with fiscal year 1962 funds except for data analysis which will require fiscal year 1963 funds. The initiation of design and fabrication of a third orbiting solar observatory, to be carried on a Thor-Agena B vehicle, rather than on the Delta vehicle scheduled for the first two units, is planned for

the fiscal year 1962. This spacecraft is to use the basic structure, controls, etc., of the first units, with those modifications added which the additional performance of the Thor-Agena B will permit. The launching of this spacecraft is planned for early in the fiscal year 1964. Additional funds will be required in the fiscal year 1963 for this third spacecraft and for the Thor-Agena B launch vehicle.

Gamma Ray Astronomy Satellite

This will be the first satellite experiment to measure cosmic gamma radiation. Later experiments in larger satellites will be based on the findings obtained by this exploratory experiment. It is hoped that a better understanding of gamma rays will contribute to the solution of one of the mysteries of modern science, the nature and origin of cosmic rays. The satellite weight will be about 80 pounds. Funding for this satellite, including data reduction and analysis, was completed with fiscal year 1961 funds. Two identical spacecraft are being fabricated so as to provide backup in case of a failure to achieve a satisfactory orbit. A developmental Scout has been earmarked for use as the launching vehicle for the backup, if needed. The backup launching is tentatively scheduled for the 4th quarter of the fiscal year 1961.

Orbiting Astronomical Observatory

This satellite is being developed to perform a series of astronomical investigations that have not been previously possible due to the limitations placed upon astronomical observations by the absorbing and distorting effects of the earth's atmosphere. Telescopes, filter and grating spectrometers, and vidicon systems designed especially for the automatic, remote control needs of this satellite will be used. The weight of instruments and stabilizing equipment for this satellite will be more than three thousand pounds. This will be the first satellite with stabilization and ground control of direction of orientation for the conduct of long-term stellar observations from above the earth's atmosphere. It is the logical follow-up of the early sounding rocket experiments in astronomy and of the orbiting solar observatory. The development of the stabilization and control equipment will provide a satellite system adaptable to all types of optical astronomical observations. A payload weight of about 3,500 pounds is the design goal. Development of the specialized sensors and instrumentation required for this experiment was started in the fiscal year 1959 under advanced research and technical development. In the fiscal year 1960 the development of prototype flight instrumentation components and assemblies was initiated. Fiscal year 1961 funds will continue the development of prototype instrumentation, and initiate the necessary subsystems and hardware development and the design and fabrication of the prototype satellite. The funding planned for the fiscal year 1962 will cover the major portion of the costs for the flight instrumentation and the prototype assembly. The flight models will be initiated and environmental testing of the instruments and supporting subassemblies such as pointing controls, command and telemetry

equipment, stabilization equipment, and power supplies will be funded. An initial increment of the cost of the launch vehicle will also be funded. Completion of this project will require fiscal year 1963 funding.

Air Density-Drag Measurements Satellite

This will be the first satellite orbiting test of the Scout vehicle. The payload will consist of a 12-foot inflatable sphere; a radio beacon will be carried by the sphere to facilitate precise tracking. The large size and small weight of this sphere should result in atmospheric drag effects of sufficient magnitude to give fairly definitive measurements of air density at satellite altitudes. The payload weight will be about 85 pounds. The sphere to be used was developed under the earlier "Beacon" program. The radio beacon was developed in connection with project Echo. Payload integration is being provided by the Langley Research Center as a part of the Scout development. Data analysis will be carried out as a part of Langley's regular research program.

Micrometeoroid Satellite

This will be the satellite of the second orbital Scout vehicle. The primary objective of the satellite is to obtain a direct measure of the micrometecroid puncture hazard for space vehicles. Five types of detectors including pressurized cells, foil gages, wire grids, cadmium sulfide cells, and piezoelectric impact detectors will be used. A total surface area of about 2.25 square meters will be exposed by the various detectors. Another experiment will determine the effects of the space environment of silicon solar cells. The payload weight will be about 115 pounds. A duplicate unit is being prepared for backup purposes. If it is not used as a backup, it is scheduled for launching in the fiscal year 1962 as part of the continuing program of micrometeoroid studies.

Atmospheric Structure Satellite

This will be the first satellite with the primary objective of studying in detail the earth's upper atmosphere. Composition, density, pressure, and temperature will be measured, and variations of these properties with latitude and the time of the day will be determined. The satellite weight will be about 370 pounds. This satellite was initiated and funded to the extent of about 20 percent with fiscal year 1960 funds. Fiscal year 1961 funds provide about 60 percent of the total cost, and the remaining 20 percent will be required in 1962.

Energetic Particles Satellite

The satellite for this project is scheduled for launch by a Delta vehicle. It will provide a continuation of the planned program for investigation of the radiation belts. In addition to energetic particles detectors, this satellite will include magnetic and optical equipment to study the directional behavior of the radiation and to study the interactions of the earth's magnetic field with the radiation belts. The

satellite weight will be about 80 pounds. Funding of the first spacecraft, including provisions for data reduction and analysis, will be completed with 1961 funds. Fiscal year 1961 funds also provide for the partial instrumentation of the follow-up spacecraft. This spacecraft is intended to follow in the fiscal year 1962 and to continue the program of observation and monitoring of the radiation belts. Here again, the second unit also stands as backup to the first. Fiscal year 1962 funds will complete the funding except for some data analysis to be completed in 1963.

Recoverable Nuclear Emulsions Probe

This Scout probe will carry nuclear emulsions into the lower portions of the radiation belts to measure the flux, composition, energy spectrum, and angular distribution of the particles in the belts. The emulsions will be selectively exposed to measure the variation of these parameters with altitude, geographic position, geomagnetic latitude, and the intensity of the earth's field. The major experimental technique will be the use of nuclear emulsions. Recovery of this probe is essential. The payload weight will be 50 pounds. Fiscal year 1960 funds provided for the design and construction of the payload package based on modification of the design of the nuclear emulsions recovery vehicle which was successfully launched in September 1960. Work on the experiments, telemetry, and other subsystems, and on environmental testing is being funded in the fiscal year 1961; 1962 funds provide for completion of this work and for procurement of the Scout launch vehicle.

Ionosphere Direct Measurements Satellite, Explorer VIII

This satellite was successfully launched in November 1960. It contains instrumentation to determine the concentration and the spectrum of the charged particles forming the ionosphere and to measure the effects of the ionosphere on the satellite's electrical charge. The satellite weighs about 85 pounds. Funding of this satellite was completed with 1961 funds, with the exception of $50,000 which will be required in 1962 for data reduction and for the analysis of the results obtained by the satellite.

Ionosphere Beacon Satellite

Analysis of the effects of the ionosphere upon radio signals generated by the satellite will be used to determine the spatial distribution and the variations with time of the charged particles forming the ionosphere. In addition, very valuable direct information about the composition of the ionosphere in the immediate region of the satellite will be obtained. The satellite weight will be about 70 pounds. Funding of this satellite was completed with fiscal year 1961 funds. This satellite is designed as an integral part of a research program being conducted by the University of Pennsylvania, the University of Illinois, Stanford University, and the

Central Propagation Laboratory of the Bureau of Standards. Their work, which is already under way using signals from satellites launched for other purposes, is funded under the advanced research portion of the program. It is expected that other interested laboratories in this country and throughout the world will conduct research using the transmissions from this satellite. A second spacecraft is being fabricated for launching in the fiscal year 1961 in the event of failure of the first attempt.

Electron Density Profile Probes

Two Scout launched probes will be instrumented to measure by means of a radio frequency impedance probe the density of electrons having thermal energies and to investigate the ionosphere by studying radiowave propagation from rocket-borne transmitters. Vehicle potential and ion sheath phenomena will also be investigated by means of Langmuir probes. The vehicle will be used to achieve a very high altitude (over 5,000 miles) sounding. Two experiments will be conducted to study day-to-night differences. The payload weight will be 100 pounds. This experiment was initiated in 1960 with the procurement of the instrumentation and system development. Fiscal year 1961 funds continued the instrumentation assembly, system development, and telemetry procurement; 1962 funds will complete the instrumentation costs and provide for data acquisition and analysis.

Swept Frequency Topside Sounder Satellite (Canada)

This satellite is being built by the Defence Research Telecommunications Establishment of the Canadian Government. The NASA, under a cooperative agreement, will integrate the payload into a satellite system for launching. The data will be shared by the scientists of both countries. This satellite will be equipped with complex electronic instrumentation designed to study the upper portions of the ionosphere. It will be an important "first" in the investigation of the ionosphere because it will obtain measurements not heretofore possible. Radio soundings of the lower portion of the ionosphere have been made from the ground for many years and much useful information has been obtained. The nature of the ionosphere and its effect upon radio waves prevents the use of this technique in obtaining information about the upper half of the ionosphere. The satellite will be designed to make these sounding measurements from above the main portion of the ionosphere. The information thus obtained, plus the results from the earlier ionospheric satellites and the sounding rocket program, should contribute materially to our understanding of the nature and phenomena of the ionosphere. The satellite will weigh about 200 pounds. Costs for the satellite itself are being borne by the Canadian Government. NASA funding will provide for the Thor-Agena B vehicles and for the integration of the satellite with the vehicle. A backup spacecraft and launch vehicle will be built for launching in the fiscal year 1963 in the event of failure of the first launching. If the first launching is successful, the vehicle will be rescheduled for other spacecraft.

Fixed Frequency Topside Sounder (U.S.)

This satellite has the same scientific objective as the Canadian sounder, although a different experimental approach is being used. In designing this satellite, the United States scientists have selected a sounding technique based on the use of six fixed frequencies, whereas the Canadians have adopted an approach based on a swept frequency sounding technique. The United States system will function as a low resolution, fast information rate sounder, while the Canadian system will operate as a high resolution but slow information rate sounder. The two satellites will be launched several months apart but close enough together so that there will be a period of time during which both will be in operation simultaneously. The results thereby obtained should be considerably more valuable than if no simultaneous observations were obtained. The satellite will weigh about 100 pounds and is presently scheduled for launch by a Scout vehicle. The instrumentation work was started early in the fiscal year 1961. Planned 1962 funding will complete hardware procurement and evaluation tests. The Central Radio Propagation Laboratory of the Bureau of Standards will have prime responsibility for data handling, reduction, and analysis. A backup spacecraft will be manufactured.

Geophysical Observatories

The basic satellite structure, solar cell power supply, stabilization equipment and telemetry and command equipment will be the same for these two satellites. They will carry different instrumentation, however, as they are being launched with different objectives into two distinctly different orbits. An Atlas-Agena B will launch one satellite into a highly eccentric orbit extending to over 40,000 miles in apogee. This satellite is intended to perform the most extensive exploration of the radiation belts that has yet been accomplished and to study the upper reaches of the earth's ionosphere and magnetic field to the region where they intermingle with the fields characteristic of interplanetary space. The other satellite will be launched by a Thor-Agena B into a much less eccentric orbit with an apogee of about 600 miles and a perigee of about 150 miles. This orbit will also be polar, that is, the satellite will pass over the northern and southern polar regions. This satellite will be instrumented to perform extensive explorations of the earth's atmosphere, ionosphere, and magnetic field phenomena to 600 miles altitude with particular emphasis being paid to the relatively unexplored polar regions. The payload weight of each satellite will be about 1,000 pounds. The initial instrumentation and hardware procurement for these satellites started late in the fiscal year 1960. The majority of the instrumentation, telemetry, solar cell power supply, and basic satellite structure will be carried throughout most of the prototype phase with 1961 funds. Fiscal year 1962 funds will complete the prototype development and environmental testing costs, and will provide for the two flight models. Construction of a third spacecraft will also be initiated. It will serve as backup for the first two

or as a follow-on satellite as needed. Fiscal year 1963 funds will be required for procurement of the Thor-Agena B launch vehicle, for check-out of the flight models, and for completion of the backup unit.

International Ionosphere Satellite (UK No. 1)

This is the first satellite under the NASA International Program and will be instrumented by scientists of Great Britain. Experiments in the ionospheric, cosmic ray, and solar radiation areas have been selected. NASA will do the payload assembly work and conduct the launching. The payload weight will be about 150 pounds. Fiscal year 1961 funds have been provided for most of the supporting systems including telemetry and solar cell power supplies and for most of the costs of payload integration and testing. The funding requested for the fiscal year 1962 will complete the satellite development and will provide for data acquisition and processing. Data analysis will be done by the participating scientists. This satellite will be launched by the last of the developmental Scout vehicles. A backup payload is being built, and 1962 funds provide for a Scout vehicle to be used for a second launching in the latter part of the fiscal year 1962 in the event of failure of the first launching.

International Program Satellite (UK No. 2)

Preliminary study is now under way for a second satellite to be developed jointly with the United Kingdom. British scientists will furnish a new set of geophysical experiments. NASA will begin design of the spacecraft in the latter part of the fiscal year 1961. Design and construction will be continued in the fiscal year 1962 with final assembly and test in the fiscal year 1963. A Scout launch vehicle will be procured in 1963. This satellite is scheduled for launching early in the fiscal year 1964.

International Program Satellite No. 3

Preliminary study will be started late in the current fiscal year for a third international satellite to be launched in the latter part of the fiscal year 1964. Design of the spacecraft will begin in the next fiscal year, and construction of the spacecraft and procurement of the Scout launch vehicle will require fiscal year 1963 funding.

Vanguard III

The reduction of data from the Vanguard III satellite launched in September 1959 is being continued with fiscal year 1961 and 1962 funds. These data are being used in studies of the Earth's magnetic field and of the effect of space drag on satellites.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

LUNAR AND PLANETARY EXPLORATION

SUMMARY OF REQUIREMENTS:

	1960	1961	1961 Supplemental	1962	Page No.
Advanced Research.....	$1,857,546	$4,156,000	---	$6,023,000	RD6-6
Advanced Technical Development.....	6,448,717	9,576,000	---	12,080,000	RD6-9
Flight Program:					
Lunar Programs.....	37,890,737	53,713,000	---	64,288,000	RD6-15
Planetary and Interplanetary Programs.	3,798,900	10,079,000	$5,000,000	21,508,000	RD6-15
Total.....	$49,995,900	$77,524,000	$5,000,000	$103,899,000	

OBJECTIVES:

General

Modern science and technology present challenging possibilities for the unmanned exploration of the solar system. An extensive program to exploit these possibilities is being undertaken by the NASA. In addition to its direct contributions to science, this program will provide a sound scientific and technological foundation for subsequent manned exploration.

The scientific objectives of this program may be generally stated to include studies of the physics of the moon and planets, solar and interplanetary physics, biosciences and extraterrestrial life, and cosmology. Nearly all of the scientific disciplines are involved in these categories. Physics of the moon and planets is comparable to geophysics of the earth and as such includes studies of atmospheres, ionospheres, trapped radiation, magnetic and gravitational fields, and properties of the surface and subsurface. Solar and interplanetary physics is concerned with the solar atmosphere and radiations, and with the properties of interplanetary space as influenced by the sun, the solar system itself, and sources from without the solar system. Biosciences encompasses not only the search for

extraterrestrial life but the study of the behavior and propagation of earth life forms in extraterrestrial environments. Lastly, cosmology is the effort to integrate the results of these studies into a better understanding of not only the nature and origin of the solar system, but of the universe itself.

In the course of carrying out this program of unmanned scientific exploration, vital technological objectives are expected to be achieved. These fall in the areas of navigation, guidance and control; long-range communication; entry into planetary atmospheres; remote landings and operations on the moon and planets; surface transportation techniques in strange environments; and possibly utilization of natural resources which are yet to be found. The process of developing these technologies will lay the groundwork for more advanced missions to follow.

Lunar Program

The primary scientific objective of the lunar science program is the exploration and investigation of the moon for the information which it can provide on the history of the earth-moon system and on the origin of planetary bodies in the solar system. The experiments are directed toward the determination of surface structure and physical properties of the surface, the origin of the surface features, chemical composition, properties of the moon as a planetary body, and the thermal history of the moon.

The surface features and structure will be determined by television systems. Physical properties of the surface to be measured include electrical and thermal conductivity, and the size distribution of surface rocks and particles. The chemical composition will be studied by a variety of methods, including, initially, X-ray fluorescence spectrometry and gamma ray spectrometry. The detection of radioactive elements in the surface will be a particularly important part of this study. Information regarding the thermal history of the moon will come from the measurement of heat flow through the surface, and from the simultaneous consideration of the chemical composition, the surface features and structure, and the degree of differentiation of the moon's interior. The primary source of information on the differentiation of the interior will be by analysis of the orbit of an advanced lunar satellite. Seismic and gravimetric measurements will be the principal source of information regarding the properties of the moon as a planetary body. The seismic and gravimetric data may also yield information on the differentiation of the moon's interior.

In addition, the moon has a biological interest through the possible occurrence of organic molecules, precursors of living organisms, in the layer of dust which has accumulated over may aeons. The chemical analysis of this surface dust layer may prove to be of immeasurable importance to the biological sciences.

Finally, the exploration of the lunar surface, and the analysis of its physical and chemical properties, are necessary steps in the planning and designing of manned instrument stations and the solution of the problems of construction and life-support for a manned lunar station.

Planetary and Interplanetary Programs

The primary objective of the planetary and interplanetary science program is the extension of man's knowledge of the solar system. Investigations for signs of planetary life are among the most important currently planned. These will be undertaken by measurements in the infrared spectrum surveying the surface for organic molecules and solvents and by examining the planet atmosphere for carbon and oxygen compounds, such as CO and ozone, to determine if the planet environment is compatible with the support of life. Some information can be obtained from earth-based observations. Additional knowledge can be learned from balloon observations at great enough height above earth to eliminate most of the ultraviolet absorption. Still additional measurements will be required from planet fly-bys, orbiters and ultimately from probes directly examining the planetary atmosphere and surface. In addition, measurements of planetary physics - atmospheres, magnetic fields, radiation belts, and surface features - are required.

Instrumentation planned for use in planetary study includes wide-band infrared photographic equipment; narrow-band spectographs suitable for space probes measuring in the ultraviolet, visible and infrared spectrum and including data storing and reporting capability; mass spectrometers for both atmospheric and surface use; long-range telemetry and command systems suitable for the distance to Mars, and energy sources to operate during the long period that the equipment will be utilized near or on the planets.

Supporting research will be conducted to find materials and develop instruments that are resistant to the atmosphere and temperatures of Venus and Mars.

Further, the structure and composition of interplanetary space itself are unknown; observation of this medium, the solar effects upon it, and its relationship to the terrestrial condition will be made with the long-range objective of understanding the nature of the solar system. This will be accomplished by obtaining measurements of the interplanetary plasma density and its energy spectrum and some data on the angular, spatial and temporal dependence of the flux. Detailed measurements of interplanetary plasma during periods of minimum solar activity as well as during periods of great sunspot activity will be emphasized. An important objective is the correlation of measurements between interplanetary probes, planet orbiters and lunar orbiters which should make it possible to establish the scale size of plasma clouds

ejected by the sun and compare the interplanetary densities at different portions of the solar system. Also a particularly important objective is the study of cosmic dust which, as representative of the building blocks of stars and galaxies, may be a key in the study of the origin of the solar system and the universe.

JUSTIFICATION:

From a scientific viewpoint, as exemplified by the previously stated scientific objectives, the motivations are compelling. The exploration of the moon is of great importance to science because the surface of this body has not been subjected to the erosion of winds and water, and therefore may carry on the surface a record of the early history of the solar system. This record has been lost forever on the Earth, Mars, or Venus, and may only be available on the moon. The moon may also have on its surface, in the layer of dust which has accumulated there, organic molecules which will give us a clue to the development of physical life on the Earth.

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

The lunar and planetary exploration program has been carefully designed to avoid duplication and to promote reliability in the spacecraft development area. Every effort has been made to minimize the number of types of spacecraft and to maximize the number of uses for each type. Wherever possible, the same basic subsystems or their advanced derivatives will be employed in successive spacecraft series. This will result in the evolutional development of a small family of unmanned exploration spacecraft, wherein the relatively simple systems and limited capabilities of early spacecraft will be extended and refined as launch vehicle weight-lifting capability is increased to the point where later spacecraft will be capable of the more sophisticated operations required by the program. This building-block concept will permit exploitation of early unmanned scientific and technological missions as part of an orderly flight-qualification sequence prior to undertaking manned exploration activities.

The proposed mission schedule under the Lunar and Planetary Exploration program follows:

Lunar Projects	Mission Objectives	Launch Vehicle	Calendar Year of first launch
Ranger	Rough landing	Atlas-Agena	1961
Surveyor	Soft landing	Atlas Centaur	1963
Surveyor	Precise orbit	Atlas Centaur	1965
Prospector	Soft landing - mobile	Saturn	1966
Planetary Projects			
Mariner	Fly-by	Atlas Centaur	1962
Voyager	Orbit and land	Saturn	1966
Interplanetary Projects			
Pioneer 5	Radiation spectrum and fields	Thor-Able	1960
Magnetometer probe	Plasma and fields	Thor-Delta	1961
Ranger, Mariner, Voyager test vehicles	Spacecraft test plus interplanetary physics	Various	1961

The detailed significance of this phasing will be apparent in the subsequent discussion of each project.

A fundamental prerequisite to the exploration of the moon and the solar system is the development of spacecraft capable of performing the desired missions. Such spacecraft do not exist today. Their realization will require perfecting and integrating many technologies, including: attitude sensing and control; midcourse navigation (radio-command techniques for lunar missions and self-contained celestial navigation for distant planetary missions); terminal guidance and spacecraft propulsion; long-range communications; precise orientation of spacecraft-borne components such as antennas, sensors, and radiators; long-term power generation sources and systems; control of internal and surface temperatures under widely varying conditions; extremely efficient structures capable of functioning under the wide range of environmental conditions to which the spacecraft will be exposed; the solution of the problems of entry into planetary atmospheres; and the development of

automatic or remotely-controlled devices for transporting instrumentation over the planetary surface, gathering samples of planetary matter, analyzing them and transmitting the data to earth.

Lunar and planetary projects evolve in such a way as to utilize the full capabilities of the new launch vehicles as they become operational. Spacecraft and instrumentation development are geared to this capability. The funding build-up in support of this program is in consonance with the ability of both the NASA and its supporting industries to implement the program. The lunar program is given initial emphasis with the planetary program phasing in from one to two years later. This makes maximum use of technological and launch vehicle capability in that the planetary spacecraft are based upon lunar developments. The earth-moon region serves as a proving ground for these advanced concepts. The increase in funding in the fiscal year 1962 results primarily from the long lead time required to prepare for the lunar soft landings and from the requirements of the Mariner spacecraft for the calendar year 1962-1964 planetary missions.

FUNDING REQUIREMENTS:

Advanced Research	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Lunar Advanced Research:			
Tektite and meteorite investigations	$205,000	---	---
Lunar ray systems	14,750	---	---
Solar wind investigations	24,506	---	---
Space vehicle sterilization	50,726	---	---
Lunar surface sampler study	17,771	---	---
Lunar gravity meter studies	55,000	$45,000	---
Chemistry of polymers and propellants	225,000	179,000	---
Testing of shock sensitivity of propellants	15,000	11,000	---
Combustion research	225,000	283,000	$345,000
Solid propellant research	60,000	69,000	144,000
Convective heat transfer	60,000	67,000	80,000
Propulsion heat transfer	76,000	86,000	96,000
Rocket motor injection research	205,000	228,000	245,000
Propellants and propellant devices	75,000	78,000	90,000
Investigations of lunar surface	115,000	215,000	435,000
Lunar mapping studies	117,630	221,000	150,000
Radiation investigations	316,163	100,000	200,000
Stresses associated with hard landings	---	65,000	---

Advanced Research	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Analysis by nuclear excitation.....	---	$150,000	---
Research in prototypical systems for space flight.....	---	104,000	$154,000
Studies of internal structure of moon.....	---	178,000	182,000
Plasma investigations.....	---	100,000	100,000
Energetic particle investigation...	---	---	75,000
Analysis and interpretation of lunar seismograph data.....	---	---	140,000
Analysis and interpretation of lunar gamma ray spectroscopy data.	---	---	75,000
Analysis and interpretation of lunar photographic data.....	---	---	100,000
Investigation of gamma ray measurements from a lunar orbiter.	---	---	100,000
Investigation of the neutron albedo from a lunar orbiter.....	---	---	100,000
Advanced techniques for the chemical analyses of the lunar surface.....	---	---	110,000
Advanced techniques for determining the physical properties of the lunar surface.....	---	---	110,000
Advanced techniques for measuring fields and particles from the lunar surface.....	---	---	100,000
	$1,857,546	2,179,000	3,131,000
Planetary and Interplanetary Advanced Research:			
Study by photographic techniques of meteorites in flight.....	---	350,000	---
Luminosity and polarization of planets.....	---	280,000	---
Mars optical system design.....	---	75,000	45,000
Solar prominences.....	---	35,000	35,000
Origin of meteorites.....	---	45,000	40,000
Solar influences on cosmic rays....	---	35,000	25,000
Planetary observational net.....	---	75,000	200,000
Basic characteristics of planetary surfaces and atmospheres.....	---	250,000	155,000
Helium content of meteorites.....	---	20,000	15,000
Age and origin of solar system.....	---	20,000	20,000
Solar atmosphere and planetary research.....	---	298,000	352,000

Advanced Research	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Interplanetary instrument research.	---	$462,000	$375,000
Advanced planetary studies.....	---	32,000	715,000
Neutron albedo.....	---	---	110,000
Solar environment.....	---	---	180,000
Properties of planetary and interplanetary space.....	---	---	225,000
Planetary investigations from balloons.....	---	---	195,000
Advanced planetary mission analyses	---	---	50,000
Lyman-Alpha studies.....	---	---	50,000
Plasma studies.....	---	---	75,000
Solar wind studies.....	---	---	30,000
	---	1,977,000	2,892,000
Total, Advanced Research.....	$1,857,546	$4,156,000	$6,023,000

Advanced Research

Supporting research in the lunar and planetary program creates and maintains a fountainhead of new ideas from which scientists and engineers draw in attaining the over-all NASA space objectives. As the lunar and planetary exploration program has matured, it has become important to support the scientific community in conducting theoretical and analytical studies. Because of the long lead time between the conception of an approach to problem solving and its successful application, a program of theoretical and analytical studies designed to advance the state-of-the-art must look years ahead of the immediate flight mission requirements. The objective is to prepare for missions utilizing the greater weight-carrying capability of the Centaur and Saturn launch vehicles. Such studies will be continued at approximately the same funding level during the fiscal year 1962.

In lunar science, supporting research is directed at studying problems related to landing instrumented packages on the surface. These studies follow a variety of directions such as the study of stresses associated with hard landings which will yield information on which to base both spacecraft and instrument design; the acquisition of lunar photographs from Earth stations from which studies of the surface can yield contours, elevations, equivalent "sea level" and geological similarities to be used in the selection of mission landing sites; and advances in the state of instrument-interpretative art so proper deductions will be developed in time to design experiments required in accomplishing stated objectives.

In addition, since the earth-moon region is considered a proving ground for trying out advanced systems for planetary missions, there is a two-fold requirement for research leading to the ability to maneuver or stabilize the spacecraft during periods when midcourse or terminal guidance corrections are made, or when critical scientific observations are to be undertaken. Since these maneuvers are accomplished at great distances from the earth and require small, but extremely closely-controlled, thrusts, it is necessary to undertake studies of relatively small engines, storable propellants and the effects of mutual constraints between the spacecraft and its guidance devices. Initial emphasis on the study of small engines and their propellants will be on the understanding of propellant chemistry, utilization, shock sensitivity, and heat transfer.

By following a systematic approach, employing earth-based and balloon-borne planetary observation stations, important planetary information can be acquired at relatively low cost. This information will then permit the scientists to design missions capable of extending knowledge of the solar system at a much more rapid rate. In addition, advanced studies are necessary to provide techniques and types of instrumentation capable of measuring and reporting characteristics of the planetary atmosphere, surface and environment.

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Lunar Advanced Technical Development:			
Geiger-Mueller tubes and ionization chambers	$148,130	---	---
Lunar photo system development	500,000	---	---
Cosmic ray detector and magnetometer development	450,000	---	---
Development of impact-proof payload components	105,000	---	---
Spacecraft sequence timer development	445,000	---	---
Spectral lamp	30,000	$50,000	---
6 kilowatt propulsion system development	1,606,000	822,000	---
Spacecraft nuclear source integration studies	10,000	109,000	---
Measurement of atmospheric pressure between earth and moon	50,000	50,000	$150,000
System study for roving vehicle	290,000	389,000	70,000
Infrared photography	103,587	159,000	105,000
Lunar seismology	125,000	300,000	300,000
Data automation system	100,000	70,000	158,000
Thrust control	76,000	58,000	41,000

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Insulating techniques and case and nozzle development.....	$155,000	$126,000	$102,000
Solid rocket motor development....	275,000	213,000	143,000
Propellant development and evaluation.....	275,000	252,000	222,000
Spacecraft retrorocket.....	15,000	29,000	41,000
Auxiliary propellant devices.....	60,000	57,000	53,000
Thrust chambers.....	100,000	72,000	36,000
High-energy liquid propulsion system.....	310,000	241,000	187,000
Propulsion systems analysis.....	75,000	125,000	138,000
Trajectory and guidance systems analysis.....	30,000	45,000	53,000
Documentation.....	15,000	115,000	135,000
Surface and subsurface electrical and thermal properties.....	---	100,000	---
Sample preparation and manipulation.....	---	50,000	---
Subsurface logging techniques.....	---	100,000	---
Television microscopic and telescopic optics.....	---	80,000	---
Ion and electron traps.....	---	50,000	---
Organic molecules and sub-life forms chromatography.....	---	75,000	---
Lunar surface reflectivity.....	---	30,000	---
Pattern recognizer.....	---	20,000	---
Instrument component development..	---	222,000	439,000
Electronic component development..	---	229,000	668,000
Mass spectrometer.....	---	100,000	150,000
Power sources development.....	---	77,000	280,000
Exploration equipment design studies.....	---	146,000	562,000
Flight mechanics analyses.....	---	31,000	220,000
	5,348,717	4,592,000	4,253,000
Planetary and Interplanetary Advanced Technical Development:			
Storable liquid propellant systems	350,000	264,000	164,000
Advanced liquid propulsion development.....	475,000	679,000	743,000
Guidance and control rocket analytical design.....	75,000	109,000	165,000
Design studies of spacecraft configurations utilizing electric propulsion.....	60,000	120,000	120,000

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Study of special structural problems of radiator integration.	$10,000	$80,000	$80,000
Study of dynamics of large propulsion system structures.....	20,000	50,000	50,000
Study of reactor radiation effects on spacecraft instrumentation....	20,000	80,000	80,000
Space charge neutralization and effects on instrumentation.....	10,000	100,000	100,000
Trajectory analysis with electric propulsion.....	60,000	150,000	150,000
Utilization of electrical propulsion power supplies with communication equipment.....	10,000	30,000	30,000
Design study of flight system to test 60 kilowatt electric propulsion system.....	10,000	33,000	41,000
Development of attitude control in presence of propulsion turbomachinery.....	---	144,000	150,000
Spurious interference fields from electric propulsion systems.....	---	70,000	70,000
Solid state radiation detectors...	---	125,000	---
Solar coronagraph.....	---	225,000	---
Planetary photogrammeter.....	---	85,000	---
Biological detection equipment....	---	75,000	---
Motor systems test.....	---	307,000	---
Space biology equipment.....	---	60,000	---
Radar measuring techniques.....	---	125,000	125,000
High-resolution spectroscope.....	---	90,000	75,000
Mass spectroscope.....	---	90,000	75,000
Wide-band infrared photography....	---	75,000	65,000
Temperature and pressure devices..	---	85,000	55,000
Guidance computer system.....	---	210,000	353,000
Guidance computer components.....	---	373,000	534,000
Guidance electronic devices.....	---	154,000	396,000
Analytical design.....	---	25,000	62,000
Structures and dynamics.....	---	169,000	237,000
Fluid mechanics and thermodynamics	---	167,000	198,000
Environmental survival of equipment.....	---	196,000	180,000
Systems integration and analysis..	---	45,000	270,000
Advanced mission parameter studies	---	138,000	226,000
Prototype evaluation and inspection.....	---	256,000	273,000
Surface infrared instrumentation..	---	---	140,000

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Atmospheric infrared instrumentation.....	---	---	$90,000
High-temperature instrumentation..	---	---	90,000
Atmospheric propagation.....	---	---	60,000
Spectrophotometry developments....	---	---	75,000
Instrument component development..	---	---	404,000
Electronic component development..	---	---	382,000
Data automation systems.....	---	---	252,000
Antenna servo systems.....	---	---	86,000
Celestial navigator.....	---	---	239,000
Celestial sensors.....	---	---	234,000
Inertial sensors.....	---	---	244,000
Power conversion devices.....	---	---	200,000
Development of materials, method and analysis techniques.....	---	---	119,000
Design technique development.....	---	---	145,000
	$1,100,000	$4,984,000	7,827,000
Total, Advanced Technical Development.....	$6,448,717	$9,576,000	$12,080,000

Advanced Technical Development

The exploration of the moon and the planets will involve many complex and varied payloads, each containing a multiplicity of instruments for the measurement of the many phenomena of interest. With the results of advanced research studies indicating feasibility and approach to the solution of a problem, there is a need for hardware development which can mechanize the end results outlined in the advanced research studies. Such efforts are necessary to produce laboratory working models and even prototypes from which selections of flight hardware approaches can be made. This is a continuing program directed at the growth development of instrumentation from the relatively simple, through the first-generation, to the advanced instrumentation required by the national space objectives and missions.

Two principal categories of instruments are needed to achieve the objectives of the lunar and planetary exploration program. The first is designed to analyze the surface of the moon or planets and their atmospheres; the second is to measure interplanetary phenomena while the payload is on its way to its destination target such as the moon or a planet. Initial measurements and capabilities have largely pointed up the need for increased dynamic range and discrimination. In all categories of instrument development there is an urgent need for improving lifetime and reliability of operation in the space environment.

Utilization of the Saturn launch vehicle will, for the first time, make it possible for scientists to conduct varied and sophisticated studies on the lunar surface. In order to take maximum advantage of this coming capability it is necessary now to develop completely automatic exploration devices and techniques through the prototype stage. These devices will be capable of measuring surface and subsurface characteristics, of taking samples on radio command, and of preparing material and conducting analyses either on command or by preprogramming. Electronic developments will also provide the means for determining the nature and quantity of any sub-life or pre-life macro-molecules existing on the lunar surface. In the fiscal year 1960 basic developments were started in a wide variety of problem areas. Additional surface and subsurface investigative techniques were initiated in the fiscal year 1961. The funding for the fiscal year 1962 is to carry on those investigations already under way.

The problems of spacecraft maneuvering will, for the next several years, be met by the use of various chemical propulsion systems. Mid-course and terminal corrections to the flight path are made by sensitive controllable thrust elements. Retrorocket systems are needed to cancel or reduce the impact velocity of a landing package. A variety of throttling and thrust control techniques are required in this area. Another (braking) system is required to permit a spacecraft to hover and maneuver briefly over the lunar surface while the desired landing spot is being chosen from televised images.

The NASA has an active research and development program on electric propulsion systems. A characteristic of electric propulsion systems is that they pose complex problems of integration with the spacecraft. These problems arise from such items as the large heat radiator, the nuclear reactor, torques from turbomachinery, electric and magnetic fields from the electrical power supply and accelerators, and the increased reliability and equipment life necessitated by the long-flight times of electrically-propelled systems. In addition, the potential utilization of the propulsion system electrical power for communications purposes is attractive and requires development. In order that these problems may be solved in time to utilize electric propulsion when it becomes available, it is necessary to carry on considerable advanced development work directed towards the spacecraft-propulsion system integration.

The work outlined for the fiscal year 1962 in these areas is a continuation of the program started during the fiscal years 1960 and 1961.

A wide variety of prototype scientific instruments must be prepared for the many specialized experiments to be conducted on the planets. It is necessary to improve the state-of-the-art in advanced circuit design, components, and packaging. Efforts will relate to development of

measuring devices and techniques; to advanced guidance and control system mechanization methods such as on-board computers for utilizing sensor outputs and generating appropriate commands; to guidance sensors and correction procedures in the vicinity of the planets; to celestial navigation aids capable of obviating drifts associated with inertial guidance units; and to the problems of integrating many scientific experiments into one package without unnecessarily degrading the performance of any individual sensor because of placement with relation to another. It will be noted that effort in these areas has just started with fiscal year 1961 funding and additional items appear for the first time in the fiscal year 1962.

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1961 Supplemental	Fiscal Year 1962
Lunar Programs:				
Atlas-Able Program...	$18,348,737	$5,575,000	---	---
Ranger Program.....	19,542,000	40,214,000	---	$30,954,000
Surveyor Program.....	---	7,090,000	---	32,311,000
Prospector Program...	---	834,000	---	1,023,000
Total, Lunar Programs.....	$37,890,737	$53,713,000	---	$64,288,000
Planetary and Interplanetary Programs:				
Pioneer V and Magnetometer Probe.....	$3,798,900	$425,000	---	---
Mariner Program.....	---	9,654,000	$5,000,000	$21,159,000
Voyager Program.....	---	---	---	349,000
Total, Planetary and Interplanetary Programs....	$3,798,900	$10,079,000	$5,000,000	$21,508,000
Total, Flight Program.....	$41,689,637	$63,792,000	$5,000,000	$85,796,000

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Lunar Programs:			
Atlas-Able Program:			
Able IV spacecraft and vehicle...	$4,746,000	---	---
Able V spacecraft and vehicle....	13,602,737	$5,500,000	---
Data analysis.....	---	20,000	---
Lunar atmosphere pressure gage...	---	50,000	---
Test and evaluation.....	---	5,000	---
	18,348,737	5,575,000	---
Ranger Program:			
Spacecraft:			
Ion chambers.....	70,000	---	---
Payload communications system testing.....	250,000	---	---
Solar corpuscular equipment and cosmic ray ionization chamber..	240,000	95,000	---
Environmental laboratory equipment.....	350,000	275,000	---
Investigation of lunar surface characteristics.....	100,000	293,000	$410,000
Gamma ray spectrograph experiment.....	20,000	239,000	99,000
Impact TV system.....	110,000	502,000	180,000
Telemetry system development....	500,000	360,000	153,000
Flight telemetry system.....	1,310,000	893,000	326,000
Command system development.....	250,000	252,000	133,000
Attitude control system.....	1,533,000	533,000	161,000
Electrical conversion equipment.	950,000	850,000	85,000
Pyrotechnics development.....	100,000	129,000	134,000
Component electronic and electromechanical packaging.....	260,000	267,000	226,000
Spacecraft design and development testing.....	200,000	685,000	259,000
Spacecraft mechanical and structural components.....	700,000	707,000	318,000
Midcourse maneuver propulsion system.....	280,000	222,000	78,000
Trajectory analyses.....	50,000	270,000	211,000
Spacecraft systems design.....	100,000	327,000	240,000
Lunar capsule contract.....	3,660,000	1,770,000	1,000,000
Systems test and field operations.....	39,000	663,000	589,000

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Electronic devices and module packaging	$340,000	$596,000	$226,000
Space environmental testing	500,000	419,000	277,000
Documentation	270,000	794,000	267,000
Magnetometer experiment	---	304,000	---
Micrometeorite detector	---	12,000	---
Spacecraft friction experiment	---	43,000	---
Systems test hardware	---	361,000	---
Spectrophotometer equipment	---	9,000	---
Optical test equipment	---	25,000	---
Calibration of instruments and preparation for handling scientific data	---	229,000	235,000
High-resolution television optics	---	255,000	99,000
Lyman-Alpha experiment	---	218,000	46,000
Single-axis seismometer	---	168,000	102,000
Solar corpuscular detector	---	429,000	96,000
Semiconductor and Geiger tube detector	---	38,000	19,000
Triple coincidence detector	---	53,000	19,000
Data automation system	---	391,000	104,000
Antenna development	---	187,000	136,000
Development and procurement 960 megacycle spacecraft equipment	---	539,000	499,000
Flight command system	---	605,000	115,000
Ground command system	---	212,000	88,000
Guidance and control analytical design	---	108,000	112,000
Navigation system simulator	---	370,000	206,000
Celestial sensors	---	531,000	119,000
Inertial sensors	---	665,000	76,000
Power sources	---	486,000	44,000
Energy storage devices	---	178,000	31,000
Assembly and systems check-out	---	595,000	407,000
Spacecraft assembly equipment	---	184,000	114,000
Ground support equipment and engineering	---	908,000	393,000
Controller timer	---	1,080,000	254,000
Communications check-out equipment	---	482,000	1,403,000
Prototype evaluation and inspection - quality assurance	---	131,000	87,000
Vibration analysis services	---	120,000	179,000
Technical facility engineering	---	231,000	103,000

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Data reduction equipment and processing	---	$436,000	$570,000
Computing services	---	1,302,000	1,072,000
Data handling system	---	166,000	273,000
Spacecraft systems integration	---	322,000	1,081,000
	$12,182,000	23,514,000	13,454,000
Atlas-Agena launch vehicles	7,360,000	16,700,000	17,500,000
	19,542,000	40,214,000	30,954,000
Surveyor Program:			
Soft-landing spacecraft:			
Analysis of mission requirements	---	438,000	529,000
Spacecraft instrumentation development	---	771,000	2,651,000
Spacecraft instrumentation hardware	---	655,000	1,124,000
Data automation system	---	275,000	314,000
Ground communications consulting and liaison service	---	63,000	71,000
Guidance and control analytical design	---	13,000	19,000
Structural and mechanical systems analyses	---	80,000	90,000
Retro-propulsion development	---	39,000	57,000
Systems analysis and integration	---	78,000	93,000
Soft-landing systems design studies	---	554,000	158,000
Soft-landing spacecraft development	---	3,106,000	18,565,000
Sterilization equipment	---	50,000	---
Analysis of communications systems requirements	---	31,000	33,000
Documentation	---	80,000	410,000
Lunar orbiter design studies	---	487,000	29,000
Lunar orbiter system integration	---	---	628,000
	---	6,720,000	24,771,000
Centaur launch vehicles	---	370,000	7,540,000
	---	7,090,000	32,311,000

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Prospector Program:			
Spacecraft:			
Analyses and studies of compatibility of subsystems....	---	$520,000	$653,000
Scientific instrumentation.....	---	314,000	370,000
	---	834,000	1,023,000
Total, Lunar Programs.....	$37,890,737	$53,713,000	$64,288,000

Lunar Programs:

The lunar flight program provides for orderly progress of advancing scientific and technological experiments necessary to detailed exploration of the moon. An evolutionary family of spacecraft, providing a maximum of continuity in developments from one series to the next, is a principal ground rule in this program.

All of these projects are steps toward a common goal and each of the earlier phases will contribute significantly to the subsequent projects. The funding includes new developments in spacecraft and instrumentation for specific lunar requirements. The fact that many new developments are required for the achievement of a successful lunar program results in the high non-recurring costs for these spacecraft and associated experiments.

Atlas-Able Program

The purpose of this lunar orbiting spacecraft utilizing the Atlas-Able V launch vehicle was to obtain scientific measurements of solar and interplanetary phenomena while "anchored" in the vicinity of the moon within convenient communication range of the earth, and to measure the magnetic field around the moon. This spacecraft effort was terminated following the failure of the launch vehicle.

Ranger Program

The Ranger Program consists of five missions. The first two of these are alike, and have mission objectives to (1) test the basic design and operational features of the lunar spacecraft, and (2) to obtain interplanetary data with scientific instruments carried in place of the lunar capsules. Because these are the first in the series, they are simpler in some respects than the spacecraft which will be used in the execution of lunar landings. The chief differences are that they contain no midcourse maneuver system, no landing capsule, and have only moderate firing constraints because no close approach to

the moon is required. Should the first shot prove successful, an alternate second shot is planned with more difficult and advanced requirements, so that maximum progress toward the eventual use of spacecraft for lunar landings can result.

Instruments to be carried on the first two Ranger spacecraft include a solar corpuscular detector, a rubidium vapor magnetometer, semi-conductor detectors and thin-walled Geiger counters, an ion chamber, triple-coincidence telescopes, and a Lyman-Alpha scanner.

The last three Ranger spacecraft are intended to approach the moon and rough land about 40 pounds of survivable payload. This series of spacecraft has been designed for the primary objective of gaining detailed data on lunar surface characteristics. Each spacecraft has two major parts: the "bus," the basic hexagonal structure with power supplies, radios, attitude control, and midcourse guidance; and the "capsule," a separable survivable instrument package, and its retrorocket.

The complete spacecraft will be launched on a lunar impact trajectory, and midcourse corrections applied to improve accuracy. At a suitable distance from the lunar surface the spacecraft will be properly oriented, and the landing capsule launched. The bus will continue on to crash into the moon, but a retrorocket will decelerate the capsule, allowing it to impact at a nominal speed not exceeding several hundred feet per second.

Experiments will be carried by both bus and capsule. The primary experiments on the bus will be an advanced vidicon system and a gamma ray spectrometer, while the major experiment in the landing capsule will be a single-axis seismometer.

The spacecraft will complete its terminal maneuvers, including stabilization and the establishment of a telemetry link with the tracking station, before the first picture is exposed. Thereafter, one complete picture will be transmitted to the tracking station every 13 seconds, providing a total of 100 pictures during the lunar approach. The first picture will contain a field of view 25 miles square with a resolution of 650 feet. The final picture will be of an area 2,000 feet square with a resolution of 10 feet.

The gamma ray spectrometer experiment is intended to determine whether or not the moon, like the earth, has formed a crust which contains a relatively high concentration of naturally radioactive isotopes. This information bears on problems such as the formation of the moon, the heat balance of the moon, and the source of chondritic meteorites.

The gamma ray spectrometer, together with a 32-channel pulse-height analyzer, is expected to operate for at least the last ten hours of the 66-hour flight time. If the most pessimistic assumptions are made relative to the gamma ray intensity of the moon compared to the interplanetary background, then during the last 15 minutes of operation of the spectrometer (prior to ejecting the capsule) the count from the lunar surface will be at least twice the background level of space.

The major scientific experiment on the landing capsule is a single-axis seismometer weighing ten pounds. Seismic measurements made on the moon can answer fundamental questions regarding the nature of the moon's surface, its interior, and its origin. The presently proposed single-axis instrument is expected to operate and transmit continuously for one to three months, and is sensitive enough to detect meteoritic impacts on the lunar surface. This first-generation seismic experiment is not only expected to obtain scientific data, but will also provide design data for future more sophisticated seismic experiments.

An additional experiment which will be included in the landing capsule includes means for making internal temperature measurements. The internal temperature measurements will be made by several simple thermocouples which will be distributed within the impact capsule to monitor the internal temperature environment. These data are required for interpretation of the other scientific measurements and for the evaluation of the engineering design of the capsule.

Much of the technology employed in the Ranger series will have direct application to follow-on programs for lunar missions. The series is designed to maximize the use of proven techniques, and with an aim toward achieving reliability by repeated use of tested components.

The Atlas-Agena B launch vehicle will be used for the five Ranger spacecraft. Incremental funding is required two years prior to launch.

Surveyor Program

The Surveyor spacecraft, designed for use with the Centaur launch vehicle, is expected to carry a net survivable instrumentation weight of 100 to 300 pounds to the lunar surface and is the first spacecraft in the national program for the lunar soft-landing mission. The instrumentation for the Surveyor will emphasize the acquisition of lunar surface data leading most rapidly toward future landings and explorations. All such data will be of great interest to scientists concerned with problems related to the formation and subsequent history of the moon, and the origin of the solar system.

The instrumentation is designed to explore the moon's surface. It will provide a television survey of the immediate landing area, the determination of the surface texture and composition, and measurements

of the general properties of the moon as a planetary body such as seismic activity, gravity variations, and magnetic fields. Physical measurements will involve probes for tests of surface hardness and for the measurement of surface thermal properties, or the measurement of sub-surface properties by a drill and sample complex. Surface composition investigations will make use of such techniques as gamma ray spectroscopy, neutron activation, and X-ray fluorescence; and seismic measurements will be taken using a three-axis seismometer. Atmospheric composition will be analyzed with mass spectrometers, and biological experiments, concerned with the search for organic molecules and primitive forms of life, may be carried. Some of these experiments can be performed by lowering the instrument onto the lunar surface, while others will require sample collection and manipulation of surface and sub-surface samples.

Several different groups of experiments will be built for the basic Surveyor spacecraft in this period. One will contain those experiments requiring large amounts of power over relatively short lifetimes; another will make use of those experiments expected to last for a year or more with low power requirements. A third will have a very long lifetime, covering an appreciable fraction of a sunspot cycle.

The design studies for this Surveyor series are now in progress, and it is expected that fabrication of the spacecraft and payloads will begin by mid-calendar year 1961.

The Surveyor project is divided grossly into two parts, the development of the spacecraft, and the scientific instrumentation which will be carried. The spacecraft will be developed and built by a systems contractor. During the fiscal year 1962 some $19 million will be required for this effort. The scientific instrumentation represents a composite of small subsystem procurements as well as contracts for complete scientific experiments, most of which are initiated in the fiscal year 1961 and continued in the fiscal year 1962. Work on the Surveyor soft-landing spacecraft series starts in the fiscal year 1961 and reaches a high level of effort, largley through industrial contracts, during the fiscal year 1962 as effort on the Ranger series falls off.

Studies of the Surveyor soft lander are under way to examine the feasibility of adapting this spacecraft to the precise orbiter mission. The lunar orbiter is of great importance to science since it will provide an opportunity to obtain integrated data for the entire moon. Detailed local information obtained from landing payloads must be interpreted in the context of the area survey which the orbiter can provide. An orbiter can also be used to collect and transmit data from surface vehicles on the back side of the moon.

The Centaur launch vehicle which will be employed with Surveyor requires incremental funding starting approximately two years ahead of launch. Four of the proposed launches thus require funds during the fiscal year 1962.

Prospector Program

The Prospector spacecraft for controlled lunar landings, designed to use the Saturn launch vehicle, will have a landed weight of from five to eight thousand pounds. This weight capability will permit detailed surface analysis and will allow the incorporation of roving surface vehicles for greater coverage of the various surface conditions of the moon. A roving vehicle can provide a many-fold increase in scientific return from a lunar soft lander. The Prospector spacecraft also offers the possibility of including a vehicle capable of returning a lunar sample to Earth.

The final design of the Prospector series will be directly influenced by the scientific information obtained from the Ranger and Surveyor missions. The first-generation experiments performed by these earlier spacecraft are expected to establish ranges for the quantities to be measured and to suggest new measurements. Lunar orbiters will have collected over-all survey data for the moon, so that detailed investigations can be made in the particular locations on the surface which are of greatest interest. The return of surface and sub-surface samples of lunar material to Earth is of great interest both scientifically and technologically. Sample return will make a complete laboratory analysis possible, including techniques not feasible with remote instrumentation payloads.

The studies conducted during the fiscal year 1961 will be followed by initial development of scientific instruments in the fiscal year 1962. The long lead time required for the development of the Saturn launch vehicle on which this program is based allows a moderate build-up in the spacecraft development, and thus enables maximum inclusion of advancements from the Surveyor program. Many of the scientific experiments must have extended development and usage, however, before they are expected to be suitable for the crucial lunar application, and work is therefore initiated on their development and integration into a generalized spacecraft design during the fiscal year 1962.

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1961 Supplemental	Fiscal Year 1962
Planetary and Interplanetary Programs:				
Pioneer V and Magnetometer Probe:				
Pioneer V.....	$2,111,000	---	---	---
Nuclear emulsion.....	361,900	---	---	---

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1961 Supplemental	Fiscal Year 1962
Magnetometer probe:				
Varian Associates services...	$120,000	---	---	---
Frequency discriminator.....	25,000	---	---	---
Telemetry encoder.....	25,000	---	---	---
Plasma probe instrument.....	97,000	---	---	---
Magnetic tape recorders.....	85,000	---	---	---
Antennas.....	20,000	---	---	---
Non-tracking antennas.....	65,000	---	---	---
Primary cosmic ray investigations.....	40,000	---	---	---
Structural components.....	85,000	---	---	---
Program switch.....	35,000	---	---	---
Computation services.....	18,000	$11,000	---	---
Reproduction and digital tape	75,000	20,000	---	---
Field Engineering services...	120,000	20,000	---	---
Component development and sub-assemblies.....	297,500	107,000	---	---
Tracking filter.....	60,000	10,000	---	---
Special space components.....	30,000	72,000	---	---
Monitoring equipment for data reduction.....	20,000	10,000	---	---
Non-magnetic components.....	40,000	20,000	---	---
Test and evaluation.....	68,500	47,000	---	---
Fluxgate magnetometers.....	---	9,000	---	---
Analyzer.....	---	20,000	---	---
Data reduction.....	---	25,000	---	---
Coating for temperature control.....	---	9,000	---	---
De-spin devices.....	---	32,000	---	---
Test mounting jigs and assembly tools.....	---	5,000	---	---
Handling equipment and special parts.....	---	8,000	---	---
	3,798,900	425,000	---	---
Mariner Program:				
Spacecraft:				
Scientific experiment studies	---	255,000	---	$235,000
Experimental ground support equipment.....	---	100,000	$100,000	86,000
Experimental systems integration.....	---	45,000	---	64,000
Spacecraft telemetry development.....	---	212,000	---	565,000

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1961 Supplemental	Fiscal Year 1962
Spacecraft command systems development.....	---	$112,000	---	$412,000
Spacecraft command systems hardware.....	---	225,000	---	679,000
Spacecraft radio ground support equipment.....	---	124,000	---	671,000
Operation of data reduction laboratory.....	---	146,000	---	663,000
Ground command system.....	---	85,000	---	124,000
Spacecraft antenna.....	---	25,000	---	200,000
Inertial sensors.....	---	135,000	---	135,000
Attitude control actuators...	---	118,000	---	181,000
Attitude control system.....	---	125,000	---	237,000
Central controller and sequencer.....	---	430,000	---	319,000
Guidance and control system design.....	---	134,000	---	78,000
Guidance and control ground support equipment.....	---	362,000	---	575,000
Guidance and control parts evaluation.....	---	366,000	---	454,000
Power conversion.....	---	523,000	---	243,000
Power storage.....	---	180,000	---	166,000
Component packaging and integration.....	---	124,000	---	214,000
Pyrotechnics.....	---	143,000	---	141,000
Environmental facility instrumentation.....	---	137,000	---	178,000
Computing services.....	---	456,000	---	977,000
Midcourse propulsion.....	---	286,000	---	186,000
Mission studies and analysis.	---	158,000	---	150,000
Preliminary systems design and integration.....	---	130,000	---	178,000
Program staff.....	---	445,000	---	491,000
Program information.....	---	124,000	---	42,000
Spectrometer experiment.....	---	336,000	$204,000	248,000
Plasma detector experiment...	---	125,000	202,000	218,000
Radiometer experiment.....	---	217,000	183,000	239,000
Magnetometer experiment.....	---	252,000	212,000	111,000
Experiment data automation...	---	342,000	405,000	212,000
Spacecraft telemetry hardware	---	381,000	486,000	517,000
Spacecraft radio equipment hardware.....	---	436,000	501,000	402,000
Celestial sensors.....	---	736,000	375,000	691,000
Power sources.....	---	286,000	100,000	386,000

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1961 Supplemental	Fiscal Year 1962
Spacecraft structure.....	---	$437,000	$280,000	$736,000
Environmental facility operation.....	---	101,000	530,000	1,036,000
Cosmic dust experiment.....	---	---	298,000	104,000
Particles experiments.....	---	300,000	587,000	610,000
Ion chamber experiment.....	---	---	336,000	225,000
Autopilot and servos.....	---	---	150,000	162,000
Design drafting.....	---	---	51,000	120,000
Systems test and operations.	---	---	---	454,000
Spacecraft assembly facility operation.....	---	---	---	114,000
Spacecraft assembly facility equipment.....	---	---	---	334,000
Spacecraft cabling.....	---	---	---	226,000
	---	9,654,000	5,000,000	15,789,000
Centaur launch vehicles.....	---	---	---	5,370,000
	---	9,654,000	5,000,000	21,159,000
Voyager Program:				
Spacecraft studies.....	---	---	---	349,000
Total, Planetary and Interplanetary Programs...	$3,798,000	$10,079,000	$5,000,000	$21,508,000

Planetary and Interplanetary Programs:

A long-term objective of the planetary series is to place spacecraft capable of gathering fundamental scientific knowledge of the planetary environments and of the planets themselves in orbits about Venus and Mars. Spacecraft technology must thus provide long life (over one year), the proper environment for the scientific instruments, adequate guidance, communication power and bandwidth for the scientific objectives, and an atmosphere entry and landing capsule.

An important constraint from the planning viewpoint on the near planet missions, as opposed to most other flights, is the relatively long wait time between opportunities. This wait is the result of periodicity between planet oppositions, and amounts to one and one-half years for Venus and just over two years for Mars. Achievement of optimum progress toward the stated scientific program objectives requires a successful shot almost every opportunity and this requires each new spacecraft series to be preceded by complete ground and flight testing. Lead times for the flight tests must

be sufficient to incorporate needed changes. The development sequence of planetary spacecraft starts with the fiscal year 1962 missions as fly-bys, which are defined as passing within several thousands of miles of a planet, and progresses through planet orbiters at about mid-decade and planet landers toward the end of the decade.

Interplanetary long-term objectives are to map and investigate the interplanetary medium and solar influence on this medium. The interplanetary medium consists of charged particles, solar radiation, electromagnetic and gravitational fields, neutral gas, and dust.

Typical instruments carried will consist of plasma and radiation detectors, magnetometers, micrometeorite detectors, and Lyman-Alpha telescopes. Besides providing new insights into solar-terrestrial relationships, such as the distribution of electric currents in the outer radiation belt of the Earth and the form of the Earth's field in regions where it merges with interplanetary space, experiments may provide the beginnings of a new theory for the understanding of the modulation of cosmic rays.

Pioneer V and Magnetometer Probe

The highly successful Pioneer V constituted the first truly interplanetary probe. Launched in March, 1960, it continued to transmit data to Earth for $2\frac{1}{2}$ months and to a distance $22\frac{1}{2}$ million miles; at this point it had travelled one-fourth of the distance around the sun. Many significant scientific findings can already be attributed to analysis of the Pioneer V data. The usefulness of these data was magnified by correlation with simultaneous data obtained from Explorer VII in a highly elliptical Earth orbit.

Observation of spatial and temporal perturbations of interplanetary radiations and fields will continue in calendar year 1961 with the rubidium magnetometer probe to be launched with a Thor-Delta vehicle. This probe carries a precise magnetometer, and in addition sensors to accurately measure fluxes of interplanetary plasma. The interrelationships of plasma and magnetic field fluxes and their significance to sun-earth effects are among the most important problems in the area of interplanetary science.

Beyond the magnetometer probe, interplanetary measurements will be made primarily on test and operational spacecraft for lunar and planetary missions.

Mariner Program

In calendar year 1962 the first spacecraft of the Mariner series will be flown. These craft will use the Centaur launch vehicles for planetary fly-bys in the time period from calendar year 1962 to 1965. The Centaur

launch vehicle can deliver, as a fly-by, approximately 1,200 pounds to Mars and 1,800 pounds to Venus. Since the Venus mission can be accomplished with shorter trip times than for a Mars mission, and since on arrival at the planet the Venus-Earth communication distance is less than the Mars-Earth distance, the spacecraft for a Venus mission is somewhat less complicated than that required for a Mars mission.

The fly-by mission is a natural first step, both scientifically and technologically. Scientific information on planetary environment will both add to the fundamental knowledge and provide the necessary input for later, more refined experimentation. A major portion of the technology needed for later orbiter flights can be proved and evaluated on a fly-by.

The first flight in calendar year 1962 will be timed to take advantage of the Venus opportunity. Modifications and remedial action, based upon lessons learned in this first planet fly-by attempt, will be incorporated and test flown as interplanetary missions during calendar year 1962-1963 period. Although these missions will be interplanetary, the trajectory will be chosen to proof-test all spacecraft subsystems required for the calendar year 1964 planet missions.

The choice of scientific instruments to be carried on Mariner is governed both by the basic scientific objectives and by the fact that the fly-bys are preludes to more thorough investigation with orbiters and landing capsules. Venus and Mars are the only planets close enough to be explored scientifically by space probes during the next few years.

For Venus, items of initial interest are the nature of the atmosphere, the surface temperature, the rotation rate, the spin axis, and magnetic field and particle measurement experiments. The structure of the Cytherean atmosphere is of great scientific interest. Knowledge of its pressure, temperature profile and constituents also is of immediate importance in planning a long-range planetary program. If current estimates of the surface temperature and pressure are correct, designing a spacecraft that can survive entry and landing will be a formidable task. On the other hand, if a predicted surface temperature of 600°K is much too high, it is probable that the unseen surface of Venus is covered by oceans. If this is true, spacecraft design problems become very different.

The strength of the magnetic field of Venus also is important to the understanding of the science of the solar system and to the engineering of spacecraft. If the magnetic field is exceptionally strong, trapped radiation may present subtle communication problems. If, on the other hand, the field is very weak it is possible that the planet could sustain a very dense ionized layer which would account for the high brightness temperature detected from Earth with microwave telescopes.

The Venus mission will carry five experiments directly concerned with the planet plus an instrument package to obtain interplanetary data enroute. These planet experiments will utilize a microwave radiometer to measure temperature brightness; an ultraviolet spectroscope to examine the upper atmosphere and look for the presence of such constituents as water vapor, oxygen and ozone; a neutron counter to attempt to measure the ratio of carbon dioxide to nitrogen in the atmosphere of Venus; a fluxgate magnetometer to determine the approximate strength and character of the magnetic field and a scintillation counter for sampling particle radiation trapped in the magnetic field.

For Mars the central question is the existence of life. Early experiments will, therefore, be oriented toward this very subtle detection problem. An infrared spectrograph will be carried to determine the existence and location of organic molecules. The upper atmosphere should be examined for ozone to determine if the surface of the planet is protected from ultraviolet radiation which in large doses is damaging to life as it is known on Earth.

A Mars mission would thus retain the ultraviolet spectroscope, magnetometer and scintillation counter of the Venus mission. The radiometer would be replaced by an infrared spectrometer which searches for organic molecules on the Martian surface. In addition, since the Martian atmosphere is clear, the spacecraft would carry an optical system mated to a vidicon capable of taking and transmitting photographs of the terrain.

Supplemental funding for the fiscal year 1961: The Mariner program is designed to give this country its first attempt at a planetary probe, a fly-by of Venus, in the third quarter of the calendar year 1962. Failure for any reason to meet this date will automatically defer such missions to calendar year 1964 when Venus and Mars are again in the proper positions. Thus every effort must be made to keep the Mariner program to its flight schedule. It has become evident that supplemental funding is required in the fiscal year 1961 for this purpose.

The additional funding requirements result primarily from a need to accelerate spacecraft subsystem development, a need to accelerate scientific instrument development, and a need for additional development on certain subsystems.

In the interest of both economy and reliability, one of the design objectives for Mariner has been to make maximum use of existing Ranger spacecraft technology. However, during the course of the preliminary design, which only started in the fiscal year 1961, it became evident that additional subsystem work was needed to accomplish a planetary mission. As examples, the much greater distance to Earth requires higher power in the communications system and this requires additional power from the solar panels as well as other components in the power supply system. The conduction of internal heat generated due to the

higher power, and the different environment at Venus result in the need for redesign of the temperature control system. The need for pointing the scientific instruments at the target planet while maintaining the basic spacecraft orientation during the fly-by also turned out to be a larger development problem than anticipated. The mission also requires changes in the Ranger celestial sensors; the earth seeker must be uprated because of the additional distance and a horizon scanner must be developed. Finally, interwoven throughout all subsystems is the need for greater operating lifetime.

Similar considerations apply to scientific instruments being incorporated in the Mariner spacecraft for the Venus mission. Many of these instruments do not exist at present; they are laboratory concepts that require an intensive combined scientific and engineering effort to mold them into reliable and successful flight systems. The ultraviolet spectrometer, for example, designed to give measurements of the spectrum of the radiation from the Venus atmosphere on both the dark and sunlit sides, has never been built before. The microwave radiometric experiment intended to provide information about the planet surface and lower atmosphere is being assembled as flight hardware for the first time. As indicated in the detailed list, there are a total of seven scientific experiments and, in addition, the data automation system, that require accelerated effort.

The Venus mission imposes reliability requirements of an unusually high order. It is desirable to accelerate both the technological and scientific preparations so as to insure as much developmental testing as possible prior to launch. The fiscal year 1961 supplemental funds will permit the solution to the aforementioned problems on a time schedule which would make this possible.

Regular funding for the fiscal year 1962: The major portion of the fiscal year 1962 Mariner budget will be employed to continue work started in the fiscal year 1961 on the design, development, and fabrication of the spacecraft. The increase in the Mariner budget in 1962 over that in 1961 reflects the increasing effort as hardware is purchased, assembled, and checked prior to flight.

Centaur launch vehicles are incrementally funded approximately two years before flight. However, the first two missions in the Mariner Program utilize development launch vehicles which are not charged to the Mariner Program.

Voyager Program

A good start on planetary missions will have been made under the Mariner series and its associated developments of terminal guidance technology, and long lifetime components. Nevertheless, to obtain measurements essential for the stated planetary scientific objectives,

many missions will require the spacecraft to fly in proximity to the target planet for long periods of time. This, in turn, establishes a need for further spacecraft refinements and associated instrumentation and technological development. The planetary spacecraft series that follows Mariner is phased in time and capabilities with Saturn launch vehicle development. This series, the Voyager planetary orbiters, begins with test shots in calendar year 1964 and 1965. Spacecraft weight in orbit will be better than 2,000 pounds. This weight is consistent with larger power requirements and with the redundancy needed for long-life orbiters.

The orbiter is the second step in planetary exploration. The long stay times will permit excellent mapping of the environment and a landing capsule will provide details of the lower atmosphere and surface. Spacecraft orbit elements will also permit evaluation of planetary mass and mass distribution. Scientific experiments will be advanced versions of those of the Mariner series.

The complete orbiter mission, including the ability to carry a large entry and landing capsule, will begin with the availability of the growth version of the Saturn launch vehicle. First mission will be to Mars in calendar year 1967. Studies on the design and utilization of the Voyager spacecraft will start in the fiscal year 1962.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

METEOROLOGICAL SATELLITES

SUMMARY OF REQUIREMENTS:

	1960	1961	1962	Page No.
Advanced Research.....	$1,331,000	$ 2,070,000	$ 1,100,000	RD7-3
Advanced Technical Development	1,606,000	2,270,000	2,850,000	RD7-3
Flight Program.....	4,993,000	13,760,000	24,250,000	RD7-4
Total.....	$7,930,000	$18,100,000	$28,200,000	

OBJECTIVES:

To establish a meteorological satellite capability for world-wide coverage and for providing observations of atmospheric elements required by the meteorologist in order to understand atmospheric processes and predict the weather. These elements include cloud cover, storm location, precipitation, temperature, wind direction, heat balance, water vapor and other constituents. To achieve this objective will require the development of stabilized satellites for polar orbits of 500- to 1,000-mile altitudes and stationary satellites for equatorial orbits of 22,000-mile altitudes; the development of suitable on-board detection equipment, including television, infrared detectors, radar and spectrometer; and the development of adequate data storage, handling and communications equipment and techniques.

The long-range objective is to develop the principles of a system of instrumented orbiting satellites and a communications network by means of which world-wide meteorological information may be transmitted to the National Meteorological Center of the Weather Bureau for its operational use.

JUSTIFICATION:

The earth satellite represents a new observational tool which promises to be of great value to the science of meteorology and to the practice of weather forecasting. Although it would be a mistake to imply that such a device will eliminate our meteorological limitations,

there is no doubt that it will supply a tremendous amount of useful meteorological data not now obtainable. It will do this not only because of its ability to give world-wide coverage to some meteorological parameters, in contrast to the current five to ten per cent coverage, but also because of its unique vantage point above the atmosphere which will make new measurements possible. Improved basic scientific understanding of atmospheric processes and a more comprehensive knowledge of world and regional climatology will result and these should assist in producing advances in weather forecasting.

The benefits to be derived from these improved capabilities in meteorology include protection of life and property from weather disasters; safeguarding transportation; crop planning, control, and protection; industrial planning of weather-dependent products, outdoor enterprises, and heating and cooling loads; convenience in planning personal activities; eventual limited weather modification and control; and good will in return for providing current global meteorological data to other nations. In addition, the same meteorological data required for world-wide civilian needs can, by proper handling, be made to meet special military needs as well.

The formulation of the operational concepts and the preliminary planning of a national operational meteorological satellite system are now being considered by the Panel on Operational Meteorological Satellites established by and under the National Coordinating Committee for Aviation Meteorology. Membership on the Panel includes representatives of the United States Weather Bureau, the Department of Defense, the Federal Aviation Agency, and the NASA.

The development of an effective operational system of meteorological satellites is dependent upon continuing programs of advanced research and advanced technical development which point the way and make possible highly productive flight programs. The advanced research program will give emphasis to the reduction and processing of data acquired by satellites. The advanced technical development program is primarily concerned with improved satellite instrumentation and equipment needed to measure and interpret critical atmospheric parameters. An evolutionary flight program of progressively more sophisticated meteorological satellites is planned to capitalize upon knowledge gained in these research and development programs. This program was begun with Tiros I and II, which are already in orbit, and continues with a third Tiros which will be launched in the fiscal year 1962. Following will be the earth-stabilized, polar orbiting Nimbus, of which four are planned with the first scheduled for launch in the fiscal year 1962. Still later will be the Aeros, a single satellite that will provide continuous data from nearly a third of the earth. A tabulation of the planned flight schedule follows:

Mission	Launch Vehicle	Fiscal Year of Launch
Tiros I	Thor-Able	1960
Tiros II	Delta	1961
3rd Tiros	Delta	1962
1st Nimbus	Thor-Agena B	1962
2nd Nimbus	Thor-Agena B	1963
3rd Nimbus	Thor-Agena B	1963
4th Nimbus	Thor-Agena B	1964
Aeros	Centaur	1965

FUNDING REQUIREMENTS:

Advanced Research	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Atmospheric dynamics.....	$380,000	---	---
Meteorological data analysis and research.....	581,000	$1,050,000	---
Radiation data studies.....	270,000	270,000	$350,000
Radiation data studies.....	100,000	100,000	100,000
Data systems analysis (ground).....	---	350,000	350,000
On-board data analysis.....	---	300,000	300,000
Total, Advanced Research.....	$1,331,000	$2,070,000	$1,100,000

Basic radiation studies, including the interpretation of balloon flown radiation sensors, will be continued in the fiscal year 1962. Systems for simplifying the presentation of data will be investigated and the reduction of data transmission bandwidth requirements through systems of on-board analysis will be studied. Fiscal year 1962 funds for the study and analysis of actual satellite data and satellite simulated data from other sources (rocket probes, aircraft reconnaissance, etc.) are being requested directly by the United States Weather Bureau.

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Radiation detector development.....	$530,000	$400,000	$600,000
Electronic instrumentation development.....	625,000	820,000	900,000
Electronic component development...	50,000	300,000	100,000
Spectrometer development.....	100,000	100,000	100,000
Mechanical instrumentation development.....	250,000	400,000	400,000

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Meteorological instrumentation development	$51,000	$150,000	$250,000
Advanced data transmission	---	100,000	500,000
Total, Advanced Technical Development	$1,606,000	$2,270,000	$2,850,000

Continuing development is necessary to improve the performance and reliability of existing flight instrumentation and to develop new instrumentation to provide additional meteorological data not yet available. The increased effort in the fiscal years 1961 and 1962 will be applied to the improvement of existing mechanical and electrical components. The development work on radiation scanning detectors, direct radiation sensors, and spectrometers will be continued in the fiscal year 1962. The program initiated in the fiscal year 1961 for the development of advanced data transmission instrumentation will be expanded in the fiscal year 1962.

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Tiros I:			
Payload development	$2,320,000	---	---
Kaena Point operations	155,000	---	---
Teledynamics	28,000	---	---
Vehicle trajectory	590,000	---	---
Thor-Able vehicle (funded by ARPA)	---	---	---
	3,093,000	---	---
Tiros II:			
Radiation tape recorder	98,000	---	---
Payload integration	400,000	800,000	---
Ground station installation and operation	---	320,000	---
Radiation data analysis	---	300,000	---
Film, duplicating and cataloging	---	20,000	---
Test and evaluation	---	8,000	---
Delta vehicle, procured with Delta vehicle development funds	---	---	---
	498,000	1,448,000	---

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Tiros (Third):			
Payload maintenance and testing...	---	$300,000	$200,000
Ground station installation and operation.....	---	120,000	200,000
Film, duplicating and cataloging..	---	---	20,000
Delta vehicle, procured with Delta vehicle development funds	---	---	---
		420,000	420,000
Nimbus (First):			
Scientific payload.....	---	236,000	209,000
Structure, integration.....	---	1,100,000	500,000
Stabilization.....	$500,000	2,000,000	---
Power supply.....	---	700,000	---
Vidicon systems and ground equipment.....	500,000	1,600,000	500,000
Electrostatic tape.....	302,000	400,000	---
Radiation subsystem.....	---	500,000	200,000
Ground station equipment.....	---	600,000	600,000
Command system.....	---	300,000	150,000
Satellite telemetry.....	---	350,000	100,000
Environmental testing.....	---	243,000	1,000,000
Command receiver.....	---	31,000	---
Coating for temperature control...	---	12,000	---
Test and evaluation.....	---	20,000	---
Ground support operations.....	---	---	453,000
Data handling.....	---	---	400,000
Radiation data analysis.....	---	---	500,000
Tape and film, duplicating and cataloging.....	---	---	300,000
Thor-Agena B vehicle.....	---	2,100,000	4,000,000
	1,302,000	10,192,000	8,912,000
Nimbus (Second):			
Payload modification.....	---	---	1,868,000
Environmental testing.....	---	---	500,000
Thor-Agena B vehicle.....	---	1,000,000	3,800,000
	---	1,000,000	6,168,000

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Nimbus (Third and Fourth):			
Structure and integration.....	---	---	$500,000
Stabilization	---	---	1,100,000
Power supply.....	---	---	400,000
Vidicon systems and ground equipment.....	---	---	800,000
Electrostatic tape.....	---	---	200,000
Radiation subsystem.....	---	---	200,000
Ground station equipment.....	---	---	500,000
Radar.....	$100,000	$400,000	500,000
Image orthicon	---	300,000	450,000
Ground display equipment.....	---	---	500,000
Thor-Agena B vehicle (Third Nimbus).....	---	---	2,100,000
Thor-Agena B vehicle (Fourth Nimbus).....	---	---	1,000,000
	100,000	700,000	8,250,000
Aeros:			
Varifocal lens.....	---	---	500,000
Total, Flight Program.....	$4,993,000	$13,760,000	$24,250,000

Tiros

The major activity in the fiscal year 1960 in the meteorological flight program was the completion of development and the successful launch on April 1, 1960, of the Tiros I satellite. During its 3-month useful operating lifetime, Tiros I transmitted almost 23,000 picture frames of which about 60 percent were of the earth and its cloud cover and applicable to meteorological analysis. The pictures transmitted by Tiros I were of exceptional quality and showed areas of weather and storms very clearly. The meteorological analysis is being conducted at the Weather Bureau, and the inclusion of other groups, primarily university research groups, is planned.

Tiros II was successfully launched on November 23, 1960. This satellite contained special infrared radiation detectors for measuring the earth's albedo, the total radiation of the earth and its atmosphere, the direct radiation from the earth's surface or cloud tops, the radiation from the earth's water vapor layer, and radiation in the visible portion of the spectrum for reference purposes. Gross measurements of the earth

and atmosphere heat budget were also made. Tiros II contains vidicon camera systems, like those of Tiros I, for cloud cover measurements. About 6 to 9 months after the launch of the Tiros II, the launch of a third Tiros satellite is planned. The variations in the data of these satellites will be studied for seasonal influences.

The first Tiros was launched with a Thor-Able launch vehicle funded by ARPA and transferred to the NASA. The remaining Tiros satellites employ two of the twelve Deltas which are being procured under the Delta vehicle development program.

Nimbus

In the fiscal year 1961, the rate of funding for the Nimbus satellite is being increased. This will be the first in a family of earth-oriented meteorological satellites which are being designed to have flexibility in carrying a variety of sensors and experiments. The Nimbus satellite will weigh 650 pounds and will be launched in a polar retrograde (about 80 degrees) 600-mile circular orbit. It will consist of power, stabilization, and sensory subsystems. The power subsystem will consist of two paddle-like structures covered with solar cells and arranged to face the sun directly whenever the satellite is in sunlight. Nickel-cadmium storage batteries will be used for power storage. The stabilization system will keep the satellite pointing directly at the earth with an accuracy of one degree in all three axes -- roll, pitch, and yaw. The sensory system will consist of improved television vidicon systems to provide almost complete coverage of the globe; an electrostatic tape system to permit higher resolution studies of specific meteorological events, such as hurricanes; a comprehensive infrared radiation system containing high resolution (five mile) sensors for coarse nighttime cloud cover representation, medium resolution (30 mile) sensors for atmospheric and terrestrial radiation measurements, low resolution (300 mile) sensors for gross measurements of the earth -- atmosphere heat balance, and auxiliary measurements of importance to meteorology; and measurements of the solar constant, solar ultraviolet radiation, and solar particle radiation to study their influence on the earth's weather.

The first Nimbus will be completed during the fiscal year 1962 and will be launched during the second half of that fiscal year. The second Nimbus will be launched about six months thereafter. It is planned to have the spacecraft structure, power, and stabilization fairly well standardized with the successful launch of the second Nimbus.

During the fiscal year 1962, work will begin on the follow-on Nimbus satellites. These will carry more advanced sensory systems such as radar, spectrometer and an image orthicon camera system which can view clouds under lower levels of illumination. On-board analysis techniques and ground data analysis and presentation systems that have been developed will be included in the advanced Nimbus flights. The techniques and systems are being developed to reduce the amount of data transmitted by the satellite and to facilitate their use.

Funding is also requested in this project for the operational Thor-Agena B vehicles required for launch of the Nimbus satellites. The first and second Nimbus Thor-Agenas will require an increment of $3,100,000 in the fiscal year 1961 funding and $7,800,000 in the fiscal year 1962. An increment of $3,100,000 will also be required in the fiscal year 1962 to initiate funding of the Thor-Agena B vehicles for the third and fourth Nimbus satellites.

Aeros

The Tiros and Nimbus satellites view different portions of the earth's geography during their transit around the earth. The meteorologist is interested in a capability of continuously observing the developments of a particular storm area. The Aeros satellites to be launched into a stationary orbit of 22,300 miles around the earth, will be designed to satisfy this requirement. The first flight is planned for the fiscal year 1965. The principle instrumentation to be developed for Aeros is a cloud cover observational system with sensors having a variable focus, in order to view in greater detail the particular storm area chosen for observation. The fiscal year 1962 funding for Aeros will permit the initial work to be undertaken for the development of such an instrument.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

COMMUNICATIONS SATELLITES

SUMMARY OF REQUIREMENTS:

	1960	1961	1961 Supplemental	1962	Page No.
Advanced Research....	$817,000	$175,000	$400,000	$800,000	RD8-5
Advanced Technical Development.....	705,000	625,000	550,000	3,650,000	RD8-7
Flight Program:					
Passive Program....	1,528,000	2,550,000	7,500,000	17,950,000	RD8-9
Active Program.....	---	562,000	15,550,000	22,200,000	RD8-10
Total.....	$3,050,000	$3,912,000	$24,000,000	$44,600,000	

OBJECTIVES:

For a period of two years NASA has been conducting a scientific research and development program of space exploration. Much valuable information has been obtained, and several "firsts" have been accomplished. It is, of course, anticipated that the knowledge acquired from these investigations will result in tangible benefits to mankind. The earliest most likely payoff of space research now appears to be in the field of world-wide communications.

Recent successful satellite flights by the United States have clearly shown the great potential utility of communications satellites as relay stations in world-wide communications systems. Two potentially useful systems--active and passive--have been demonstrated. Industrial interest in bringing about an operational communications satellite system at an early date has been expressed. However, there are many technical problems yet to be investigated and solved, particularly in the matter of space environment effects, before commercial utilization of communications satellites can be soundly undertaken. The NASA Communications Satellite program has as

its objective the rapid solution of these problems so that the characteristics of operational communications satellites can be established.

The specific NASA objectives in passive and active communications satellite research are as follows:

Passive Communications Satellites

The Echo I flight has demonstrated the technical capability of reflecting ground-transmitted radio signals from a space-borne reflective surface to remote ground receiving stations. Even though the Echo I satellite was a non-rigid structure, it has shown that the inflated sphere concept can yield relatively long orbital life with the predictable orbital elements necessary to obtain accurate ground antenna pointing. The program effort now has three major objectives for early solution: (1) the development of techniques for rigidizing the reflecting structure in space to increase orbital life, (2) the development of techniques for ejecting more than one satellite into a predictable orbit from a single launch vehicle, and (3) the development of improved ground transmission and receiving equipment including equipment operating at high, more nearly optimum microwave frequencies.

Active Communications Satellites

The tremendous potential of active communications systems has been indicated by the success of specialized communications satellite experiments conducted recently by the Department of Defense. This potential is further supported by recent industry advances in the development of communications system components. The NASA program has as its objective the early demonstration that an active satellite communication system is both feasible and suitable for civilian application. Maximum interchange of applicable technology will be made with the Department of Defense where the principal continuing interest is in the synchronous orbit (24-hour) satellite. The NASA approach will be to develop a relatively low altitude, long-lived, instantaneous repeater satellite. Necessary to the development of this satellite are: (1) the development of long-lived components, (2) the testing of components and systems in the space environment, (3) the development of required ground communications and tracking equipment, and (4) the launching of satellites which will contribute to the determination of an optimum operational system.

JUSTIFICATION:

The limited capabilities of existing communications facilities are being pressed by today's demands, and will be inadequate in the next decade. A most attractive possibility for providing the needed increase in communications capability is the communications satellite system. The communications satellite has the potential ability to provide long distance communications at ultra-short wave and microwave frequencies where bandwidths are available to permit the transmission of television or, alternately, many simultaneous

voice messages (600 two-way conversations per television channel). Thus, the satellite holds the promise of new and reliable links in long distance, transoceanic telephonic and telegraphic communications as well as new means for intercontinental radio and television services.

The communications satellite program has heretofore been primarily concerned with research in signal propagation, the demonstration of inflation techniques for large spherical structures in space and the perfection of techniques for tracking these structures. The recent advancements in communications satellite technology demonstrated by Echo I and development of long-lived components clear the way for rapid developments in both passive and active communications satellite systems. This budget proposes a rapid move forward toward the demonstration of operational feasibility of both types of systems. A necessary prerequisite to this accelerated move forward is the approval of supplementary fiscal year 1961 funding which is required for the following purposes:

1. Research must be initiated immediately to determine the extent of radiation damage to satellite components in the space environment. Little knowledge is now available on the effect of radiation upon the performance of solar cells, transistors, and other solid state components.

2. Concurrently, the development of radiation resistant materials must be undertaken. New materials such as gallium arsenide and cadmium sulfide offer promise of greater resistance to radiation damage.

3. Immediate funding is required in the passive program to initiate lead time procurement of launch vehicles. The rapid advance in passive communications technology places this program in a position of requiring launch vehicles to accomplish missions not previously contemplated on this time scale.

4. Recent developments in long-lived components, particularly in travelling wave tubes, indicate the technical and economic feasibility of an active repeater satellite system. Funds are required to initiate the rapid development and demonstration of an operational system utilizing low altitude active repeater communications satellites. The fiscal year 1962 program is a continuation of this accelerated fiscal year 1961 program.

Passive Communications Satellites

The technical feasibility of a passive communications system has been undeniably confirmed by the spectacular success of the Echo satellite communications experiments. In spite of this success, the Echo experiments have only scratched the surface of the passive satellite communications field. The desirability of any communications satellite system depends heavily on the reliability and life expectancy of the satellite. Since a passive satellite does not depend upon satellite-borne electronic components, it is a useful communications medium as long as the satellite retains its shape and reflectivity.

The fact that Echo did not become significantly distorted after loss of internal pressure indicates that only a nominal increase in material stiffness is required to insure a really long-lived satellite. This would indicate that regidization of these structures can be accomplished without a major increase in satellite weight. Studies have indicated that with suitable ground facilities about 60 satellites similar to Echo placed randomly in selected orbits of 2,000 miles altitude could provide a communications system which would be operable 99 percent of the time between points on the earth's surface 3,000 miles apart. Thus, solution of the rigidization problem coupled with the possibility of placing a number of satellites in orbit from one launch vehicle will make possible a durable (10 years or more in orbit) and efficient operational satellite communications system whose capacity would be limited only by the number of ground stations.

Active Communications Satellites

Active repeater communications satellites, those which receive and retransmit messages, are of three general types: (1) the instantaneous repeater in a low-altitude orbit, (2) the instantaneous repeater in a 24-hour synchronous orbit, and (3) the delayed repeater in a low-altitude orbit which receives a message from one point on earth, stores it, then on command from another ground station, transmits the recorded message. The Department of Defense is investigating types two (Project Advent) and three (Project Courier) although the bulk of this effort is centered on type two. The NASA active communications program will be of the first type.

The instantaneous repeater satellite in a low-altitude orbit appears at this time to offer the most promise for early achievement of an operational high-quality active communications satellite system. The technology exists for assembly of such a satellite; its early test in orbit will reveal any problems associated with its use, and will assist in their solution.

However, the low-altitude application does pose problems. For example, it has been discovered that serious radiation damage to solid state components may occur at these altitudes. Both ground and flight tests will be initiated to determine the extent of this problem and indicate possible solutions.

The flight schedules for the passive and active programs are as follows:

Mission	Launch Vehicle	Fiscal Year of Launch
Passive Program:		
Echo (nonrigid)	Delta	1960*
Echo I (nonrigid)	Delta	1961
Echo (rigid):		
Suborbital test	Thor	1962
Suborbital test	Thor	1962
Orbital test	Thor-Agena B	1962
Rebound (3 rigid spheres)	Atlas-Agena B	1963
Rebound (6 rigid spheres)	Centaur	1964
Active Program:		
Radiation measurement at 24-hour altitude	Centaur	1962
Radiation measurement at 24-hour altitude	Centaur	1962
Phase I low-altitude repeater	Delta	1962
Phase I low-altitude repeater	Delta	1962
Phase II low-altitude repeater	Atlas-Agena B	1963
Phase II low-altitude repeater	Atlas-Agena B	1963

*Failed to achieve orbit.

FUNDING REQUIREMENTS:

Advanced Research	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1961 Supplemental	Fiscal Year 1962
Electrically steerable antenna arrays for ground and spacecraft applications - experimental studies.....	$43,000	$4,000	---	$100,000
Influence of ultimate utilization on communications satellite design and orbit.....	86,000	---	---	---
Frequency interference problems - study.....	50,000	---	---	100,000
Operational switching techniques for multi-satellite communications systems - study	100,000	---	---	---
High-gain reflective space structures - experimental studies.....	---	---	---	300,000

Advanced Research	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1961 Supplemental	Fiscal Year 1962
Attitude stabilization - study.....	$84,000	$21,000	---	---
Satellite materials and components - environmental studies.....	---	100,000	$400,000	$150,000
Deep-space communications - study.....	100,000	---	---	---
Analysis of communications satellite experiments.....	50,000	50,000	---	150,000
Scattering properties of aluminum-coated inflatable sphere - experimental study..	120,000	---	---	---
Economic evaluation of various communications satellite systems - study.....	184,000	---	---	---
Total, Advanced Research.....	$817,000	$175,000	$400,000	$800,000

The research and development programs are designed to provide the studies which are necessary to the proper direction of the development effort and to bring along those technological developments which are the prerequisites of operational communications satellite systems.

The fiscal year 1960 work on high-gain antenna concepts, particularly of the kind that can be "pointed" electrically rather than mechanically, will be continued in the fiscal year 1962. The fiscal year 1960 initiated study to determine the optimum design and orbit for communications satellites will be completed during 1961. One of the factors influencing design of both satellites and ground-based equipment is the interference of satellite ground terminals with other communications media; studies of these problems, begun with 1960 funds, will be intensified in the fiscal year 1962.

Multi-satellite systems operations require a concept of switching between one satellite and another to avoid breaks in transmission; correlation between ground stations is essential. The study of multi-satellite switching techniques, funded in the fiscal year 1960, will provide the knowledge necessary for use of such systems.

Studies on high-gain reflective space structures will be initiated in the fiscal year 1962. The use of such structures which are inherently more efficient than spheres, is dependent upon attitude stabilization, which was studied in 1960.

The requirement of long life for communications satellites makes necessary intensive investigation into the effects of the space environment

on materials and components from which such satellites are fabricated. Supplemental 1961 funds are required to initiate studies which will determine radiation effects upon the performance of solid state components such as transistors, diodes and other semiconductor devices. Tests will be conducted in various cyclotrons and electron accelerators which will provide radiation data on proton damage. These data will be used to predict the performance life of components exposed to protons in the inner Van Allen radiation belt and electrons in the outer belt. In addition to this determination of radiation effects on existing componentry, new materials such as gallium arsenide will be investigated. This and other high atomic weight materials show promise of greater resistance to radiation damage.

Critical analyses of the experiments carried out as part of the flight programs are essential to insure appropriate follow-on effort. These studies were initiated in the fiscal year 1960 and will continue. The fiscal year 1960 experimental work on the scattering properties of aluminum-coated spheres will provide necessary data for complete analyses of the Echo experiments.

The choice of which type of communications satellite system will eventually be established for civilian operational use is dependent to a great extent on the relative cost of each. The economic evaluation study, funded in the fiscal year 1960, will give a cost comparison of the various systems, and the trade-off between cost and performance for each.

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1961 Supplemental	Fiscal Year 1962
Echo transmitter.....	$45,000	---	---	---
Digital antenna-pointing equipment.....	70,000	---	---	---
Parametric amplifiers.....	300,000	---	---	---
Rigidization techniques for space structures.....	190,000	$125,000	---	---
Instrumentation system for passive satellites.....	100,000	---	---	---
Development of radiation resistant materials and components.....	---	---	---	$600,000
Long-lived travelling wave tubes.....	---	---	---	250,000
High-powered (40 Kw) transmitter development.....	---	500,000	---	2,000,000
Attitude stabilization system	---	---	---	500,000
Development of improved spaceborne batteries.....	---	---	550,000	---
High-powered spaceborne broadcast transmitter.....	---	---	---	300,000
Total, Advanced Technical Development.....	$705,000	$625,000	$550,000	$3,650,000

Development of a special purpose transmitter, digital antenna-pointing equipment, and parametric amplifiers for experimentation at the Jet Propulsion Laboratory's Goldstone facility in connection with Project Echo were completed in the fiscal year 1960. A development program for the rigidization of space structures such as the Echo sphere was initially funded in the fiscal year 1960 and is planned for completion with fiscal year 1961 funding. The multi-sphere flight scheduled for 1963 will take advantage of these techniques. The instrumentation system funded in 1960 will provide for the measurement of such parameters as pressure, temperature and skin stress, and the telemetering of this information. This system will be incorporated on passive satellites upon completion of development.

In addition to the investigation of radiation damage to satellite components and advanced research on new radiation resistant materials (advanced research effort) fiscal year 1962 funding is necessary to initiate the development of components employing the new materials which show a higher resistance to radiation damage.

Ground and spaceborne components for active satellite systems are being developed. Fiscal year 1962 funds are required to develop travelling wave tubes capable of long life in the space environment. It is intended that tubes such as these will be used in the Phase II low-altitude repeater satellites. Development of a high-powered (40 kilowatt) transmitter will be initiated in the fiscal year 1961 and fully developed during 1962. This higher powered transmitter is required to provide an adequate signal for reflection from the higher orbit passive satellites. The initial portion of this development will be directed toward a power output tube in the 6000 megacycles region, and the effort should culminate during the fiscal year 1962 with the development of complete 40 kilowatt transmitters at this frequency. This higher power will provide for the demonstration of feasibility of the transmission of television bandwidths via the satellites of Project Rebound.

Development of an attitude stabilization system for high-gain passive satellites will also be initiated in the fiscal year 1962. This development will be an outgrowth of attitude stabilization research funded in 1960, and it will emphasize a reevaluation of stabilization systems which do not rely on a supply of propellant which can be exhausted. This reevaluation is made necessary because of technological advances in providing large erectable structures. For example, a reevaluation of gravity stabilization possibilities may be in order with the possibility of erecting satellites with extremely large separations of mass concentrations.

Batteries are and will continue to be a necessary part of any satellite or space probe containing active components. Work is being pursued on the development of reliable batteries for space applications, with emphasis on nickel-cadmium rechargeable batteries having lifetimes up to one year. In order to be useful, however, active communications satellites will require much longer battery lifetimes. Immediate effort is required to initiate the

development and simulated service-testing of both nickel-cadmium and silver-cadmium batteries that show promise of meeting the reliability requirements of communications satellites. Supplemental funds for the fiscal year 1961 are requested to initiate and accelerate this effort.

Finally, the development of higher power (1000 watts) satellite-borne power output tubes will be initiated in the fiscal year 1962. This timing will be consistent with the realization of high output power sources for satellite applications such as the 3 kilowatt Sunflower unit which is being developed under the Space Power Technology Program. This power level will provide for a satellite capable of broadcasting directly to the home radio.

Flight Program (Passive)	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1961 Supplemental	Fiscal Year 1962
Echo (nonrigid sphere):				
Basic spacecraft.....	$616,000	---	---	---
Beacons.....	9,100	---	---	---
Delta third-stage hardware..	33,833	---	---	---
Data acquisition and reduction.....	46,062	---	---	---
Operation of Goldstone transmitter and receiver site...	378,000	---	---	---
Operation of Holmdel transmitter and receiver site...	145,870	---	---	---
Operation of USAF Scotland radar site.....	22,135	---	---	---
Ground communications equipment modification and improvement.....	277,000	---	---	---
Delta launch vehicle (funded under Launch Vehicle Development Program).....	---	---	---	---
	1,528,000	---	---	---
Echo (rigid sphere):				
Suborbital tests:				
Spacecraft development, fabrication and assembly.....	---	1,700,000	---	---
Spacecraft-vehicle integration	---	350,000	---	---
Type approval and flight check-out.....	---	---	$450,000	---
Thor launch vehicles.....	---	---	2,000,000	$400,000

Flight Program (Passive)	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1961 Supplemental	Fiscal Year 1962
Orbital test:				
Fabrication, assembly, and test.....	---	---	---	$900,000
Ground support and operations.....	---	---	---	200,000
Thor-Agena B launch vehicle	---	---	$3,400,000	3,200,000
	---	$2,050,000	5,850,000	4,700,000
Rebound (3 rigid spheres):				
Design, fabrication, assembly, mating and check-out..	---	500,000	250,000	3,000,000
Low-noise receivers.....	---	---	---	450,000
Antenna feeds and equipment.	---	---	---	300,000
Atlas-Agena B launch vehicle	---	---	1,400,000	5,700,000
	---	500,000	1,650,000	9,450,000
Rebound (6 rigid spheres):				
Design study.....	---	---	---	300,000
Centaur launch vehicle.....	---	---	---	3,500,000
	---	---	---	3,800,000
Total, Passive Program....	$1,528,000	$2,550,000	$7,500,000	$17,950,000
Flight Program (Active)				
Phase I - Low-altitude Active Repeaters:				
Systems engineering.....	---	$562,000	---	---
Systems integration and operational management.....	---	---	$1,250,000	$1,000,000
Spacecraft fabrication and assembly.....	---	---	3,500,000	500,000
Transmitters.....	---	---	---	560,000
Receivers - low noise, 2200 megacycles.....	---	---	---	370,000
Feed modifications for U. S. site.....	---	---	---	150,000
Initial and operating spares	---	---	---	370,000
Data acquisition and services	---	---	---	250,000
Delta launch vehicles.....	---	---	6,500,000	1,000,000
	---	562,000	11,250,000	4,200,000

Flight Program (Active)	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1961 Supplemental	Fiscal Year 1962
Phase II - Low-altitude Active Repeaters:				
Spacecraft design, development, and fabrication.....	---	---	$800,000	$7,700,000
Atlas-Agena launch vehicles.	---	---	1,500,000	10,300,000
	---	---	2,300,000	18,000,000
Radiation Measurements at 24-hour Altitudes:				
Spacecraft fabrication and test.....	---	---	2,000,000	---
Centaur launch vehicles (funded under Launch Vehicle Development Program).....	---	---	---	---
	---	---	2,000,000	---
Total, Active Program....	---	$562,000	$15,550,000	$22,200,000

Passive Program:

Echo I (nonrigid sphere)

The first passive communications satellite, Echo I, was placed in orbit on August 12, 1960. Its spectacular success has demonstrated the feasibility of placing large inflatable structures in orbit, and the utility of such structures as passive communications relays. Specifically, Echo I has provided the following:

1. Adequate demonstration of the feasibility of passive communications satellites.

2. A confirmation of radio propagation theory which indicates no fundamental barriers to the use of such systems.

3. A confirmation of orbital behavior theory which will permit adequate prediction of the exact position of these large, light-weight satellites so that communicating antennas may be pointed with sufficient accuracy.

4. Justification that such large, erectable structures can be provided which will live in the space environment for long periods of time.

A primary objective of Echo I was to determine what it takes to provide a satellite which will not degrade in shape or reflectivity with time.

The life of Echo I was insured for approximately 16 days through the use of a sublimating powder, carried inside the satellite, which by evaporating would provide a sustaining internal pressure over this period. Leakage and micrometeorite damage caused dissipation of this material a few weeks after launch, yet the satellite continued to maintain its shape long afterward. There has been some wrinkling of surface of the sphere, resulting in variations in the reflected signal strength, but not severe enough to destroy its usefulness.

The fact that Echo I did not become distorted significantly after loss of internal pressure is highly encouraging. It indicates that only a nominal increase in material stiffness is required to insure a really long-life satellite, and this in turn means that it can be accomplished without a major increase in required satellite weight.

All of this indicates the need for an acceleration of the NASA passive communications satellite follow-on effort to develop the technology necessary to passive satellite systems on an earlier time scale than originally planned.

Echo (rigid sphere)

The first step toward a passive satellite system is the development of an improved sphere - one that will be larger (approximately 140 feet in diameter) and more rigid than Echo I. This development will include tests of inflation and ejection techniques in suborbital flights, the procedure which proved to be extremely useful in the development of Echo I. Two Thor launch vehicles will be used in these tests, early in the fiscal year 1962. The 700-mile altitude orbital launch, scheduled later in 1962, will employ a Thor-Agena B.

Supplemental fiscal year 1961 funds in the amount of $5,850,000 are requested to perform ground tests in preparation for the suborbital flights scheduled for early fiscal year 1962, and to provide the necessary lead-time funding of two Thor vehicles and one Thor-Agena B vehicle. The fiscal year 1962 funding will provide for fabrication, assembly, and testing; for ground support and operations; and for completion of the vehicle funding.

Rebound (3 rigid spheres)

Operational passive communications satellite systems can be achieved most economically by placing several satellites into orbit with a single launch vehicle. Project Rebound has been established to bring about the perfection of this technique on an early time scale.

A spacecraft capable of carrying three rigid spheres and ejecting them once orbit has been attained will be developed. In the fiscal year 1963 an Atlas-Agena B launch vehicle will be employed to place the spacecraft in the 1500-mile operational altitude orbit. The inclination will be

approximately 45 degrees. A design study is being initiated in the fiscal year 1961 with spacecraft development and ground test to start in late 1961, and fabrication in 1962.

Supplemental fiscal year 1961 funds in the amount of $1,650,000 are requested to initiate this development and to provide the necessary lead-time funding for the Atlas-Agena B vehicle. An additional increment in the fiscal year 1962 will complete the Atlas-Agena B funding.

Rebound (6 rigid spheres)

The final stage in the development of passive systems consisting of spherical satellites calls for the Centaur launching of a spacecraft containing six spheres in the fiscal year 1964. Again, this launching will result in an operational orbital altitude of 1,500 miles with 45 degree inclination. Both the Atlas-Agena and Centaur launches will therefore contribute to the eventual system, in addition to providing at least a nominally useful intermittent capability by themselves. This multiple launch technique may also be applied to establish an active repeater system. Fiscal year 1962 funding of $3,500,000 will provide the first increment for the Centaur vehicle.

Active Program:

The low-altitude active repeater satellite is one likely form of satellite for commercial use. There are two distinct advantages to such satellites compared with active satellites in a 24-hour orbit:

1. Ability to provide large bandwidths at rather nominal ground equipment costs.

2. Promise of relatively long life (assuming that the radiation damage problem is not serious). For example, the life of a 24-hour satellite is in part determined by the quantity of propellant carried abcard to continually control position and altitude. The low-altitude active repeater does not require attitude stabilization and therefore is not subject to this limitation.

The objective of the NASA active communications satellite flight program is to provide an early demonstration (Phase I) that a relatively low-altitude active satellite is both feasible and suitable for commercial applications. Such an early demonstration will provide many answers regarding the operational problems in using such satellite systems in addition to the testing of typical componentry in the space environment. This will result in an earlier realization of operational systems.

Following this early determination of the parameters, a more sophisticated satellite (Phase II) will be developed capable of being launched in the numbers required for operational systems.

Phase I Low-altitude Active Repeater

This phase calls for two launchings of a very simple active repeater satellite into an 1800-mile altitude orbit inclined at approximately 45 degrees to the equatorial plane. This satellite will weigh approximately 80 pounds, be capable of one-way transmission of a television bandwidth, and will be instrumented to indicate deterioration of satellite componentry which may fail in orbit.

This step will provide the demonstration of feasibility of the low-altitude active repeater satellite. A trans-Atlantic capability will be demonstrated by a communication experiment between the United States and Europe, via the satellite. An existing antenna in the eastern United States will be utilized in conjunction with a selected European site.

Supplemental fiscal year 1961 funding in the amount of $11,250,000 includes $6,500,000 as an increment on the two Delta launch vehicles required for Phase I; the remaining increment is included in the 1962 requirements.

Phase II Low-altitude Active Repeater

This phase of the program calls for the development of an active repeater satellite capable of two-way transmission (television bandwidth or 600 two-way voice circuits), and two launchings of this satellite into operational orbital altitudes. At this time the altitude will be 3,000 miles unless Phase I and the investigations indicate a severe radiation damage problem. Should this be the case, the altitude may have to be increased.

The previously selected European facility will be used in conjunction with the tracking facility to be built on the East Coast of the United States, to provide operational demonstration during this phase.

This step when completed will bring technology to the point where operational systems may be considered. Multiple spacecraft launches will be desirable for the ultimate system and the experience gained in the multiple launchings of Project Rebound will be of considerable value in this regard. Continued upgrading of componentry to further extend the useful life of such satellites will probably be necessary.

Supplemental fiscal year 1961 funding in the amount of $2,300,000 will provide incremental funding of $1,500,000 for two Atlas-Agena B launch vehicles and $800,000 for spacecraft design. The 1962 estimate of $18,000,000 provides $10,300,000 as a follow-on increment for the two

Atlas-Agena B vehicles plus $7,700,000 for spacecraft design, development and fabrication.

Radiation Measurements at 24-hour Altitudes

The Department of Defense is planning to assemble test packages of components for evaluation of radiation damage in a 24-hour orbit in support of the Advent program. These flights will be made on NASA experimental Centaur vehicles. As part of the NASA communications satellite program, supplemental fiscal year 1961 funding is requested to provide instrumentation for measuring the quantities of energized particles encountered at the 24-hour altitude. This NASA developed equipment will provide valuable correlation and verification of the space environment and its effect on the components of the Advent satellite.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

MERCURY

SUMMARY OF REQUIREMENTS:

	1960	1961	1962	Page No.
Advanced Technical Development	$3,418,600	$5,850,000	$2,510,000	RD9-2
Flight Program.....	80,909,770	103,675,000	71,735,000	RD9-8
Total.....	$84,328,370	$109,525,000	$74,245,000	

OBJECTIVES:

The objectives of the Mercury program are twofold: (1) to develop the technologies required to construct a manned satellite capsule which can be either manually or automatically controlled and which will provide a safe environment for man during launch, orbit, reentry, landing, and recovery; and (2) to determine what effects, if any, a prolonged weightless environment may have on man's ability to perform useful functions in space.

JUSTIFICATION:

It has become increasingly apparent that full exploitation of the potentialities of space flight will be strongly dependent on the development of practical capabilities for carrying man into space. Many space missions can be and are being accomplished without man. However, there are many advanced missions in which the presence of man will greatly enhance the research value and over-all reliability. The weight of future spacecraft will be sufficiently large that trade-offs can be made between man and instrument payloads. When operating in the new space environment, mission flexibility and reliability will be increased by incorporating a human operator who can evaluate the flight progress, perform maintenance, make observations, and modify the flight plan to insure maximum mission usefulness. Because of these considerations, it is a basic objective of NASA to develop and utilize manned space flight capabilities.

The Mercury program was chosen to accomplish the initial objectives of manned space flight. Mercury uses a one-man space capsule which will be launched eastward from the Atlantic Missile Range, circle the earth three times and accomplish a parachute water-landing. Communications and tracking support for this mission will be provided by a world-wide network of ground stations. Maximum use will be made of existing tracking and communication facilities. Through the accomplishment of the Mercury

program we expect to be able to establish the degree to which a pilot can be expected to operate in an advanced manned spacecraft. Earliest achievement of manned orbital flight dictated the use of an ICBM launch vehicle and a ballistic high-drag reentry capsule. This approach uses an essentially unmodified launch vehicle and a proven ICBM reentry nose cone technique in order to achieve minimum development time compatible with reliability and safety. Many ICBM high-drag nose cones have successfully undergone reentry heating rates much higher than will be encountered during the Mercury program and the Atlas launch vehicle is developing a history of successful flights.

FUNDING REQUIREMENTS:

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Configuration and Performance Tests:			
Construction of special test models	$2,800	$313,000	---
Instrumentation and support equipment	2,700	260,000	$50,000
Ground environmental tests	1,000	300,000	10,000
Analytical investigations	343,800	120,000	40,000
	350,300	993,000	100,000
Escape System Development	74,100	270,000	250,000
Landing Tests:			
Air drop support	130,700	220,000	70,000
Test equipment	---	130,000	30,000
	130,700	350,000	100,000
Retrograde, Posigrade and other Pyrotechnic Tests	821,500	450,000	120,000
Structures and Impact Tests	72,500	350,000	430,000
Navigation, Stabilization and Control:			
Component test rigs	32,000	400,000	70,000
Instrumentation	24,000	100,000	85,000
Test equipment	12,400	100,000	90,000
Analytical investigations	8,000	100,000	30,000
	76,400	700,000	275,000

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Recovery Equipment Tests:			
Test support services.....	$45,300	$167,000	$50,000
Receiver development.....	14,200	48,000	30,000
Beacon development.....	23,900	65,000	20,000
	83,400	280,000	100,000
Communication and Instrumentation Systems Hardware Tests:			
System component development..	231,400	240,000	120,000
Systems test apparatus.....	161,200	190,000	100,000
Test support services.....	87,300	105,000	80,000
	479,900	535,000	300,000
Development of Mercury Life-Support Equipment:			
Pressure suit modifications...	39,100	77,000	150,000
Improved survival equipment...	34,100	50,000	50,000
Test equipment.....	2,000	250,000	45,000
Instrumentation for test equipment.....	3,000	45,000	15,000
Component hardware.....	2,000	150,000	25,000
Biological tests.....	8,000	20,000	10,000
Improved biosensors.....	18,000	40,000	40,000
Environmental equipment and pilot compatability tests...	51,700	155,000	60,000
	157,900	787,000	395,000
Mercury Pilot Training and Capsule Simulator Support:			
Analog equipment for simulator No. 1.....	---	40,000	---
Computer for simulator No. 2..	---	75,000	---
Environmental chamber for pressure suit and equipment check-out.....	---	100,000	---
Pilot training and development of motion simulators.....	60,000	115,000	90,000
Services of engineers and technicians for simulators Nos. 1 and 2.....	80,000	120,000	110,000
Navigational training and equipment.....	205,100	195,000	150,000
	345,100	645,000	350,000

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Mercury Acceleration Tolerance Tests:			
Test equipment for centrifuge and sled.....	$190,000	$120,000	$40,000
Instrumentation.....	72,800	95,000	---
Restraint support tests and equipment.....	224,000	115,000	10,000
Biological tests.....	40,000	30,000	15,000
Landing impact program.....	300,000	130,000	25,000
	826,800	490,000	90,000
Total, Advanced Technical Development.....	$3,418,600	$5,850,000	$2,510,000

When the Mercury program was initiated in mid-fiscal year 1959, a wide range of studies and experimental investigations was undertaken to define the concept of the Mercury satellite and provide fundamental technical data on which to base the design of the capsule and its various operational systems. Detailed specifications were evolved for the development and construction of the Mercury capsule. After evaluating several proposals from industry, a production contract was awarded. At the same time, the Mercury pilots were selected and an extensive program for their training was initiated.

These initial efforts were continued and extended during the fiscal year 1960. This included the conduct of a wide range of studies and investigations for further refinement of capsule arrangements; the solution of critical aerodynamics, hydrodynamics, loading, structures, materials, propulsion, electronics, mechanical, functional, and performance problems; the development of alternates for critical components and systems; and the detailed evaluation and proof testing of prototype hardware.

The new Little Joe launch vehicle was first flown in the fiscal year 1960 and used to launch prototype Mercury capsules for successful demonstration of the abort capabilities of the escape system at critical flight conditions and for simultaneous tests of the parachute landing and recovery systems. During this same period, a major milestone was reached when the capsule heat shield concept was successfully demonstrated with an Atlas-launched full-scale model duplicating the trajectory of reentry into the atmosphere from orbit. These tests also permitted demonstration and refinement of the techniques being developed for using aircraft and Naval ships for post-flight location and recovery of the space capsule.

These activities are being continued and extended in the fiscal year 1961. The program for training of the pilots is continuing and includes further familiarization with the details and operation of the capsule systems, learning to control the capsule through the use of the capsule simulator on the Navy Centrifuge at Johnsville, Pennsylvania, and the use of various NASA motion simulators.

A number of Mercury capsules are being delivered in the fiscal year 1961, and the initial qualification flight test program is being carried out. The purpose of this flight test program is to identify design and manufacturing deficiencies of a type that could not be found in the extensive ground test program. Historically, in manned flight programs, a gradual buildup of capability is required to achieve a system that is safe for manned operation under design conditions. With this background in mind, the Mercury flight test program was set up to include a step-by-step buildup in mission objectives. Experience in this project, to date, has amply demonstrated the need for such a program; unexpected problem areas have been uncovered, while the adequacy of many systems has been demonstrated. Inevitably, the results of each test require a re-examination of some of the systems, an improvement in design or fabrication techniques, or a change in some component part.

Because the largest part of the flight qualification program will be carried out in the latter part of the fiscal year 1961, the resulting re-examination, improvement, and modification program will carry well into the fiscal year 1962. Continuing technical development will be required in the following areas:

Configuration and Performance Tests

These tests, involve, in part, the complex stability areas which are encountered with the Mercury capsule. For instance, as a result of the early Little Joe escape tests, it was learned that the stability of the escape configuration was lower than anticipated. This result caused the retrofit addition of a stability augmentor on the base of the escape tower. This modification necessitated additional wind tunnel runs. Using the wind tunnel data, computer studies were made to predict the dynamic motions of the capsule. Data from successive flight tests will be used to update capsule motion predictions. These types of calculations will continue throughout the flight test program. Other investigations which will continue into 1962 involve emergency drag stabilization and reentry systems which could be used in the event of malfunction of the capsule reaction control system and the retro-rockets.

Escape System Development

The capsule escape system consists of tripod support legs which are attached to the capsule at the base of the conical-shaped antenna canister. Voice and telemetry signals are attenuated by radio interference caused by the metallic legs of the escape tower. Although the capsule can be flown in the current configuration during the early flights, a modified tower configuration must be developed in 1962 which, based on early flight-test results, will produce minimum interference with radio transmissions.

Landing Tests

The capsule weight distribution must be such that after a water landing the capsule will float in the correct attitude, allowing pilot egress and permitting the recovery radio antennas to operate above the water line. Because the flotation characteristics are dependent upon capsule weight distribution, parachute release timing, wind velocity, and sea state, many tests will continue into 1962 to simulate the capsule configurations and environmental conditions which will be encountered with the rocket-launched orbital versions of the capsule.

Retrograde, Posigrade, and other Pyrotechnic Tests

The capsule contains retro-rockets to initiate descent from orbit and posigrade rockets to separate the escape tower from the capsule and to separate the capsule from the launch vehicle. Although all of these rocket motors are being qualified within the required specifications, development work will continue into 1962 in an effort to extend the operating temperature limits. A unique requirement for pyrotechnics is in the explosive-operated egress hatch. Since the early capsules utilize mechanical-latching hatches, there will be no opportunity for flight test experience with the explosive hatch until later in the flight program. Consequently, development tests of this device will continue into 1962.

Structures and Impact Tests

The presence of man in a parachute-landing space capsule requires that the structure maintain pressure integrity during water impact and that vertical and lateral impact accelerations be attenuated. A landing impact bag has been fabricated which will reduce the vertical and lateral impact forces transmitted to the capsule and pilot. Development work will be conducted to extend the impact protection for higher lateral impact velocities.

Navigation, Stabilization, and Control

The capsule stabilization and control system is one of the most complex and important systems in the capsule. It is required to orient the capsule in the proper position for visual navigation and to hold the capsule in the correct attitude during retro-firing. The control system utilizes hydrogen peroxide reaction jets which can be either manually or automatically controlled. Manual control of the capsule is required in case of failure of the automatic system during early flights and will be required for the development of manual piloting and navigation techniques on later flights. A continuing test and analysis effort will be directed toward investigating all the control modes to be used in these later flights.

Recovery Equipment Tests

The Mercury capsule is equipped with a number of transmitter beacons and other devices that are used to aid in the location of the capsule after it has landed. The recovery beacons installed in initial versions of the capsule have a rather limited range, thereby necessitating the use of a large number of search and retrieval ships and airplanes. New equipment is currently being developed that will nearly double the transmitting range of the recovery beacons. Final evaluation testing and installation will take place during the fiscal year 1962. The use of this equipment will enhance the probability of a fast recovery.

Communications and Instrumentation

Detailed monitoring of the capsule systems is accomplished through an elaborate instrumentation system. Nearly one hundred parameters are being monitored. It is necessary to transmit this information to the ground stations by voice and radio telemetry. Because the capsules will fly various missions, and because instrumentation parameters will depend on the results of the previous flight, a continued effort to provide new instrumentation is required throughout the flight program.

Development of Mercury Life-Support Equipment

As a result of the pilot training program, recommendations for pressure suit modifications are continually being carried out. Although the Mercury pressure suit is now adequate for manned operations in space, its safety and reliability aspects will be improved as more flight test experience becomes available.

The environmental control system in the Mercury capsule is entirely new, designed without prior experience with similar systems. Consequently, this system will undergo continuing improvement and testing as the flight program progresses.

Mercury Pilot Training and Capsule Simulator Support

Because of the unique control modes and emergency manual systems, considerable pilot familiarization and training is required. Two capsule simulators have been procured from the capsule contractor. One simulator is located at the Langley Center and the other is installed in the Mercury Control Center complex at the Atlantic Missile Range. In order to gain maximum benefit from these simulators, they have been augmented by analog computers and special navigation map-projection equipment. In order to keep maximum continuity between capsule and simulator details, the services of contractor engineers and technicians are necessary. In addition to the capsule simulators, a special air-bearing motion simulation is being developed for pilot training. Pilot familiarization and training must continue throughout the flight program.

Mercury Acceleration Tolerance Tests

Acceleration tolerance testing has been accomplished at the Air Force impact acceleration facilities at the Wright Air Development Center and at the Holloman Air Force Base. These were impact tests which simulated the high onset rates which are expected during capsule impact on both land and water. The tests performed at the Navy Johnsville Centrifuge served the dual purpose of tolerance testing and pilot training. The centrifuge cab controls were arranged similar to the Mercury capsule controls. The pilot actually controlled the motions of the simulated reentries through a closed-loop centrifuge computer circuit. Coincident with many of the previous tests, several pilot restraint systems were tested. Centrifuge training and impact testing will be continued into the fiscal year 1962.

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Capsules, Support Equipment and Services:			
Capsules.....	$45,183,800	$39,800,000	$24,832,000
Training simulators.....	3,660,400	1,408,000	860,000
Spare parts.....	2,466,900	469,000	425,000
Ground support equipment.....	6,810,200	1,959,000	908,000
Flight test support.....	2,706,170	3,286,000	3,875,000
Support equipment and services	1,022,300	1,798,000	1,100,000
	61,849,770	48,720,000	32,000,000

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Network Operational Implementation:			
Overseas transportation.....	$780,000	$250,000	---
Dynamic check-out of network.	---	200,000	---
Design of training simulation system.....	160,000	400,000	---
Hookup of simulation system..	85,000	300,000	---
Training aids.....	230,000	650,000	---
Back up electronic supplies for telemetry and ground communications.....	284,000	700,000	110,000
Back up electronic equipment for telemetry and ground communications.....	190,000	650,000	90,000
Flight controller training equipment.....	90,000	210,000	---
Back up electronic supplies for tracking and data acquisition.....	214,200	750,000	155,000
Field equipment modifications	482,000	1,824,000	170,000
Back up electronic equipment for tracking and data acquisition.....	180,000	800,000	225,000
	2,695,200	6,734,000	750,000
Network Operations:			
Bermuda station.....	---	2,007,000	3,109,000
Australia stations.....	---	1,852,000	3,004,000
Canary Islands station.....	---	705,000	1,276,000
Kano station.....	---	786,000	1,422,000
Zanzibar station.....	---	613,000	1,108,000
West Mexico station.....	---	1,460,000	2,644,000
Southern California station..	---	119,000	215,000
Hawaiian station.....	---	110,000	200,000
Canton Island station.....	---	316,000	573,000
Atlantic Missile Range.....	110,300	313,000	1,424,000
Corpus Christi and White Sands stations.....	30,000	848,000	1,534,000
Air Proving Ground station...	4,500	18,000	35,000
Ocean range vessels.....	---	958,000	2,608,000
Port Louis ship support station	---	193,000	349,000
Training.....	---	209,000	134,000
Lincoln Laboratory services..	---	1,500,000	---
IBM computing center services	---	212,000	---
	144,800	12,219,000	19,635,000

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Recovery Operations:			
Navy Bureau of Ships support	$125,000	$4,079,000	$3,147,500
Navy Bureau of Weapons support.....	175,000	5,890,000	3,982,500
Retrieval equipment.....	53,000	604,000	720,000
	353,000	10,573,000	7,850,000
Launch Vehicles:			
Redstone.....	4,477,000	2,450,000	---
Atlas.....	11,390,000	22,979,000	11,500,000
	15,867,000	25,429,000	11,500,000
Total, Flight Program..	$80,909,770	$103,675,000	$71,735,000

Because of the urgency of the Mercury program, its various phases are being conducted in parallel. Portions of the research and development program, such as parachute and escape system development, have been accomplished concurrently with the capsule manufacture. The flight program consists of research and development flights, followed by qualification flights of increasingly complex capsules, terminating in manned ballistic and orbital flights. Twenty-four capsules are being built by the contractor for the ground tests, qualification flights, and manned flights.

After a production contract was awarded in the fiscal year 1959, a program of large-scale flight experiments was initiated to permit demonstration of the practicability of design and operational concepts for protection of the capsule from critical aerodynamic heating on atmosphere reentry from orbital flight, for safe escape of the manned capsule from the launch vehicle in the event of imminent catastrophic failure, and for landing and sea recovery of the capsule at the termination of the flight. The initial full-scale demonstrations of the parachute landing system and launch pad escape of the capsule from the booster were successfully accomplished.

Modification and construction programs on suitable launch vehicle systems, including the liquid-fueled Redstone and Atlas and a specially designed Little Joe solid-propellant system,were undertaken to support the conceptual proof tests and the planned series of development and qualification flight tests leading to manned orbital flight.

During the fiscal year 1960, progress was made in fabrication, assembly, and check-out of operational Mercury capsules. Three capsules were delivered. The first was launched at the Wallops Station in a simulated launch pad abort. Subsequently this capsule underwent severe structural testing. The second capsule was fully instrumented for a structural and heating flight test. The third was prepared for later flight on the first Mercury-Redstone vehicle.

Blockhouses and launch pads were modified and check-out facilities were constructed at the Atlantic Missile Range. Personnel were trained for the preflight check-out and preparation of the Mercury capsules for short-range Little Joe and Redstone flights and for the long-range ballistic or orbital Atlas flights.

During this period, a program for using lower primates in some Little Joe, Redstone, and Atlas flights with simplified and operational Mercury capsules was begun to provide biological loading tests of the capsule environmental and instrumentation systems prior to manned operation. As a result, animal experiments were successfully conducted in two of the previously mentioned capsule escape system tests with Little Joe launch vehicles. Methods were established for the conduct and integration of various activities necessary for the launch, global flight tracking and data acquisition, flight monitoring and control, capsule recovery, and debriefing. Provision of necessary training aids, including operations simulators for flight monitoring and control activities, and associated personnel training were initiated.

During the fiscal year 1961, these activities are being continued and extended. Detailed development and construction of the operational Mercury capsules is continuing and, as dictated by various qualification and preliminary flight test programs, necessary refinements to the capsule systems are being evolved and incorporated.

Basic design and construction of the Mercury tracking and ground instrumentation network is being completed, and check-out and demonstration of the systems undertaken. Training of network operations and maintenance personnel is facilitated by operation simulation programs and by the support of the initial unmanned orbital flights. As proved necessary by initial experience, system refinements will be made to provide adequate support to the ensuing flight operations.

Major efforts are being directed during the fiscal year 1961 to the qualification and progressive flight demonstration of the operational Mercury capsules. Extensive vibration and noise environment tests will be made to qualify the capsule under simulated launch vibrations, and a Little Joe launch vehicle will be used for qualification of the escape system at the most severe abort conditions during boosted flight. Atlas launch vehicles are being used to test the adequacy of the heat protection methods and landing and recovery systems of the operational capsules in trajectories duplicating atmosphere reentry from orbit, and in demonstrating the effectiveness of both capsule and ground support.

systems for handling emergency abort of the flight during the orbital insertion phase.

Concurrently, a program of suborbital ballistic flights of the operational Mercury satellite capsule with Redstone launch vehicles is being undertaken. Initial flights are being used to qualify the capsule systems and demonstrate the operational techniques. Only after these objectives have been accomplished will manned Redstone flights be undertaken. These flights will provide initial experience for both the pilot and ground support personnel in handling a manned flight operation, permit major evaluation of both flight and ground systems in actual manned flight operation, and contribute directly to the flight training of the pilots prior to the orbital missions as an adjunct to their extensive ground training program.

Orbital flight tests will be conducted in the fiscal year 1962. For this purpose, it is again planned to pursue a build-up of experience, with necessary correction and refinement of the hardware systems and operational methods, through preliminary orbital flights of the operational Mercury capsule. When all the systems have proven sufficiently reliable, manned orbital flights will be undertaken. These flights will provide for detailed investigation of the effectiveness of the Mercury systems and operational techniques, and the influences of the space environment on human reactions. Later phases of the orbital flight program will also permit attainment of initial experience in using the capabilities of manned space flight for the conduct of specialized scientific or advanced technological operations in space. Following is a description of each major category within the flight program.

Capsules

The initial contract with the capsule contractor specified only 12 capsules. It was not obvious at the time the contract was signed whether recovered capsules should be refurbished or additional capsules should be ordered. As the design details and operational procedures materialized, it became clear that the scheduling difficulties involved in refurbishing capsules, the uncertainties in capsule damage, and the long lead times would make refurbished capsules impractical. Cost estimates for the refurbished capsules were equal to those for new capsules. A total of 24 capsules are now on order but production has not started on the later capsules. The complexity of the Mercury capsules increases as they are phased into subsequent stages of the flight qualification program so that the later capsules are more expensive than the early models. During the fiscal year 1962, the majority of the flights will involve orbital capsules with complete subsystem components. In addition to increased construction costs, the systems test and check-out procedures will require a greater degree of contractor effort.

Training Simulators

The contractor was directed to construct two capsule simulators which would provide capsule familiarization and training for not only the pilots, but also for the flight controllers who will monitor the capsule systems' operation from the various tracking stations. The simulators are doubly complex in that they must simulate the operation of all the pilot's instruments and also permit an instructor to easily simulate nearly all possibilities of launch vehicle and capsule systems' failure. Funding for the trainers will continue into the fiscal year 1962 because they must be continually updated to maintain compatibility with the various capsule configurations.

Spare Parts

Spare parts must be available in order to provide an expeditious means for handling capsule subsystem malfunctions at the Atlantic Missile Range check-out facilities and launch sites. This item will require 1962 funding to cover capsule configurational changes.

Ground Support Equipment

Fiscal year 1962 funding is required to maintain ground hardware compatibility with the continually modified orbital capsules. This equipment serves the purpose of exercising and checking the operation of the various capsule systems at the contractor's plant and at the Atlantic Missile Range. The blockhouse and launch site instrumentation must also be modified to meet the specific mission requirements.

Flight Test Support

The contractor's effort in flight-test support will peak in 1962. From the standpoint of flight-test support activities, the most complex capsules will be used during the orbital flights, most of which are scheduled during the fiscal year 1962. A major consideration in this category is the post-flight tear down and analyses of the capsules. It is expected that very detailed post-flight analyses will be conducted on the early orbital capsules since they will be the first final-configuration capsules and will have been subjected to a space environment for a much longer duration than the ballistic capsules.

Support Equipment and Services

As mentioned above, capsule development work will continue throughout the duration of the Project. This work will require contractor-furnished support equipment and services in 1962.

Network Operational Implementation

Maximum probability for mission success and safety can be insured by a world-wide network of tracking and communication stations. There are 16 stations spotted under the orbital flight paths. Maximum use has been made of the Department of Defense communications network and existing stations in the United States and Hawaii. The NASA Wallops Station facility is being used as a demonstration and check-out site. The Goddard Space Flight Center will act as the network computing and communication center. The Mercury Control Center at the Atlantic Missile Range will coordinate and exercise command authority over the network stations.

In the fiscal years 1960 and 1961, the construction phase at all sites was being implemented and completed. Funds were required for the overseas transportation of station equipment, for the dynamic check-out of all stations, for the design and installation of a training simulation system, and for back up supplies and equipment. As a result of the diversified nature of this network, the operational implementation was found to be a tremendous undertaking, involving not only the complete functional check-out of each station, but also the integration of the entire network together with Mercury capsule equipment.

By the fiscal year 1962, all stations will have achieved a state of operational readiness. Funding will then be required to replace and update electronic equipment, and to make changes dictated by corresponding changes in capsule components.

Network Operations

Most of the network stations will not be manned until the last half of the fiscal year 1961; all stations will be manned continuously during the fiscal year 1962. The operating costs are dependent upon the amount of tracking and communications equipment which must be maintained and operated, and also upon the amount of Department of Defense support already existing at established tracking stations.

The stations at Bermuda, Canary Islands, Kano, Zanzibar, and West Mexico will be operated directly under NASA contract. The Australian Government will contract for the operation of the stations in Australia and the Department of Defense, or its contractors, will operate the remaining seven stations and the ships in the Atlantic and Indian Oceans.

Recovery Operations

Recovery ships and aircraft will be deployed in the Atlantic Ocean along the launch track and at the end of each of the three orbits. Widespread deployment along the launch track is necessary to provide

emergency pickup in the event the flight is aborted during the launch or if Atlas burnout occurs before orbital velocity is attained. Recovery ship deployment for the ballistic Atlas and Redstone flights will be down the Atlantic Missile Range. Helicopters will be stationed on some of the ships and at the launch site.

In addition to deployment during flight missions, considerable recovery training is being accomplished with full-scale boilerplate models of the capsule. Additional participation by recovery forces is also required during the evaluation of recovery beacons. Recovery costs include only those that are additional to normal operational expenses of these military units.

Launch Vehicles

Eight Redstone launch vehicles are scheduled for short-range ballistic qualification flights of the Mercury capsule. The Redstone was chosen for these intermediate flights because of its relative simplicity and inherent aerodynamic stability. Redstone flights were initiated in the second quarter of the fiscal year 1961.

The Atlas launch vehicle was selected for the design orbital mission. Preliminary Atlas flights, however, will be ballistic and will flight-test the capsule under severe abort reentry conditions and normal atmospheric reentries. The initial ballistic qualification flight took place early in the fiscal year 1961. A total of 15 Atlas launch vehicles are currently programmed for the Mercury program and are being incrementally funded at a rate compatible with production effort.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

APOLLO

SUMMARY OF REQUIREMENTS:

	1960	1961	1962	Page No.
Advanced Technical Development	$100,000	$1,000,000	$5,099,000	RD10-5
Flight Program.....	---	---	24,401,000	RD10-10
Total.....	$100,000	$1,000,000	$29,500,000	

OBJECTIVES:

To provide the capability for the manned exploration of space through the development of a spacecraft suitable both for manned lunar exploration and for use as an earth-orbiting laboratory.

JUSTIFICATION:

In the past, man's scientific and technical knowledge was limited by the fact that all of his observations were made either from the earth's surface or from within the earth's atmosphere. Now man can send his measuring equipment on satellites beyond the earth's atmosphere and into space beyond the moon on lunar and planetary probes. The knowledge that has been derived from these initial ventures into space is already extensive, but the exploration of space in its truest sense will begin only when man himself can participate directly.

Man is destined to play a vital and direct role in the exploration of the moon and the planets In this regard, it is not easy to conceive that instruments can be devised that can effectively and reliably duplicate man's role as an explorer, a geologist, a surveyor, a photographer, a chemist, a biologist, a physicist, or any of a host of other specialists whose talents would be needed. In all of these areas, man's judgment, his ability to observe and to reason, and his decision-making capabilities are required. Only man can cope with the unexpected; and the unexpected, of course, is the most interesting.

The search for extraterrestrial life, for instance, is a problem of formidable difficulty for pure instrumentation systems that is much more easily within the scope of man's abilities. Even in more prosaic endeavors such as photography, it is extremely challenging to duplicate man's ability to select pertinent subject matter and optimum photographic methods, to focus and choose the most profitable instant for exposure, to recognize that his view is obstructed, or even to note that the lens has become dirty.

Closer to earth, man's special abilities would be employed in manned orbiting space laboratories or space stations. Man's observational, analytical and functional capabilities can provide an advantage in the conduct of a range of meteorological, communication, broadcasting, mapping and search activities in orbiting vehicles. Orbiting laboratories will also permit the investigation and proof-testing of vehicular components and operating techniques required for the development of other advanced space vehicles and missions. Of note in this area are the evaluation of micro-meteorite and radiation damage to space materials, the development of space propulsion systems, the study of spacecraft erection and construction, the investigation of rendezvous techniques, and the detailed assessment of the long-duration capabilities of man in a weightless environment.

The initial step in providing the capability for the manned exploration of space is the Mercury program, designed to put a manned satellite into an orbit more than 100 miles above the earth's surface, let it circle the earth three times, and then bring it back safely. From the Mercury program we expect to learn much about man's capabilities in a space environment; such knowledge is vital in determining what must be done in order to allow man to participate effectively in other, more difficult, space missions. But the determination of man's capabilities in a space environment is only one of the benefits that will be derived from the Mercury program. Of equal importance is the technical knowledge being gained during the design, construction, and operation of the first vehicle specifically engineered for manned flight in space.

Acquisition of extended capabilities for manned space exploration and investigation beyond the Mercury program will need to proceed in logical steps as defined by the growth of pertinent technologies. A primary constraint resides in the scheduled availability of suitable propulsion systems for accomplishment of the required flight missions. Within the next ten years, the Saturn launch vehicle offers the best possibility for important advances in manned space flight. This launch vehicle should provide a capability for launching relatively large manned space laboratories into earth orbits, or a manned spacecraft into a circumlunar trajectory, with possible close lunar-orbiting for extended scientific observation before return to the earth. While the latter flight mission will not yield the ultimate potentialities of a manned lunar landing mission, it is expected to offer important scientific rewards and at the same time provide for the development of a proven spacecraft system that can be directly used in a manned lunar landing mission when suitable launch

vehicle advancement makes this possible. The size of the step into the future visualized for the Apollo program will take full advantage of the Saturn development. The Apollo spacecraft will be capable of manned lunar reconnaissance, as a logical step toward future goals of landing men on the moon and the planets; the design of the spacecraft will also be sufficiently flexible to permit its use as an earth-orbiting laboratory, as a necessary intermediate step toward the establishment of a permanent manned space station.

During the fiscal year 1960, initial efforts were made in establishing the long-range objectives of the advanced manned space flight and the rational steps that should be taken to extend manned space flight capabilities beyond those being developed in the nation's initial programs. This work included examination of the interrelation between desired objectives, the limitations imposed by the programmed availability of suitable launch vehicles, the general technological problems confronting the accomplishment of various flight objectives, the existing confidence that such problems could be adequately resolved in time by diligent application of advanced engineering and development techniques, and possible specific approaches to the solution of some of the fundamental problems. Preliminary efforts were also directed to the analysis of specific flight missions and of associated vehicle requirements and concepts that would meet basic objectives while reducing technological uncertainties and long-range cost factors. This work then permitted formulation of general guidelines for proceeding with the detailed development of the Apollo program.

Of great promise is a modular concept for a vehicular system that would be initially utilized for performance of manned orbiting laboratory functions, but would ultimately be capable of manned circumlunar flight and readily adaptable to lunar landing. Such a vehicle might consist of three component modules. The first module could be called the command center, which would house a multimanned crew during launch, serve as the control center during the basic mission, and generally be the only component designed for return with the crew to the earth. To this would be added a propulsion module that would provide the necessary energy for safe return of the command module to earth in the event of an emergency abort of the mission, for mid-course corrections, for lunar-orbit insertion and ejection, for earth-orbit corrections or rendezvous with other satellites, and for reentry corridor control. For later lunar landing missions, the propulsion module would be used to launch the spacecraft from the moon back toward the earth. For circumlunar flights, an additional special purpose mission module would be added to provide the extra life-support and power supply requirements of this mission and the particular laboratory facilities associated with the scientific study of the earth-moon system. For earth-orbiting flight a different special mission module of considerably greater weight-carrying capacity would be substituted that would support the basic needs of the mission and provide for an array of equipment for scientific and technological space experiments, or for pertinent meteorological, communication, observational or related services. In addition, the command center and

propulsion modules might be used together as a unit for special space applications such as the re-provisioning and maintenance of other satellites or the construction and support of future permanent manned space stations.

In the Apollo program it is planned to embody the great flexibility and utility that is inherent in the modular scheme. It is apparent that the use of multipurpose components for a variety of missions should offer significant financial advantage over the provision of comparable capabilities by development of a number of special purpose spacecraft.

The Apollo spacecraft, therefore, will be a versatile vehicle having dual mission capability that will enable man to accomplish important functions in space. The spacecraft will be capable of a variety of scientific and technological services as an earth orbiter, and will also serve as an intermediate step toward the establishment of manned space stations. It will also provide the capability for scientific observation of the earth-moon system through lunar reconnaissance as a logical step toward future goals of landing scientific teams on the moon and the exploration of other elements of the solar system.

In addition to formulating the mission guidelines, intensive research and study programs on many of the technical problem areas of the Apollo program were initiated at the NASA research and space flight centers during the fiscal year 1960.

During the fiscal year 1961, the analytical and experimental investigations undertaken by the NASA centers are being continued. Wind tunnel and free-flight model tests are being made to determine the aerodynamic, stability, loads, and heating characteristics of possible spacecraft configurations. Results of these tests will aid in the selection and design of optimum arrangements, and will permit detailed evaluation of flight performance characteristics. Corresponding investigations are also being undertaken in the areas of structures and reentry heating protection, space navigation, stabilization, flight dynamics control, and landing and recovery.

During this period, three contractors were selected, by competitive bid, to define the characteristics of a feasible manned spacecraft system to meet the Apollo mission objectives. Their investigations will include an analysis of launch, circumlunar, lunar orbit, and reentry trajectories; studies to establish structural requirements imposed by the expected environmental and operational conditions; analyses of the onboard propulsion needs to satisfy mission requirements; evaluations of the effects of radiation on spacecraft occupants; studies to define crew display and flight control requirements; and studies to define the characteristics of environmental control, crew support, power supply, communications, telemetry, guidance, stabilization, control, instrumentation, landing, and recovery systems.

FUNDING REQUIREMENTS:

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Spacecraft Design and Feasibility Studies.....	$100,000	$1,000,000	$2,000,000
Mission Analysis and Simulation:			
Analysis of optimum mission and abort trajectories, and associated flight characteristics.....	---	---	218,000
Mission simulation and evaluation.	---	---	156,000
	---	---	374,000
Loads and Heating:			
Analysis of heat inputs, and means of attenuation or dissipation.....	---	---	24,000
Analysis of configuration aerodynamics.....	---	---	17,000
Wind tunnel and free-flight model tests of aerodynamic characteristics, loads and heating.....	---	---	363,000
Model tests of land and water impacts.....	---	---	48,000
Airdrop test payloads and services for landing system concepts developments.....	---	---	411,000
Rocket models for high Mach number tests of landing system deployment.....	---	---	180,000
Analysis and evaluation of land and water impacts, impact load attenuation, and buoyancy.....	---	---	11,000
Models for launch pad escape system conceptual development tests.....	---	---	275,000
	---	---	1,329,000
Materials and Structures:			
Analysis and evaluation of basic construction methods, and materials.....	---	---	11,000
High temperature and space environmental tests of materials, and structural concepts and components.....	---	---	358,000

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Development of special structures for impact attenuation.....	---	---	$125,000
	---	---	494,000
Radiation:			
Investigation of space radiation and solar flare prediction methods for Apollo mission.....	---	---	127,000
Evaluation of radiation - biology factors, and shielding effectiveness of possible Apollo configurations.....	---	---	52,000
	---	---	179,000
Crew Accommodations:			
Development and evaluation of special pressure suits; support and restraint gear; food, health and survival methods; and bioinstrumentation system.....	---	---	146,000
Evaluation of Systems and Components:			
Guidance, stabilization and control system:			
Analysis and evaluation of guidance and control methods...	---	---	27,000
Simulated pilot displays and control simulation.....	---	---	65,000
Onboard propulsion system:			
Analysis and evaluation.....	---	---	25,000
Vacuum chamber tests of propulsion components.....	---	---	140,000
Environmental control system:			
Evaluation of methods for environmental control.....	---	---	12,000
Environmental testing of systems components.....	---	---	23,000

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Communication and telemetry system:			
Analysis and evaluation of frequencies and special transmission problems.....	---	---	$12,000
Component evaluation.....	---	---	11,000
Instrumentation:			
Development and evaluation of scientific instrumentation....	---	---	85,000
Investigation of operational instrumentation techniques....	---	---	42,000
Power supplies:			
Evaluation of alternate power supply methods.....	---	---	15,000
Power supply component development.....	---	---	17,000
	---	---	474,000
Ground-based Flight Support Methods and Systems:			
Development of requirements for ground monitoring and control of spacecraft flight.....	---	---	23,000
Development and evaluation of tracking and ground instrumentation techniques and equipment for flight support.....	---	---	60,000
Investigation and refinement of spacecraft location and recovery techniques.....	---	---	20,000
	---	---	103,000
Total, Advanced Technical Development.....	$100,000	$1,000,000	$5,099,000

Spacecraft Design and Feasibility Studies

By mid-May, 1961, the three study contractors will have completed the preliminary work of defining the characteristics of the Apollo spacecraft system. Detailed design of the spacecraft and its components, based on the composite findings of the preliminary study, must then be carried out in the fiscal year 1962 in preparation for the start of Apollo spacecraft fabrication the following year.

Mission Analysis and Simulation

Mission trajectories must be analyzed, with particular emphasis on all possible return trajectories for aborted or unsuccessful missions. The analyses will include evaluations of required guidance accuracies and related dispersions. Complete missions will be simulated on analog computing devices.

Loads and Heating

Because the heating problem is far greater for reentry from circumlunar flight than for reentry from satellite missions, important extensions of technology in the area of aerodynamic heating and on means of attenuating or dissipating the expected heat inputs will be required. Analyses of aerodynamic characteristics such as loads and stability parameters must be made. Extensive wind tunnel and free-flight model testing will be carried out to complement these analytical investigations.

Landing impacts on both land and water, impact load attenuation, buoyancy, and hydrodynamic stability, are problems of considerable concern for vertical-landing manned flight. These problems will be studied analytically and experimentally through the use of small-scale model tests in ground facilities and larger-scale models to be released from aircraft and helicopters. The loads associated with the all-important pilot escape system must be similarly investigated, both analytically and experimentally.

Materials and Structures

The expected high levels of reentry heating will impose severe requirements on the spacecraft's structure. The structure must not only be able to withstand the space environment, and the attendant hazards such as meteorite and radiation damage, but also must survive the loads of a launching, and the loads and heating of reentry. Alternate concepts of structural design and various materials and components must, therefore, be evaluated and tested in high temperature and vacuum facilities.

Radiation

In the Apollo mission, three types of radiation will be encountered: trapped radiation in the Van Allen radiation belts; cosmic radiation; and solar flare particles. The trapped radiation in the Van Allen belts is of rather high intensity but of sufficiently low energy to make shielding feasible. The energies of cosmic radiation, on the other hand, are so high that shielding becomes impractical. However, the peak intensity is sufficiently low that no danger is anticipated in a circumlunar flight.

The most serious problem results from the particles generated by some solar flares. The energy of these particles is of a magnitude that may require more shielding than is practical from the standpoint of weight; following a major flare, the intensity may be so high as to cause severe biological damage. However, there are some indications that it will be possible to predict major flares, or at least their absence, several days in advance, thus allowing missions to be scheduled during relatively safe periods.

In order to attack these problem areas as specifically related to the Apollo mission, studies must be supported to evaluate radiation-biological factors and to establish reliable solar flare prediction methods.

Crew Accommodations

The further development and evaluation of special pressure suits will be undertaken; reliable garments with proper provisions for quick donning, and with proper mobility for use both within and outside the spacecraft, will be required. Special pilot support and restraint gear, food, health and survival methods, and bioinstrumentation systems must be studied.

Evaluation of Systems and Components

A spacecraft as complex as the Apollo craft will require the judicious selection of many systems and components; these systems must be exceedingly reliable, sufficiently light, and compatible with operation in many environments.

It will be necessary to evaluate, on a continuing basis, new technological developments as they become available in an effort to develop, ultimately, the most efficient and reliable spacecraft. For example, guidance and control methods must be investigated and components must be evaluated as they become available. Similarly, many different approaches to the dynamic pilot display system must be simulated for proper evaluation. Onboard propulsion environmental control, communications, instrumentation, and power supply systems must all be evaluated.

Ground-based Flight Support Methods and Systems

A basic requirement for all future manned space missions is that the primary command of the mission be on board the spacecraft. However, there will be a need for nearly continuous communication, and for exact tracking, to provide a reference for the onboard systems. A study must be made to determine the detailed requirements for ground monitoring and control with a view toward maximum utilization of existing facilities. New techniques for monitoring and flight control

during the critical reentry phase will have to be developed. In view of the world-wide aspects of these flights, it will be necessary to develop new techniques for the location and recovery of the spacecraft after emergency landing.

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Developmental Spacecraft for Short-Range Ballistic Flight Tests, using Little Joe Booster:			
Design and engineering.....	---	---	$700,000
Component and subsystem development.....	---	---	360,000
Spacecraft construction.....	---	---	389,000
Systems integration.....	---	---	51,000
Rocket and airframe procurement..	---	---	400,000
	---	---	1,900,000
Orbital Flight Tests:			
Component and subsystem development.....	---	---	1,585,000
Spacecraft construction.....	---	---	2,604,000
Systems integration.....	---	---	411,000
Atlas launch vehicles.....	---	---	1,200,000
	---	---	5,800,000
High-Speed Reentry Tests:			
Design and engineering.....	---	---	3,274,000
Component and subsystem development.....	---	---	2,175,000
Spacecraft construction.....	---	---	1,600,000
Systems integration.....	---	---	522,000
Atlas-Agena launch vehicles.....	---	---	8,200,000
	---	---	15,771,000
Developmental Spacecraft for Saturn High-Speed Reentry Tests:			
Design and engineering.....	---	---	800,000
Operations and Services:			
Spacecraft preflight preparation.	---	---	30,000
Spacecraft launch handling equipment	---	---	100,000
	---	---	130,000
Total, Flight Program.....	---	---	$24,401,000

The initial phase of the Apollo flight program will consist of research and development flights using Little Joe, Atlas, Atlas-Agena-B, and Saturn launch vehicles. Ultimately, flights of production spacecraft using the Saturn launch vehicle will be made. In the fiscal year 1962, construction of the spacecraft for the research and development flights will be started and the funding for launch vehicles for these flights will be initiated. Spacecraft and launch vehicles are incrementally funded during the fiscal year 1962.

Developmental Spacecraft for Short-Range Ballistic Flight Tests

One of the most critical times in the launching of a manned vehicle, from the standpoint of pilot safety and spacecraft recovery, comes during the initial phases of the launch trajectory. At this time the aerodynamic drag is very high, and it becomes exceedingly difficult to execute a safe and controlled escape maneuver. The very large launch vehicles required later in the flight program will not be needed to duplicate this phase of the flight trajectory. Reasonably small vehicles, such as Little Joe, can be used for this simulation. Three Little Joe flight tests are required to develop and test the Apollo escape system under conditions of high aerodynamic pressures. These tests will also aid in the development of a capable landing system. In the fiscal year 1962, the design and construction of the spacecraft for these tests will be undertaken, and three of the Little Joe rockets and airframes will be ordered. Flight testing will start in the fiscal year 1963.

Orbital Flight Tests

The Apollo spacecraft will require many new developments, including practical methods for accomplishing onboard attitude and position referencing, stabilization, velocity vector control, and energy management in normal and emergency trajectories. Although many of these developments will be supported by laboratory tests, flight testing will also be required. For the purpose of developing satisfactory man-machine systems, prototypes of such systems will be flight-tested aboard Mercury capsules.

Construction of these capsules will be initiated in the fiscal year 1962, and required components for the complete integration of man-machine systems will be developed. Two flight tests are planned for the fiscal year 1963, with five additional flights scheduled for later years. Atlas launch vehicles for these flights will require initial funding in the fiscal year 1962 because of the lead time required.

High-Speed Reentry Tests

When a spacecraft returns from the moon, it will enter the earth's atmosphere at a velocity of about 25,000 miles per hour, or nearly one and one-half times the speed of a reentering satellite. Reentry at this high velocity, referred to as parabolic velocity, causes new and severe spacecraft heating problems which must be investigated experimentally. Because laboratory facilities cannot yet completely simulate this condition, flight-testing is necessary.

The Atlas-Agena-B launch vehicle and reduced scale models of Apollo spacecraft will be used for these tests. This launch vehicle has the capability of boosting relatively large-scale developmental spacecraft to parabolic velocity. During the spacecraft's reentry, measurements of heating and stability characteristics will be made. Recovery of the model is planned because of the importance of post-flight inspection and materials analysis.

In the fiscal year 1962, the design, engineering and fabrication of these developmental spacecraft will be initiated. Two flight tests are planned for the fiscal year 1963, and two tests will be performed in the following year. Initial funding for the Atlas-Agena launch vehicles will be required in the fiscal year 1962.

Full-Scale Developmental Spacecraft for Saturn High-Speed Reentry Tests

In the fiscal year 1964-1965 time period, full-scale parabolic reentry tests, using the Saturn launch vehicle, will be undertaken. These tests will be used to verify the external aerodynamic and structural design of the final command center or reentry module. Reentry at parabolic velocity along various flight paths in the entry corridor will be accomplished. In order to meet the long lead times required for Saturn spacecraft, the design and engineering phase for these spacecraft must be carried out in the fiscal year 1962.

Operations and Services

Initial preparations for the flight missions utilizing the Little Joe, Atlas, and Atlas-Agena-B vehicles will be made in the fiscal year 1962. Special handling equipment required at the launch sites will be purchased.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

LAUNCH VEHICLE TECHNOLOGY

SUMMARY OF REQUIREMENTS:

	1960	1961	1962	Page No.
Systems.....	---	$3,392,000	$5,150,000	RD11-2
Components.....	---	2,703,700	5,450,000	RD11-3
Supporting Effort.....	---	3,004,300	4,400,000	RD11-4
Total.....	---	$9,100,000	$15,000,000	

OBJECTIVES:

To advance the technology that will be required to support future launch vehicles; to solve technical problems faced by launch vehicles that are now being designed; and to examine alternate design concepts and systems to accomplish space missions.

JUSTIFICATION:

The design and development of any complex system presupposes the existence of a large body of theory, extensive knowledge of material properties, the appropriate structural techniques and the "know-how" to develop the necessary sub-systems. Generally, this information can be obtained from a variety of technical sources; however, in the field of rockets the rate of progress is so rapid that in many areas the background of basic technology has been outdistanced by requirements for specific developments. In order to meet the long-range goals of manned flights, lunar orbits and landings, and eventual planetary missions, the basic technology must keep pace with advancing vehicle concepts. The lack of such data could result in a temporary stoppage of multi-million dollar projects with an inevitable sacrifice of dollars and time.

The long lead times associated with the development of launch vehicle systems require that basic technology be available well in advance of the design of a particular vehicle. For example: an improved guidance system will be required by the very long transit times associated with planetary flights; sensors, communication systems and power supplies must be improved to survive prolonged operating times; very large vehicles pose problems in materials and fabricating techniques and in the fluid motion of the propellant within large tanks; computer studies are needed on lunar and planetary trajectories; and aerodynamic forces and aero-heating effects must be investigated

for advanced vehicle designs. In addition, the relative size of stages for advanced vehicle designs must be studied to determine optimum sharing of propellant between stages.

In connection with the solution of technical problems now faced by current vehicles, the demands for results are immediate. Problems of providing instrumentation and data for multi-barrelled engines, the motion and state of liquefied gaseous propellants after long periods of free-fall, sloshing of propellants in large diameter booster tanks, are but a few of the areas that are being supported. These types of problems characteristically arise during the design phase of a vehicle and must be solved before the design and development stage can proceed.

Alternate ways of performing space missions must be examined to determine, for example, whether it is economically more feasible to refuel a manned lunar vehicle in orbit (or assemble the vehicle in orbit) than it is to fire directly from the surface of the Earth; or, in the area of flight control, to determine whether or not a forward or "canard" set of control jets may be a better design solution than attempting to swivel the very large rocket engines that are now being built.

The 1962 effort in this program will be geared to current and growth versions of the Saturn and to the advanced vehicle systems that are now contemplated. A major task will be the establishment of vehicle design requirements that are being generated by advancing technology in the related fields of propulsion, space flight, and launch operations.

FUNDING REQUIREMENTS:

Systems	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Advanced Vehicle Design.....	---	$2,332,000	$3,600,000
Orbital Operations.....	---	1,060,000	1,550,000
Total, Systems.....	---	$3,392,000	$5,150,000

Advanced Vehicle Design

This area provides for conceptual and preliminary design of advanced vehicles, stage size studies, studies of logistic and economic aspects of launch vehicle systems. In addition, operational analyses will be performed to provide objective guidance for future planning. In the fiscal year 1962, for example, studies will be made aimed at a 2- to 3-million pound thrust launch vehicle concept, lunar transportation systems, and vehicle configuration requirements based on the concept of clustering the 1.5 million pound thrust F-1 rocket engine.

Orbital Operations

Included here are analytical study and investigation of problems relating to orbital rendezvous, orbital launch, vehicle refueling, assembly and transfer in orbit. Knowledge in this area is prerequisite to the development of vehicles which will be capable of meeting long-range interplanetary flight goals.

Components	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Structures and Mechanics.....	---	$1,508,700	$2,800,000
Guidance and Control.....	---	1,195,000	2,650,000
Total, Components.....	---	$2,703,700	$5,450,000

This area covers design investigations of electrical and electronic parts, improvement of material properties, effect of space environment on material properties, and the development of specific component items and assemblies to meet existing and anticipated space requirements.

Structures and Mechanics

Investigations to determine radiation effects and spectral emissivities, for determination of material properties, development of new materials for space application, and the design, development, and testing of vehicle components for orbital rendezvous. Among studies to be conducted in fiscal year 1962 are: evaluation of hemispheric and spectral emissivities of selected materials; study of radiation effects at extremely high rates of irradiation; determination of thermal properties of materials at temperatures ranging from -250°C to +1500°C; development of inorganic polymers and adhesives for use as sealants at high and low temperatures; and development of automatic fuel line couplings, fuel transfer equipment, and mechanical links for orbital rendezvous operations.

Guidance and Control

This area includes improvements to and the development of telemetry transducers, gyros, accelerometers, and other vehicle components as required to meet new space environments and conditions. Effort will be placed on: development of cryogenic accelerometers; miniaturization and reliability improvement of missile borne heavy-duty electrical contactors; small, lightweight, pressure transducer development; development of digital input-output devices; and lateral photocell techniques applied to position sensing of a space vehicle in three axes.

Supporting Effort	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Aeroballistics.....	---	$940,000	$1,500,000
Fabrication.....	---	514,300	700,000
Computation and Data Processing...	---	1,325,000	1,300,000
Instrumentation.....	---	225,000	400,000
Total, Supporting Effort.....	---	$3,004,300	$4,400,000

This area includes investigations and developments that will support the System and Component areas or will have broad functional application to the overall field of vehicle development, as follows:

Aeroballistics

Work is conducted here on aerodynamic and ballistics theory, aeroheating effects, trajectories, and real-time computer evaluations. Examples are: adaptive control studies, statistical trajectory studies; basic empirical wind shear investigations, aerodynamic effects of fuel sloshing, and real-time computer evaluation of test data.

Fabrication

This includes techniques, process, methods and specialized equipment for the fabrication and assembly of space vehicle structures. Examples are: the development of tooling concepts for large diameter tanks, the basic study of electrical discharge phenomena as related to metal forming, and the study of techniques for forming stainless steel elements to 100,000 pounds per square inch yield strength level.

Computation and Data Processing

This includes the development of improved methods for reduction of flight data and for the application of data processing techniques to the requirements for test, analysis and automatic check-out of vehicle systems. Examples are studies of: Doppler data reduction techniques; investigation of methods and techniques applicable to automatic or semiautomatic instrumentation and testing in the area of radio frequency systems, measuring systems, electronic components, and electrical wiring systems; design and development of high-speed digital computers for simulation of flight conditions; and the development of a digital incremental function generator for use in flight simulation and other computation problems.

Instrumentation

The development of specialized instrumentation equipment and component testing methods is carried on under this heading. The 1962 estimate provides for the development of densitometers for liquid hydrogen, for automatic pressure calibration system development, and for development of an end-to-end automatic thrust calibration system.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

LAUNCH OPERATIONS DEVELOPMENT

SUMMARY OF REQUIREMENTS:

	1960	1961	1962	Page No.
Launch Operations Studies.....	---	$100,000	$500,000	RD12-2
Advanced Instrumentation.....		---	1,000,000	RD12-2
Total.....	---	$100,000	$1,500,000	

OBJECTIVES:

To analyze operational requirements and to provide advanced ground instrumentation for launch vehicle operations. Analysis of launch operations requirements will be concerned with the determination of the most desirable sites for launching nuclear and very large vehicles, definition of problem areas which must be dealt with in launch operations from various sites, and proper sequential modifications of the various NASA launch complexes in future years. Advanced instrumentation relates to measuring, tracking, ground telemetry, timing, data reduction and analysis, and over-all launch complex instrumentation.

JUSTIFICATION:

A continuing requirement exists to modify and improve existing launch operations equipment and to develop new devices or techniques in parallel with advances in vehicle technology. This work must take the form of hardware development and a variety of analytical studies.

The hardware effort will be aimed at satisfying the unique requirements imposed by current and near future vehicles and will take the form of advanced instrumentation dealing with telemetry, measuring, tracking, and data reduction. Specific items will include optical devices, telemetry equipment and a frequency reference station.

In the analysis and study area, the major effort will be directed toward advanced planning to meet future vehicle requirements. The advent of more sophisticated vehicle systems, and the resultant need for massive, complicated and expensive launch complex installations has created an urgent demand for the best possible planning approach in this area.

FUNDING REQUIREMENTS:

Launch Operation Studies	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Launch Equipment Studies.....	---	$100,000	---
Launch Safety Studies.....	---	---	$500,000
Total, Launch Operation Studies	---	$100,000	$500,000

Launch Equipment Studies

Studies in the fiscal year 1961 are aimed at the general aspects of reliability with particular emphasis on standardization of ground support equipment. The reliability phase will determine the interfaces between manned and automatic functions and the resulting effect on design, test, inspection, transportation, and operations at the launch site. Ground support equipment standardization study will determine the interchangeability of expensive ground support equipment between programs with a view toward possible simplification.

Launch Safety Studies

In the fiscal year 1962, advanced vehicle concept and nuclear upper stage studies will be conducted to enable a definition of site requirements in sufficient detail to provide a basis for launch site selection. In view of the size, complexity, and possible remoteness involved in the launch operations of such advanced vehicles, it is estimated that, if additional sites are required, as much as one year will be needed for topographical surveys and site selections with additional time required for facility design. Launch site selection and ensuing site construction must be initiated in sufficient time to insure timely completion of the required launch facilities. Completion of the subject study is required early in the calendar year 1962.

Advanced Instrumentation	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Development of Optical Equipment and Devices.....	---	---	$475,000
Development of Telemetry Equipment..	---	---	275,000
Offset Frequency Reference Station..	---	---	250,000
Total, Advanced Instrumentation	---	---	$1,000,000

Advanced instrumentation that is oriented specifically to NASA missions is required: to provide automatic optical tracking; to permit real-time telemetered parameters during launches with self-checking and fail-safe features; and to develop a frequency reference station for the ultra-high frequency Doppler system for tracking offset transponders of the Ranger type. This improved instrumentation is required in the fiscal year 1962 to permit adequate and properly calibrated data to be made available for development of the Saturn vehicle.

Development of Optical Equipment and Devices

Improved optical instrumentation is required to provide light sources with greater intensity than existing systems and to provide flash devices with considerable reduced on-board weight as a primary tracking device and for use in the calibration of electronic tracking systems. A major objective during the fiscal year 1962 will be to develop a light source with a 50 percent increase in intensity over those presently available.

Development of Telemetry Equipment

During the fiscal year 1962, experimental tracking antennas will be developed for the reception of ultra-high frequency telemetry that will be used when the very high-frequency telemetry band is vacated in 1970. The ultra-high-frequency transmitting equipment which will be developed under other programs will require these antennas during the experimental period of operation.

New equipment and techniques will be developed in the fiscal year 1962 for reliable real-time display of telemetered parameters for launches that require instantaneous decisions on the ground. To ensure crew safety, the new equipment will be designed to incorporate self-checking and fail-safe features. In addition, provisions will be made for reliable demodulation equipment related to single side band telemetry systems, as will be utilized with future Saturn vehicles.

Offset Frequency Reference Station

This item will provide a synthesized reference signal as required for the advanced transponders that will be used in the Ranger-type spacecraft. The combination of reference signal and the advanced vehicle transponder is designed to achieve greater accuracy for determining vehicle position by minimizing the effect of ionospheric refraction. Development of the basic hardware will be initiated in fiscal year 1962 for delivery in fiscal year 1963.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

SPACECRAFT TECHNOLOGY

SUMMARY OF REQUIREMENTS:

	1960	1961	1962	Page No.
Advanced Research.....	$4,019,349	$7,875,000	$10,360,000	RD13-2
Total.....	$4,019,349	$7,875,000	$10,360,000	

OBJECTIVES:

The objectives of this program are to obtain research data, to develop advanced techniques, and to demonstrate the feasibility of improved materials, components, subsystems, and systems which can be applied in future spacecraft.

JUSTIFICATION:

The successful accomplishment of an ambitious program of space exploration will require the development of spacecraft which embody major advances in the state of the art of materials, structures, components and subsystems. In many cases, spacecraft designs must be established with a minimum of new concepts or unproven components in order to assure mission reliability. The basic objective of the Spacecraft Technology program is to provide a demonstration of the feasibility of new and improved materials components, and techniques, in order that they may be incorporated in future spacecraft which will be able to perform their functions more adequately and reliably with minimum weight.

The program objectives will be achieved by a combination of research, development, and testing in ground facilities, supplemented by flight testing of components and subsystems as engineering test payloads on test vehicles which are primarily intended for launch vehicle development.

The program is being conducted by a combination of in-house effort at the Jet Propulsion Laboratory, supplemented by a program of contracting with industry, institutions, and universities.

FUNDING REQUIREMENTS:

Advanced Research	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Spacecraft Materials and Structures:			
Materials research.....	$254,000	$833,000	$950,000
Structures research.....	300,000	107,000	200,000
	554,000	940,000	1,150,000
Spacecraft Chemistry and Physics:			
Chemistry and chemical physics.....	---	918,000	1,015,000
Physics research.....	157,900	960,000	1,100,000
Fluid mechanics and thermodynamics research.....	---	103,000	130,000
Gas dynamics research.....	---	619,000	655,000
	157,900	2,600,000	2,900,000
Guidance and Control:			
Sensors and actuator research.....	364,800	242,000	330,000
Guidance systems research.....	1,169,349	107,000	270,000
Digital control devices research...	---	173,000	400,000
Cryogenics research.....	45,000	138,000	400,000
	1,579,149	660,000	1,400,000
Environmental Simulation and Laboratory Instrumentation Research....	78,000	240,000	500,000
Data Handling, Reduction, Analysis, and Computation:			
Digital data systems research.....	213,300	424,000	500,000
Research in analytical techniques and systems analysis.....	150,000	183,000	250,000
Scientific data processing research	---	105,000	150,000
Research in basic numerical analysis techniques.....	---	88,000	100,000
	363,300	800,000	1,000,000
Spacecraft Wind Tunnel Testing and Program Support.....	1,287,000	2,635,000	2,710,000
Engineering Research in Space.....	---	---	700,000
Total, Advanced Research.....	$4,019,349	$7,875,000	$10,360,000

Spacecraft Materials and Structures

The research being conducted on spacecraft materials and structures includes the determination of properties of high-temperature refractory metals, ceramics, graphites, and ablation materials; the effects of laboratory vacuum and high temperature on organic materials and lubricants; and the development of analytical methods for use in the design of spacecraft structures. This effort will be broadened in the fiscal year 1962 to include research on improved structural materials, electronic materials, improved thermal insulation materials, and surface coatings with desired values of absorptivity for solar radiation and emissivity for thermal radiation.

Spacecraft Chemistry and Physics

The research being conducted on spacecraft chemistry and physics includes studies of the microwave spectra of gases, the kinetics of chemical reactions and combustion, the effect of molecular forces on viscosity of liquids, the synthesis of high-energy chemical compounds, research on analytical chemistry methods, stability problems in fluid mechanics, turbulence in gas dynamics, low-density gas dynamics, and studies of the physical properties of ionized gases and plasma and magneto-fluid-dynamics.

The program planned for the fiscal year 1962 will continue these research projects and will provide for additional research in chemical physics, solid state physics, radiation chemistry, and the use of radioactive tracer techniques to study chemical reactions.

Guidance and Control

A major effort on guidance systems research was conducted in the fiscal year 1960. The funding level is lower in the fiscal year 1961 as a result of initiation of major spacecraft development programs, but the funding should be increased in the fiscal year 1962 to provide basic guidance and control capability for future spacecraft. The efforts presently underway in guidance and control include research on infrared and optical sensors, servo-actuators, digital control devices and inertial devices including gas-bearing, electrostatic and magnetic suspension of spherical flywheels and research on the cryogenic gyro for orientation reference and control. The funds for the fiscal year 1962 will provide for continuing and expanding these research projects and for conducting research on guidance computers, inertial components, and attitude control devices.

Environmental Simulation and Laboratory Instrumentation Research

The research being conducted in this field includes studies and research on methods for simulating space environmental conditions and development of unique instruments and transducers for use in spacecraft research projects. The funds for the fiscal year 1962 will provide for an expanded effort to devise new and more economical means for simulating space environmental conditions, particularly the simulation of uniform, parallel

rays of sunlight having the proper spectral distribution for operation in space vacuum chambers. Additional research will be conducted on the simulation of meteoroid penetration phenomena and space radiation damage.

Data Handling, Reduction, Analysis, and Computation

The research presently underway in this field includes the investigation of new and improved methods for processing mathematical data by means of digital computers, the preparation of computer programs, and the use of analog and digital computers to support research projects in spacecraft technology. This research is directed primarily toward the improvement of spacecraft equipment rather than ground equipment. The funds for fiscal year 1962 will provide for continuation and expansion of this effort.

Spacecraft Wind-Tunnel Testing and Program Support

This effort is being devoted to aerodynamic, heat transfer, and stability testing of spacecraft models to simulate conditions of flight in the atmospheres of earth or the planets. Studies are also conducted on the properties of the plasma sheath which is formed around a spacecraft at hypersonic speed, and which affects radio signal propagation. The funds requested for the fiscal year 1962 will provide for the continuation of test operations in various wind-tunnel facilities, including the Jet Propulsion Laboratory hypersonic tunnel.

Engineering Research in Space

The difficulty in providing an adequate simulation of the combined space environment during ground testing of spacecraft components, makes it more economical in certain cases to conduct engineering research experiments in the actual space environment. This is particularly true when a space experiment can be devised which is light in weight, relatively inexpensive to develop, and when it can be carried without interference in spacecraft which are flown for other purposes. Beginning in the fiscal year 1962, it is planned to initiate the preparation of two types of engineering experiments which will later be flown as "piggy-back" payloads in spacecraft which are primarily intended for vehicle testing but which can carry additional experiments. The two flight experiments for which funding will be initiated in the fiscal year 1962 are:

1. Performance testing of experimental solar photovoltaic cells, transistors and other electronic components in the proton and electron fluxes of the Van Allen belts, in order to evaluate the performance of new or improved designs and to verify the results of radiation damage experiments conducted in particle accelerator facilities on the ground.

2. Measurement of the long-time stability of the values of absorptivity for solar radiation and emissivity for thermal radiation of special spacecraft surface coatings which will be exposed to space vacuum, meteoroids and plasma bombardment. This experiment is required to permit the rational design of thermal control systems for long duration spacecraft.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

SOLID PROPULSION

SUMMARY OF REQUIREMENTS:

	1960	1961	1962	Page No.
Advanced Systems and Components.....	$1,720,000	$1,300,000	$3,100,000	RD14-2
Total.....	$1,720,000	$1,300,000	$3,100,000	

OBJECTIVES:

The purpose of this program is to establish, on an experimental basis, the background that will permit exploitation for space vehicle use of the high reliability, simplicity, and economy which are intrinsic to solid propellant engines. Advanced techniques will be utilized to make possible very high performance solid rockets for upper states. Techniques will also be developed for improving the utility and versatility of solid propellant rockets by devising advanced methods for vectoring, modulating, and terminating thrust. Studies and experimental programs will be conducted to determine the specific application of solid propellant motors as a first stage, high-thrust booster.

JUSTIFICATION:

Solid propellant rockets have many potential advantages. From a manufacturing and logistic point of view, the following characteristics are significant: (1) solid propellant motors are extremely simple in design, since they contain no complex components nor moving parts; (2) the complete loaded motors are prepared at the manufacturing plant, can be shipped easily and safely by common carriers, and no further loading or preparation at the launch site is required; (3) the propellants are non-toxic, non-corrosive, and non-explosive, and can be made from materials easily available in large quantities at a low price by basically simple processes; and (4) the loaded motors can be stored on the ground for extended periods of time and remain ready for immediate use with no further preparation. As a result of these characteristics, the solid rocket enjoys a relatively low development and manufacturing cost with a high degree of reliability in operation.

From a performance standpoint, solid propellant rockets also have characteristics which can be exploited to great advantage. The high density of solid propellants and the high volumetric loading in the motors result in a very high ratio of propellant to inert weight. This characteristic is particularly desirable for upper stages. The thrust level and burning time of solid propellant motors can be varied over a considerable range as desired so that the losses involved in overcoming the effects of gravity and air drag are minimized for initial stages. In addition, solid rockets possess quick and reliable ignition characteristics and simple thrust reversal capabilities.

The proposed program will aim at improvement in the general state-of-the-art of solid rockets with emphasis on application of the performance, reliability, and logistic advantages of solid rockets for NASA missions. In the area of basic propellants, NASA will rely on the results obtained from research and development programs conducted by the Department of Defense.

FUNDING REQUIREMENTS:

Advanced Systems and Components	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Large Motor Technology.....	$370,000	$250,000	$420,000
High Mass-Fraction Motors.....	830,000	450,000	980,000
Thrust Vector and Velocity Control and Modulation.....	372,000	260,000	1,100,000
Improved Motor Materials, Fabrication Techniques, and Space Environment Studies.....	148,000	340,000	600,000
Total, Advanced Systems and Components.....	$1,720,000	$1,300,000	$3,100,000

Large Motor Technology

This area of endeavor is designed to investigate the engineering feasibility, and probable development cost, of solid rocket motors with thrust levels of 1- to 2-million pounds. In the fiscal year 1961, studies were initiated to define the dimensions and structure of these motors, and to give rough estimates of mission capabilities. Small-scale experimental programs were also conducted to investigate the concept of a tapered, segmented structure (through sub-scale firing) as a design approach for very large motors. In the fiscal year 1962 a detailed design study will be made of a specific vehicle using a cluster of solid motors in the first stage with a combined thrust totalling approximately 15-million pounds. The

experimental program will continue the investigation of the segmented motor, will examine the problems in clustering solid motors, and will investigate the feasibility of fiberglass structures for large motor cases. This phase of the program reflects the growing importance of the large solid booster concept, and the growth of sub-scale experimental work to prove new concepts.

High Mass-Fraction Motors

Experimental development in the high mass-fraction motors (high ratio of propellant to inert weight) was initiated in the fiscal year 1961 and will be continued in the fiscal year 1962. Effort will be concentrated on refinement of the basic designs and utilization of the best propellants. Lightweight nozzle configurations investigated in prior years will be adapted to lightweight chambers for final evaluation. Nozzle weight reduction is a particularly fertile area for improving mass-fraction because of the disproportionate amount of inert weight that exists in the current nozzles. Funding in this area covers manufacture of full-scale flight-quality motors and components, costs incidental to flight test evaluation, and the initiation of new studies on low pressure systems.

Thrust Vector and Velocity Control and Modulation

Two of the steering and velocity control systems investigated in the fiscal year 1961 will be ready for flight tests in the fiscal year 1962. Other vectoring techniques, such as secondary injection (injection of a fluid into the nozzle expansion cone, forming a shock wave and diverting thrust), will be well established by the fiscal year 1962 and adaptations to flight design motors will be initiated. For thrust modulation, the acoustical concept (injection of sound waves for varying thrust), will be pursued, and hybrid motors will be studied.

During the fiscal year 1962 a number of the programs will reach the stage of flight testing, the very early work on the acoustical system will grow to include larger motors, and new applications of fluid injection will be investigated. The requested increase is geared to this expanded level of effort.

Motor Materials, Fabrication Methods, and Space Environment Studies

Studies of methods for fabricating extremely large first-stage solid rockets will continue in the fiscal year 1962. Space environment studies will also continue to determine whether or not any degradation occurs when solid rocket motors and propellants are exposed to long-term space storage. Work towards solution of the problems resulting from these studies also will be initiated. Other studies will relate to improvements in the high temperature and gas erosion resistance of construction materials.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

LIQUID PROPULSION

SUMMARY OF REQUIREMENTS:

	1960	1961	1962	Page No.
Prototype Development:				
1,500,000 pound thrust engine.....	$24,217,000	$40,000,000	$42,320,000	RD15-2
200,000 pound thrust engine.....	1,700,000	15,000,000	28,700,000	RD15-4
Advanced Systems and Components.....	1,300,000	2,000,000	7,000,000	RD15-6
Total.....	$27,217,000	$57,000,000	$78,020,000	

OBJECTIVES:

To develop liquid propellant rocket engines of improved reliability and performance as necessary to support launch vehicle development; to anticipate requirements for space operations involving rendezvous between vehicles, lunar orbiting and landing operations, and extended duration flights to planets or deep space; and to undertake the required advanced design and experimental investigations so that the basic technology will be available when specific equipment developments are needed.

JUSTIFICATION:

The liquid propellant rocket engine is currently the principal propulsion device for launch and maneuver of space vehicles. Since NASA objectives in space exploration are pointed towards manned operations in space, improved propulsion systems of greater thrust, improved reliability, better performance, and lower cost will be required. For booster vehicles it is NASA's intent to provide a small number of appropriately sized engines to meet these requirements.

The prototype development part of this program includes two engines in the fiscal year 1962: the 1,500,000-pound thrust liquid oxygen-RP-1 engine for booster application; and the 200,000-pound thrust hydrogen-oxygen engine for general purpose upper stage use.

The 1,500,000-pound thrust engine will be clustered to provide the extremely high thrust vehicles required to launch manned spacecraft and to conduct manned lunar explorations. Development of the engine is being performed by Rocketdyne, a division of North American Aviation, Inc., under the technical direction of the Marshall Space Flight Center. Design and fabrication is accomplished at the Rocketdyne plant in Canoga Park, California; component test operations are conducted at the Santa Susana, California facility of Rocketdyne; and engine tests are run on test facilities provided at Edwards Air Force Base in California. The current development program is aimed at completion of preliminary flight rating tests during the calendar year 1963 with completion of engine qualification by the early part of the calendar year 1965. The level of funding requested for this project during the fiscal year 1962 is required to assure that this development schedule will be maintained. A limited portion of these funds will be spent on long-lead-time hardware procurement for the qualification program.

The 200,000-pound thrust hydrogen-oxygen engine is a general-purpose, high specific impulse rocket engine that will be used in upper stages of advanced vehicles, and is specifically planned for use in the second stage of the Saturn C-2 configuration. The 200,000-pound thrust engine project is also being developed by Rocketdyne under the technical direction of the Marshall Space Flight Center. The development program is scheduled to complete preliminary flight rating tests in the calendar year 1963 and qualification of the engine in the calendar year 1964. With this stage, the Saturn payload capability can be more than doubled in earth orbits and tripled for missions to the moon.

FUNDING REQUIREMENTS:

Prototype Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
1,500,000-Pound Thrust Engine:			
Design	$500,000	$430,000	$415,000
Component development	12,215,000	17,150,000	8,770,000
Component test	2,188,000	4,450,000	7,490,000
Engine development	5,145,000	9,725,000	9,882,000
Engine test	---	2,125,000	7,178,000
Fabrication and test equipment	2,969,000	3,820,000	3,765,000
Propellants	1,200,000	2,300,000	4,500,000
Propellant transport equipment	---	---	320,000
Total, 1,500,000-Pound Thrust Engine	$24,217,000	$40,000,000	$42,320,000

The development of the 1,500,000-pound thrust engine thus far has progressed through design and preliminary component tests. Engine tests, supported by experimental testing programs on each component, will be conducted during the fiscal year 1962 at a rate of approximately one test per day.

Design

This area covers primary engineering design of all components of the engine and the integration of these components into a complete system. Design work during 1962 will be concentrated on detailing engineering modifications resulting from improved fabrication procedures and from test program results. In addition, this area will provide for design modifications resulting from vehicle application studies.

Component Development

The major engine components are the thrust chamber, turbopump, gas generator, and the engine valves and controls. Each component in turn, comprises several subassemblies. For example, the turbopump consists of two large high-pressure centrifugal pumps and a two-stage turbine mounted on a single shaft. The design, fabrication, and test of components will continue throughout the engine development program. The component development costs in the fiscal year 1962 include engineering supervision, purchase of materials, tooling for shop support, fabrication labor and supervision. Additional component development will be required to incorporate modifications indicated desirable by vehicle design and application studies.

Component Test

Experimental testing is required for each major engine component, wherein each component is subjected to a planned series of tests that will generally continue throughout the life of the engine development program. Funding during the fiscal year 1962 will include the cost of test materials (not including propellants), test labor and supervision, data reduction and analysis, and the preparation of engineering reports.

Engine Development

This area covers engineering and fabrication of the complete engine system and includes the cost of materials, engineering shop supervision, fabrication and assembly labor, and inspection and quality control. By the end of the fiscal year 1961 three engine systems will have been assembled. Seven additional assemblies will be completed during the fiscal year 1962 with the requested funds. To assure the engine development schedule, it will be necessary to increase the test hardware inventory and provide funds for rebuilding engine equipment damaged or worn during testing operations. In addition, long-lead-time hardware items will be purchased in anticipation of the engine qualification test program beginning in the fiscal year 1963.

Engine Test

Funds are included for the cost of complete engine system testing to be conducted on stands 1-A and 1-B at the Edwards Air Force Base in California. Testing will include the actual test run, data reduction, test analysis and the preparation of engineering reports. The engine development and testing program will reach its maximum activity during the fiscal year 1962 with test runs reaching an approximate rate of one test per day.

Fabrication and Test Equipment

Fabrication and test equipment covers the cost of special instrumentation, fabrication machinery and tooling required for manufacture and test of the engine and its components. Specific items include gaging and inspection equipment, systems handling jigs and transport equipment, instrumentation and expendable materials for test. Since many of the items are subjected to wear, deterioration or obsolescence, continuing replenishment will be required during the fiscal year 1962.

Propellants

Liquid oxygen, liquid nitrogen and other propellants will be obtained through Air Force procurement channels for use in engine component and engine system testing. Approximately 80,000 tons of liquid oxygen and nitrogen and approximately 6,000,000 gallons of kerosene will be used during the fiscal year 1962.

Propellant Transport Equipment

During the fiscal year 1962, the NASA demand for propellants to support the F-1 development program will exceed the propellant handling capability now provided by the Air Force. The funds requested will provide for six truck transport trailers that are equipped with insulated vessels for handling cryogenic propellants.

Prototype Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
200,000-Pound Thrust Engine:			
Design	---	$585,000	$200,000
Component development	---	4,415,000	4,730,000
Component test	---	910,000	4,050,000
Engine development	---	490,000	2,600,000
Engine test	---	---	6,190,000
Fabrication and test equipment	$1,700,000	5,100,000	5,560,000
Propellants	---	3,500,000	5,370,000
Total, 200,000-Pound Thrust Engine	$1,700,000	$15,000,000	$28,700,000

During the fiscal year 1961, the major effort in the 200,000-pound thrust engine development is being devoted to component design and testing, engine systems planning, and to the modification of existing test stands to accommodate the use of liquid hydrogen. The first testing of the complete engine will be undertaken in the fiscal year 1962.

Design

Since the 200,000-pound thrust engine is approximately the same size as several missile engines that have already been developed by the contractor, and since the fuel pump is similar to that being developed for the Rover project, progress in the design phase has been extremely rapid. The design effort during the fiscal year 1962 will be maintained at a nominal level as necessary to refine system design details and incorporate changes resulting from tests.

Component Development

Component development during the fiscal year 1962 covers engineering, procurement of materials, and fabrication and shop support for all components and subassemblies of the engine system. Major components are the thrust chamber assembly, two separate turbopumps (one for oxidant and one for fuel) the gas generator, and controls and valves.

Component Test

Funding under this heading covers stock materials (other than propellants), test engineering and labor, procurement and maintenance of general special test equipment, data acquisition and reduction, and the preparation of engineering reports. The purpose of component testing is to eliminate design and fabrication deficiencies and to develop reliable, high-performance units prior to incorporation in the engine system.

Engine Development

This area covers engineering, purchase of materials, fabrication, assembly, inspection, and check-out as well as the preparation of engineering models and mockups. During the fiscal year 1962 the effort in this area will increase markedly with a corresponding decrease in the component area beginning in the fiscal year 1963.

Engine Test

Funds for test operations include the costs of engineering and labor, test crews, special test equipment, transportation, data reduction and analysis, and the preparation of reports. The engine tests consist

of experimental runs with the complete engine assembly to prove its reliability and performance and to detect and eliminate any design or construction faults that may have been undetected during the component test phase or may result in the future when the components are combined into an integrated system. The first complete engine test firing will occur during the fiscal year 1962.

Fabrication and Test Equipment

A requirement for the procurement of special fabrication, assembly, and testing equipment, and for the procurement of the associated tooling and jigs will be continued into the fiscal year 1962. As the program progresses, funding in this area will be reduced principally to maintenance and replacement costs.

Propellants

The increased test effort in the fiscal year 1962 will result in a commensurate increase in propellant requirements. Liquid oxygen will be purchased through Air Force channels and liquid hydrogen from commercial sources.

Advanced Systems and Components	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Advanced Design Investigations.....	$1,100,000	$1,150,000	$2,750,000
Materials and Instrumentation.....	---	150,000	1,300,000
Propellant Investigation.....	200,000	566,000	1,550,000
Operating Problems.....	---	134,000	1,400,000
Total, Advanced Systems and Components.....	$1,300,000	$2,000,000	$7,000,000

To meet the requirements for advanced missions, systems and components investigations are planned to improve and extend the capabilities of liquid propellant rocket engines. The advanced technology budget also supports investigations of the fabrication techniques and operating problems associated with rocket engine development.

The advanced systems and components effort is oriented principally to the requirements of "space" rather than "booster" propulsion. These requirements include planetary landing and take-off, orbit maneuvers, retrorocket systems, trajectory correction, and attitude control. Unlike booster propulsion, which has a background of intense technological development, the space application of liquid propulsion is relatively undeveloped. It is therefore necessary to intensify the effort in this area to ensure that the basic technology is abreast of new mission requirements.

Advanced Design Investigations

The advanced design investigations will involve component studies and experimental investigation of rigidly mounted rocket engines, variable thrust rocket engines and small control rocket systems.

Studies of various nozzle designs and propulsion concepts in the application of rigidly mounted rocket engines in contrast with a gimballed engine for vehicle directional control were initiated in the fiscal year 1961. This effort will continue in the fiscal year 1962 in an attempt to evolve a design approach and to identify more precisely the advantages of a stationary engine system, in terms of reliability and over-all launch costs.

Variable thrust engines will be required in order to accomplish lunar and planetary landing and take-off operations (with men or impact-sensitive equipment) and for space flight rendezvous. Experimental work to establish the techniques and equipment for accomplishing controllable thrust will be carried out as a follow-up to the conceptual studies that were initiated in the fiscal year 1961.

The advanced design investigations will also include experimental projects to develop highly reliable propulsion systems for vehicle attitude control and trajectory adjustment.

Materials and Instrumentation

Advancement in rocket engine technology involves improvement in materials and fabrication methods and in the instrumentation required for developmental and flight testing. NASA will undertake investigation of alternative methods and materials of fabrication of rocket engine components with the objective of improved quality, minimum weight, and reduced cost. Associated with these objectives is a re-examination of the design and construction of liquid rocket engine propellant injectors in terms of the factors affecting performance. Improved techniques of injector-face cooling will be investigated as part of this effort.

Space operation of rocket engines will permit realization of increased propellant performance through use of very large expansion ratio nozzles. Investigations will be conducted of thin high-temperature metallic nozzle materials cooled in space by radiation and of ablative chamber and nozzle materials. In the area of metering and sensing, work will be initiated to develop improved instrumentation for both test stand and flight use.

Propellant Investigation

The work in this area covers studies on the effects of space environment, the applicability of new higher specific impulse propellant combinations, and the possible substitution of new propellants in existing systems.

The environmental work is the continuation of investigations started in the fiscal year 1961 to define the character of the space environment as it affects the storability of propellants. This work involves the design of suitable thermal insulation, and provisions for protection against the hazards of micrometeorites and against ionizing forms of radiation.

Promising new high specific impulse propellants will be studied experimentally to determine their performance characteristics and the feasibility of their use. This work is part of a continuing program which must be carried out in order to provide the technology that will be required to apply such propellants to space propulsion use. Studies of substitute propellants to upgrade the performance of existing engine systems without requiring extensive changes in the system will be undertaken.

Operating Problems

Continuing work on several basic operating problems inherent to rocket engines is necessary to achieve improved reliability, and to establish a firmer basis for future improved engines.

Combustion instability is frequently responsible for the destruction of rocket engines in testing and in flight. Continuation of work started in previous years is needed to better rationalize the design of stable combustion chambers and to insure a more rapid thrust chamber development. Performance improvements of liquid propellant rocket engines can be achieved by several approaches, some already indicated in other projects in this program. In addition to propellant improvement, it is possible to increase performance by raising the operating chamber pressure, which tends to reduce the size and weight of the engine. To do so it will be necessary to refine and further develop, by experimentation, the basic heat transfer and cooling technology. Different approaches to the cooling problem such as use of high-strength, high-temperature materials will be investigated.

The phenomenon of "non-equilibrium" flow in rocket exhaus nozzles makes it extremely difficult to predict the performance and behavior of an engine, particularly one with a large expansion ratio nozzle. Studies leading toward better understanding of the problem will be undertaken.

A detailed analysis and design study of the engine equipment to carry out the NASA space missions is required. In particular, the best engineering compromises to meet the requirements for lunar landing and take-off and for orbit trajectory corrections are needed. More detailed examinations of the problems of rendezvous in space will require precise control of the motion of the approaching vehicles in order to achieve the "docking" maneuver. These studies were initiated in the fiscal year 1961 and will be continued in 1962.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

ELECTRIC PROPULSION

SUMMARY OF REQUIREMENTS:

	1960	1961	1962	Page No.
Advanced Systems and Components.....	$100,000	$1,500,000	$3,000,000	RD16-2
Prototype Development.....	1,200,000	1,800,000	3,800,000	RD16-4
Total.....	$1,300,000	$3,300,000	$6,800,000	

OBJECTIVES:

To advance the basic technology necessary to exploit electrical propulsion for general space application, and to develop the specific engines required in support of anticipated space missions.

JUSTIFICATION:

The ability of future vehicles to boost increasingly larger payloads into orbit around the earth will overcome many of the major obstacles for space flight and space operations. It becomes apparent, however, that once a payload has been placed into orbit, a small electrical thrust applied for long durations of time can be utilized to maintain a fixed programmed flight position in relation to the earth, to travel to a higher orbit, or even to deviate from orbit and fly an interplanetary space mission. The inherent propellant economy of the electric engine takes on particular significance for missions of this type, since every pound of propellant that can be eliminated imposes that much less of a weight penalty on the boost vehicle system; also, a decrease in the weight of the propellant required for a given space mission means a corresponding increase in the weight of the vehicle's payload. In this context, the electric engine appears promising as a primary propulsion system for unmanned and manned interplanetary missions; for lunar missions where long transit times are acceptable or for slow transport of spacecraft from low-altitude orbits to high-altitude orbits; and for satellite attitude stabilization or for control of trajectories for lunar and interplanetary missions and space probes.

Applied research and advanced engineering developments are needed to translate these basic concepts into specific engine applications. To this end, NASA is developing three general types of electrical rockets for space propulsion. These are: the ion engine; the electrothermal (arc jet) engine; and the magneto fluid dynamic engine. In each instance, the engine will receive its required electrical power input from nuclear electric power units discussed under Nuclear Systems Technology program.

FUNDING REQUIREMENTS:

Advanced Systems and Components	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Ion Engine.....	$100,000	$975,000	$1,700,000
Arc Jet Engine.....	---	125,000	200,000
Magneto Fluid Dynamic Engine....	---	200,000	900,000
Mission Studies.....	---	200,000	200,000
Total, Advanced Systems and Components.....	$100,000	$1,500,000	$3,000,000

This area comprises advanced experimentation and studies needed to provide information for the design, development, and testing of electrical engines. Support for this area was initiated in the fiscal year 1961 and will continue in the fiscal year 1962. At the present time, special emphasis on this part of the program is necessary since new knowledge is needed immediately to support the engine developments.

Ion Engine

The ion engine, employs a principle of propulsion that is based on the acceleration of charged particles. The major problem areas are those related to the ionizer materials which transform the cesium atoms to positive ions; the techniques used to neutralize ion beams; the alternate methods of producing a positive ion beam by collision between electrons and mercury gas; the improvement in the propellant flow control system; materials that will permit longer operation time, and measurement techniques and instruments for the ground and flight tests.

On the assumption that, in the near future, power supply units of capacities greater than 30 kilowatts will be available, action must be initiated at this time to delineate clearly the problems which must be solved in order to develop ion engines capable of operating at higher levels. In addition to the usual critical problems of propellant feed, ion sources, electrode focusing systems, neutralization methods and measurement techniques, other formidable problems exist relative to the clustering, scaling and parallel

operation of ion engines, and to the integration of the engine with the power supply and control devices of the spacecraft. The study results in this area will point the way for detailed investigations of the many aspects of high-powered ion engines.

Arc Jet Engine

The arc jet engine is based on the acceleration of a gas through the use of a high-intensity arc heat source. Investigations aimed specifically at improvement of the component parts will include: regenerative cooling of the chamber and nozzle walls; reduction of gaseous recombination and dissociation energy losses; energy exchange mechanisms between the arc and the propellant; determination of the optimum propellant; improved electrode materials for longer operations; effect of the radio frequency signals from the jet upon communications; and instrumentation for ground and flight tests.

Magneto Fluid Dynamic Engine

This engine is based on the acceleration of a conducting plasma. It has great potential for space application in that the trade-off between thrust and specific impulse may be varied with comparative ease. Since a predominantly neutral gas is ejected, there is no problem of neutralization.

Acceleration of the plasma in the magneto fluid dynamic engine is obtained by the application of various combinations of electric and magnetic fields. Some arrangements use a moving magnetic field to achieve plasma acceleration; others use a combination of fixed electric and magnetic fields. By varying the type of gaseous plasma, the percentage of ionization and the values of electric and magnetic fields, a wide range of specific impulse values may be obtained.

In continuation of the fiscal year 1961 investigations, the fiscal year 1962 effort will be concerned with the optimum specific impulses, techniques for ionizing selected gaseous fluids, problems of propellant storage and feed, and instrumentation techniques.

Mission Studies

These studies are designed to determine the optimum sizes, types and operating characteristics of electrical propulsion systems for various spacecraft missions. The effort will be based on fairly definitive engine and power supply data, (such as weight, dimension, specific impulse, thrust and operating life) and will be aimed at the application of low- and high-specific impulse electrical engines for course correction and main drive, the optimum time use of arc jet engines on earth-orbiting and lunar flights, as well as the combined use of chemical and electrical engines for one-way and round-trip planetary missions.

Prototype Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
30 Kilowatt Ion Engine.....	$500,000	$900,000	$2,500,000
1 Kilowatt Arc Jet Engine.....	200,000	100,000	300,000
30 Kilowatt Arc Jet Engine.....	500,000	800,000	1,000,000
Total, Prototype Development	$1,200,000	$1,800,000	$3,800,000

The objectives in this area are to develop three basic engines: a 30 kilowatt cesium ion engine (0.1 lb. thrust); a 1 kilowatt arc jet engine (0.01 lb. thrust); and a 30 kilowatt arc jet engine (0.5 lb. thrust). The 30 kilowatt cesium ion engine, with its high specific impulse, could be employed as the main propulsive unit to propel spacecraft on missions to Mars, Venus, and for other deep space missions; the 1 kilowatt arc jet engine could be used to control the stability and attitude of spacecraft; and the 30 kilowatt arc jet engine could provide a main propulsive drive for an earth-orbiting spacecraft or for spacecraft on lunar missions. All three engines are being developed by industrial organizations under contract.

30 Kilowatt Ion Engine

The objective here is to develop a 30 kilowatt cesium ion engine that can be powered from a Snap-8 power supply unit. The first step toward this goal is the construction of a laboratory model by the end of the fiscal year 1961. This model will be a complete engine including not only the thrust unit, but also the zero gravity propellant feed system, automatic feed controls, neutralization system, and instrumentation. During the fiscal year 1962, a fully engineered flight model engine will be completed and by the end of the fiscal year 1962, approximately ten such engines will have been produced. A number of these engines will be given complete environmental ground tests and prepared for flight testing to be conducted during 1963.

1 Kilowatt Arc Jet Engine

During the fiscal year 1961, work continues on the development of a laboratory model of a complete arc jet engine for use in vehicle attitude control; the model should be developed to the point that work can proceed on a flight test model. A number of these flight test models will undergo ground environmental tests in preparation for flight testing in 1963.

30 Kilowatt Arc Jet Engine

The basic pattern of development for the 30 kilowatt arc jet engine is the same as that for the 30 kilowatt ion engine and the 1 kilowatt arc jet engine. It is expected that by the end of the fiscal year 1962 a laboratory model engine capable of operating from a Snap-8 unit will have been developed as the predecessor of a flight test model which will be undergoing development during the fiscal year 1963.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

NUCLEAR SYSTEMS TECHNOLOGY

SUMMARY OF REQUIREMENTS:

	1960	1961	1961 Supplemental	1962	Page No.
Nuclear Heat Transfer Rocket.....	$3,999,768	$6,110,000	$2,600,000	$17,500,000	RD17-2
Nuclear Electric Power Systems.....	1,613,232	3,890,000	---	10,500,000	RD17-5
Total.....	$5,613,000	$10,000,000	$2,600,000	$28,000,000	

OBJECTIVES:

To develop nuclear rocket propulsion systems capable of carrying large payloads on space missions over extended distances; and to develop nuclear electric power generating systems as required for electrical space propulsion or for auxiliary power sources in spacecraft.

JUSTIFICATION:

The principal applications of nuclear energy that are considered suitable for propulsion of heavy spacecraft into space are the nuclear heat transfer rocket and the nuclear electric generating system as source of power for thrust producers discussed under the Electric Propulsion program.

The nuclear heat transfer rocket engine embodies a propulsion system in which hydrogen is heated to high temperature in a nuclear reactor and ejected as a propulsive jet. Because of the high specific impulse inherent in the nuclear rocket engine, long range missions involving large payloads (manned lunar or interplanetary missions) may be accomplished with lighter and simpler vehicles requiring fewer stages than can be obtained from the more conventional forms of propulsion. The current NASA-Atomic Energy Commission program for development of a nuclear rocket engine is aimed at experimental ground tests to demonstrate the feasibility of achieving the potentially high specific impulses within a reasonable weight and size configuration. During the fiscal year 1962 this joint effort will cover the continued development and testing of a nuclear reactor, engine

component development and subsystem integration, and several advanced technology programs necessary to provide design data. Three research reactor tests have been conducted to date by the Los Alamos Scientific Laboratory of the Atomic Energy Commission. During the fiscal year 1962 the non-nuclear component development that has been funded by NASA will result in the installation of liquid hydrogen turbopumps and liquid hydrogen cooled nozzles into the Kiwi-B reactor series. Radiation effects, radiation shielding, hydrogen properties evaluation work, and steady-state and dynamic instrumentation necessary to supply the data needed for operational nuclear rocket systems are examples of the advanced technology that will be conducted.

The area of nuclear electric power generating systems is oriented to general advancement of the basic technology with specific application in the development of a 30 kilowatt power generating unit. The 30 kilowatt unit, identified as the Snap-8, is being undertaken as a joint development by NASA and the Atomic Energy Commission. The Snap-8 will exist in two configurations: as a 30 kilowatt nuclear electric generating system using one reactor and one conversion unit; or as a 60 kilowatt unit using one reactor with two conversion units operating in parallel. In the 60 kilowatt version, the Snap-8, when combined with the electrical thrust devices described under the Electric Propulsion program, will provide an electrical propulsion capability for missions to Mars and Venus, out-of-the-plane-of-the-ecliptic probes, solar probes and other missions where a long duration propulsion capability is required. Depending upon the results obtained from the Snap-8 development and concurrent studies in the basic technology, a larger nuclear electric generating system in the order of 1 megawatt (electrical) may become practical. Applied research and component development in this area is under way to determine the feasibility of higher powered systems.

FUNDING REQUIREMENTS:

Nuclear Heat Transfer Rocket	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1961 Supplemental	Fiscal Year 1962
Advanced Systems and Components:				
Reactor test support; non-nuclear component development	$2,135,185	$3,950,000	---	$4,500,000
Reactor test support; propellants.....	1,154,628	1,110,000	$800,000	2,000,000
Nuclear rocket technology.....	509,955	450,000	300,000	2,000,000
Vehicle studies.....	---	300,000	---	1,000,000
	3,799,768	5,810,000	1,100,000	9,500,000

Nuclear Heat Transfer Rocket	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1961 Supplemental	Fiscal Year 1962
Experimental Engine Development:	$200,000	$300,000	$1,500,000	$8,000,000
Total, Nuclear Heat Transfer Rocket.....	$3,999,768	$6,110,000	$2,600,000	$17,500,000

Reactor Test Support - Non-Nuclear Component Development

NASA has the responsibility for supplying and developing certain non-nuclear components for the Rover Reactor test program of the Atomic Energy Commission. During the fiscal year 1962, the liquid hydrogen pump development that has been in process during the past two years, will advance to a full rated flow and pressure configuration. Turbopump feed systems will be completed and installed at the Nevada Test site of the Atomic Energy Commission and provided with the necessary supporting spare parts and equipment. Hardware development of turbopumps for use in higher power systems will be undertaken.

In addition, a high heat intensity jet nozzle is required for the Atomic Energy Commission reactor test program. This item covers the cost of completing development of a suitable hydrogen cooled nozzle and of conducting the necessary hardware development of nozzles that will be capable of operating at higher heat fluxes and powers than those that will be encountered in the early tests.

Reactor Test Support - Propellants

Hydrogen is used in the reactor tests, and in the development of all of the non-nuclear components. In addition, nitrogen and helium are required at the various test facilities to purge and to precool or chill the system so that excessive evaporation of the costly hydrogen can be eliminated. Supplemental 1961 funding in the amount of $800,000 is required for propellants to permit acceleration of the turbopump development program. This acceleration results from a decision to go directly to the turbopump liquid hydrogen feed system previously planned for use in later reactor tests.

Nuclear Rocket Technology

The work covered by this item is aimed at developing the technology that is necessary before nuclear rocket systems can be designed, build and

operated. This technology involves problems that result when the reactor and other components in the nuclear rocket are packaged closely together as they would have to be in a flight system as well as analysis and experimentation to determine and solve the problems associated with the use of hydrogen in a reactor radiation field. Procurement of the necessary experimental equipment and instrumentation is included in this requirement.

The packaging of the non-nuclear components around the reactor in a nuclear rocket results in the operation of certain components in a radiation field at liquid hydrogen temperatures as low as 430 degrees below zero. Although a considerable amount of work on the effects of radiation on the engineering properties of materials has been and is being done as part of the various nuclear power plant programs, to date no work has been directed at the extremely low temperatures that will be encountered with the use of hydrogen in the nuclear rocket. It is, therefore, necessary that these effects be experimentally evaluated since the effects of radiation may be much more pronounced in the lower temperature of the nuclear rocket than they are in other nuclear systems. Supplemental 1961 funds amounting to $300,000 have been requested to permit incorporation of design features needed to comply with rigid safety requirements of the test reactor and to provide for the high rate of data output necessary to the effectiveness of this project.

The application of nuclear power to rocket propulsion systems will require shielding of the payload and the hydrogen propellant tank. For high-power systems, or for long duration flights, severe shielding requirements can be anticipated. To maintain the maximum payload capability, new light weight shield concepts for use in a space environment and accurate methods of calculating shield performance must be developed.

It has been determined that many of the properties of hydrogen that are required in system design and operation are unknown at this time. In addition, it is necessary to develop instrumentation that will be used to measure hydrogen conditions throughout the nuclear rocket so that these data may be sensed and fed into the automatic control system of the nuclear rocket. Because of the background of experience of the National Bureau of Standards Cryogenic Laboratory in this area, funds will be transferred to that laboratory to determine the data that are necessary and to establish suitable means of measuring such factors as hydrogen mass flow, pressure, and temperatures.

Instrumentation for sensing reactor power thrust, temperature, and specific impulse under steady-state and dynamic operating conditions will be developed. Such instrumentation must be radiation resistant and, at the same time, extremely accurate in order to make certain that the vehicle will achieve the necessary trajectory when assigned to a particular mission.

Vehicle Studies

Design of a nuclear rocket for incorporation in a vehicle involves interactions between the engine system and the vehicle which are not encoun-

tered in chemical rockets. For example, a reduction in shielding weight can be effected by increasing separation between the propellant tank and the engine. This approach, however, creates major design problems. Research studies and experimental component development pertaining to such vehicle requirements will be initiated during the fiscal year 1962 in order to assure a suitable engine design capable of adaptation to a vehicle.

Experimental Engine Development

The initial phase of the experimental engine development involves design, program planning, and research on engine systems components to establish detailed development plans and to determine testing requirements and reliability goals. Supplemental 1961 funds are required to initiate development at an earlier date than previously planned. Funds will be applied to the experimental design, engine subsystem applied research, and other supporting functions as required to advance to the stage of ground testing an experimental nuclear rocket engine.

During the fiscal year 1962 the engine contractor selected late in the fiscal year 1961 will initiate research and development work aimed at ground testing an experimental engine. Concurrently, the contractor will continue his initial effort in engine and subsystem design and will participate in supporting work required by the Los Alamos Scientific Laboratory of the Atomic Energy Commission.

Nuclear Electric Power Systems	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1961 Supplemental	Fiscal Year 1962
Advanced Systems and Components:				
High-power systems technology	$746,063	$1,790,000	---	$6,500,000
Reactor direct conversion....	---	100,000	---	500,000
	746,063	1,890,000	---	7,000,000
Prototype Development (Snap-8):	867,169	2,000,000	---	3,500,000
Total, Nuclear Electric Power Systems.....	$1,613,232	$3,890,000	---	$10,500,000

High-Power Systems Technology

This work is aimed at developing the new technology required for high-powered systems. Included are experimental work to extend the knowledge of the thermodynamic and transport properties of liquid metals and related work on corrosion, emissivity, condensation and boiling of liquid metal,

and heat transfer studies. Application of the results of this work to the design of high-powered components (including turbines, generators, and heat rejection systems), will be accelerated as part of a preliminary design study of the complete engine system.

Reactor Direct Conversion

The direct conversion of nuclear heat into electricity has significant potential for the development of a simple, high-powered electrical conversion system. Such systems are expected to require fewer moving parts and therefore will offer a potential increase in reliability when compared to the turboelectric generator systems. Studies have indicated the feasibility of this approach, provided that a suitably long-life electrode can be developed. The work planned in 1962 relates to physical and metallurgy property determination necessary to evaluate the electrode life.

Prototype Development

NASA responsibility for the Snap-8 includes development of the power conversion system and integration of the reactor and conversion unit into an operational system. During the fiscal year 1962, design work and test equipment construction will be completed and component and subsystem testing will be under way. A target test flight date of spring 1965 is planned.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

SPACE POWER TECHNOLOGY

SUMMARY OF REQUIREMENTS:

	1960	1961	1962	Page No.
Advanced Research.....	$1,250,000	$985,000	$1,200,000	RD18-2
Advanced Technical Development.....	2,264,000	3,215,000	4,300,000	RD18-5
Total.....	$3,514,000	$4,200,000	$5,500,000	

OBJECTIVES:

To develop the technology of generating electrical power from solar and chemical energy sources for use in spacecraft.

JUSTIFICATION:

Nearly all spacecraft require an electrical power supply (auxiliary power system) to provide electricity for operating instruments, communications and other equipment. Solar photovoltaic cells and batteries are used at present, but research is needed to determine the amount of shielding required to protect solar cells from radiation damage and development is needed to provide more reliable, lighter weight storage batteries. For power requirements of 500 watts to 30 kilowatts, other auxiliary power systems should be developed which will have lower weight, higher reliability or lower cost. Solar-heated systems using solar collectors and either turboelectric or thermionic power conversion equipment appear promising for long duration missions. Chemical combustion auxiliary power systems and fuel cells are desirable for certain relatively short duration missions, such as manned spacecraft. Improved lightweight electrochemical storage units such as electrolytically regenerated fuel cells are desirable for use with solar auxiliary power systems.

FUNDING REQUIREMENTS:

Advanced Research	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Radiation damage to solar cells..	$170,000	$390,000	$250,000
Fabrication techniques for solar collectors.....	100,000	---	100,000
Solar collector testing.....	30,000	---	---
Space power systems.....	200,000	200,000	200,000
Thermionic conversion.....	300,000	200,000	300,000
Thermal energy storage materials for solar-thermionic systems....	200,000	---	100,000
Spray condenser for space heat rejection.....	100,000	---	---
Electrolytically regenerative fuel cells.....	50,000	50,000	100,000
Magnetohydrodynamic power generation.....	100,000	---	150,000
Thermal radiation properties of spacecraft materials.....	---	145,000	---
Total, Advanced Research....	$1,250,000	$985,000	$1,200,000

Radiation Damage to Solar Cells

The purpose of this work is to determine the radiation damage effects of proton and electron bombardment on various types of solar cells with various types of shielding. A contract initiated in the fiscal year 1960 has resulted in the very significant discovery that silicon solar cells made with a thin layer of negative-doped silicon on top of positive-doped material were considerably more resistant to radiation damage than the positive or negative type which are presently in production. Radiation testing has shown that radiation damage to solar cells by high energy protons in the inner Van Allen belt and from solar flares will be more severe than anticipated. Therefore, research is being expanded in scope during the fiscal year 1961 to include testing in six different cyclotrons to cover the proton energy range of interest. Research will be continued in the fiscal year 1962 to evaluate new and improved solar cells which are being developed, particularly of the negative on positive type, and to provide a basis for interpretation of solar cell performance as telemetered from spacecraft.

Fabrication Techniques for Solar Collectors

The purpose of the work under this heading is to investigate various techniques for fabricating optically accurate, lightweight, parabolic solar concentrating mirrors for use with solar-heated power systems.

With fiscal year 1960 funding, techniques were developed which make it possible to fabricate a lightweight replica of a searchlight mirror. No funds are required in the fiscal year 1961 because the existing contract extends through this period. Funds are required in the fiscal year 1962 to solve some of the problems which are being encountered, particularly the optical distortion caused by temperature gradients in the structure. This fabrication technology may prove useful for antennas and telescopes as well as for solar-thermionic power systems.

Solar Collector Testing

Fiscal year 1960 funds were used to purchase special test equipment for solar collectors. No funds are required for the fiscal years 1961 or 1962.

Space Power Systems

Fiscal year 1960 funds under this heading were utilized to conduct analyses and design studies of various power systems for use in spacecraft. These studies provided the basis for selection of a solar cell power system for the Ranger spacecraft. Funds for the fiscal year 1961 are being used to study and compare solar-thermionic, solar cell, and other power systems for potential application in planetary probes and satellites. The fiscal year 1962 funds will provide for study contracts to compare the merits of various power systems for application in manned satellites and for lunar landing missions and to study sun orientation systems for solar power systems.

Thermionic Conversion

The purpose of this work is to gain a basic understanding of thermionic conversion processes and to determine ways to optimize the performance of thermionic converters. A goal is to find means for maximizing the efficiency and the power output with cathode temperatures low enough to assure long life. Fiscal year 1960 funds were used for research on thermionic converters of various types, including vacuum diodes, cesium diodes and gas-filled converters. The 1961 funds are being used to evaluate the feasibility of utilizing a cesium vapor thermionic converter with a solar concentrator as the heat source. Funds for the fiscal year 1962 are required to perform continuing research on cesium and gas-filled thermionic converters to permit the attainment of higher efficiency and longer life.

Thermal Energy Storage Materials for Solar-thermionic Systems

A promising method of energy storage for use with solar-thermionic power systems is to melt a material while in the sun and let it freeze, giving up its latent heat of fusion while in the shade, to operate

thermionic converters at constant power. Research is needed to determine the heat of fusion and other properties of various materials having melting points above 2000°F., and to find materials which can be used to contain the molten material. Fiscal year 1960 funds were used to conduct exploratory research on materials and structures for the containment of molten silicon and its alloys. No funds are required in the fiscal year 1961, but it is anticipated that the research will uncover problem areas requiring continued effort in the fiscal year 1962 to determine whether thermal energy storage is feasible for use with solar-thermionic power systems.

Spray Condenser for Space Heat Rejection

The purpose of this work is to investigate the basic processes involved in condensation of a liquid metal vapor by injection of sub-cooled liquid. The potential applications include a condenser for liquid metal cycles which would not be affected by zero-gravity. The feasibility of the spray condenser was established in the fiscal year 1960, and continuing effort under the contract established for this purpose will provide data to permit the design of spray condensers for mercury which may be used in solar or nuclear turboelectric power systems such as Sunflower-1 or Snap-8. No additional funds are required in the fiscal years 1961 or 1962.

Electrolytically Regenerative Fuel Cells

Research is under way to gain an understanding of the electrochemical behavior of fuel cells when operated cyclically, being alternately charged and discharged like a storage battery. A contract was initiated in the fiscal year 1960 to conduct research on a hydrogen-oxygen fuel cell. The contract is being extended in the fiscal year 1961. Funds for the fiscal year 1962 will provide for continuing the research effort on hydrogen and oxygen fuel cells and for initiating exploratory research on other high energy electrochemical systems which may have potential advantages for a rechargeable fuel cell battery.

Magnetohydrodynamic Power Generation

Studies are required on the plasma properties, electrode processes, and on the design optimization of magnetohydrodynamic power converters which use chemical combustion to produce electrically conducting gases (plasma). Potential applications are for generation of high power levels for relatively short durations. Funds for the fiscal year 1960 were utilized to fund a contract for research on a vortex magneto-hydrodynamic power generator. This contract is funded until the fiscal year 1962 and no additional fiscal year 1961 funds are required. The fiscal year 1962 funds are required to perform additional research on materials and plasma properties and to determine the feasibility of using

hydrogen-oxygen combustion products, seeded with an alkali metal, as the plasma working fluid in a magnetohydrodynamic power generator.

Thermal Radiation Properties of Spacecraft Materials

The objective of this project is to measure the absorptivity for solar radiation and the emissivity for infrared radiation of various special coatings and metal surfaces which may be used in controlling the temperature of spacecraft. Temperature control is important for proper operation of payload components, such as batteries. Fiscal year 1961 funds were used to support a contractual research program. No funds are required in the fiscal year 1962 because work of this type will be performed under various spacecraft development projects.

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Solar cell array technology.....	$314,000	$180,000	$200,000
Improved solar cells and power system components.....	445,000	435,000	200,000
Improved storage batteries.....	300,000	300,000	300,000
Testing of batteries in simulated space environments.....	135,000	---	---
3-kilowatt solar auxiliary power system (Sunflower-1).....	1,070,000	1,500,000	1,800,000
Primary fuel cells.....	---	500,000	500,000
Solar concentrators.....	---	300,000	400,000
Chemical combustion auxiliary power unit.....	---	---	300,000
Solar-thermionic power system....	---	---	500,000
Electrolytically regenerative fuel cells.....	---	---	100,000
Total, Advanced Technical Development.....	$2,264,000	$3,215,000	$4,300,000

Solar Cell Array Technology

The objective of the work under this heading is to evaluate the potential of solar cell power systems by the testing of developmental solar cell arrays under simulated operational conditions. Advanced development and testing of solar cell panels in the fiscal year 1960 lead to the development of the solar cell panels for the Ranger spacecraft. Funds for the fiscal year 1961 are being used for the development of improved solar cell arrays with solar energy concentrators to increase the power output per unit area of solar cells. Funds for the fiscal year 1962 are required to develop solar cell arrays of lighter weight which have rugged and reliable construction.

Improved Solar Cells and Power System Components

Fiscal year 1960 funds were used to develop and test components for solar cell power systems and to develop radiation resistant solar cells. The 1961 funds are being used to initiate several contracts for the development of lower cost solar cells, radiation resistant solar cells, solid-state power converters, and circuit-breakers. The contracts initiated during the fiscal year 1961 will be continued in 1962.

Improved Storage Batteries

Funds for fiscal years 1960 and 1961 are being utilized to support the development of both nickel-cadmium and non-magnetic silver-cadmium batteries. A critical need exists to improve the quality of batteries used for energy storage with solar cell power supplies. Funds for the fiscal year 1962 are required to continue the existing contracts and to concentrate on the development of reliable batteries for application in satellites with at least a one-year life expectancy.

Three-kilowatt Solar Auxiliary Power System (Sunflower-1)

Work on this system was initiated in the fiscal year 1960 with the objective to deliver two experimental prototypes by mid-1963. Funds for the fiscal year 1962 will be primarily devoted to the conduct of performance, environmental, and endurance testing.

Primary Fuel Cells

Contracts are being initiated in the fiscal year 1961 to develop fuel cells for potential use in manned spacecraft or lunar and planetary landing vehicles. This effort will be continued in the fiscal year 1962 leading to a developed modular unit by 1964.

Solar Concentrators

Fabrication methods will be developed for large parabolic solar concentrators (diameters from 15 to 70 feet) for use in solar heat sources with turboelectric or thermionic conversion systems. Fiscal year 1962 funds will provide for initiation of the development of a solar heat source applicable for use with the 30-kilowatt Snap-8 turboelectric conversion system. The primary application for a solar heated Snap-8 system will be for a manned orbital laboratory.

Chemical Combustion Auxiliary Power Unit

It is proposed to demonstrate the feasibility of a power conversion system for use with hydrogen and oxygen combustion products. Potential applications include manned spacecraft and lunar landing vehicles,

including power for propulsion of a roving lunar surface vehicle. The fiscal year 1962 funding will be used to determine the feasibility of an internal combustion engine, operating with liquid hydrogen as the fuel, and liquid oxygen as the oxidizer.

Solar-thermionic Auxiliary Power System

It is proposed to initiate the development of a solar-thermionic power system capable of generating 1 to 5 kilowatts in satellite or space probe missions. It is estimated that the system will require five years for development and total funding of several million dollars. The system will utilize no moving parts and is intended to be a general purpose power system which will ultimately replace the Sunflower-1 solar-turboelectric power system for specialized satellite and space probe missions. Work will be started in the fiscal year 1962.

Electrolytically Regenerative Fuel Cells

Fiscal year 1962 funding is requested to initiate the development of a modular rechargeable fuel cell battery with at least 50 watt-hours capacity which can be used for energy storage with solar cell power systems. An objective is to achieve at least five times more energy storage per pound than is obtainable with nickel-cadmium batteries.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

SCOUT

SUMMARY OF REQUIREMENTS:

	1960	1961	1961 Supplemental	1962	Page No.
Vehicle Development	$1,612,000	$1,510,000	$1,075,000	$1,075,000	RD19-2
Engine Development.	1,079,000	140,000	---	1,100,000	RD19-3
System Support.....	309,000	500,000	750,000	1,500,000	RD19-4
Total.....	$3,000,000	$2,150,000	$1,825,000	$3,675,000	

OBJECTIVES:

The purpose of the Scout program is to develop a reliable, relatively inexpensive vehicle for general space research. The vehicle's capabilities include orbital, probe, and reentry missions. It is the smallest of the basic NASA family of launch vehicles and is planned to fulfill a large variety of requirements for small size payloads.

JUSTIFICATION:

The Scout development program comprises a total of eight development vehicles, three of which have been launched to date. Scout Nos. 1 and 2, launched on 1 July and 4 October, respectively, performed satisfactorily; Scout No. 3, launched on 4 December, failed to achieve second-stage ignition; Scout No. 4 is scheduled for launch in early 1961.

Until recently, the complete system management and some manufacutring of specific components for these first four vehicles was performed as an in-house effort at the Langley Research Center. To provide for an orderly transition from development to operational procurement, the four remaining vehicles of the eight-vehicle program are now being procured through a prime vehicle contractor.

The Scout vehicle, in its present configuration, is capable of placing a 150-pound payload, with a maximum diameter of 25 inches into a 300 nautical mile orbit. Anticipated NASA and Department of Defense missions in mid-calendar year 1962 will increase this requirement to a payload of 200 pounds and a maximum diameter of 30 inches. By increasing the

performance of the third and fourth stage motors, a standard vehicle can be achieved to meet the requirements of both agencies with a resulting simplicity of logistics and economy of production. As currently planned, the Scout development program is oriented to this concept.

The combined fiscal year 1961 and fiscal year 1961 supplemental funds will complete procurement of the basic eight development vehicles. The supplemental amount for 1961 will cover increases resulting from the realignment of costs in the establishment of a prime contractor, and other elements that were not anticipated at the time of the original pricing of the program. The level of effort in the fiscal year 1962 will be applied primarily to development of the improved motor capability, increased cone diameter, standardization of the basic vehicle design and completion of component qualification tests.

FUNDING REQUIREMENTS:

Vehicle Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1961 Supplemental	Fiscal Year 1962
Vehicle.....	$786,000	$400,000	$825,000	$575,000
Guidance and Control.....	826,000	1,110,000	250,000	500,000
Total, Vehicle Development	$1,612,000	$1,510,000	$1,075,000	$1,075,000

Fiscal Year 1961 funds, including the supplemental, will be applied to the procurement of the second four Scout development vehicles with design modification and qualification testing of critical components. The fiscal year 1962 funding will be applied to the changes required for standardization of the vehicle to meet both NASA and Department of Defense requirements, increased reliability, and simplification of check-out procedure at the launch site.

Vehicle

The vehicle consists of the airframe, instrumentation, electrical networks, and destruct systems. The requested supplemental funding for the fiscal year 1961 will be used to manufacture instrumentation that was conducted initially as an in-house effort at the Langley Center. During the fiscal year 1962, a design and test effort will be initiated to determine the optimum nose cone diameter to length ratio for the standard vehicle and to establish compatibility of electrical and destruct systems with range requirements. In addition, all of the new components will be qualified to standards established by flight test experience.

Guidance and Control

During the initial testing of the Scout vehicle unexpected "roll forces" were encountered in the third-stage motor to the extent that they completely overpowered the roll control system. The supplemental 1961 funds will be applied to the correction of this problem through modification, redesign, test and qualification of critical components. Fiscal year 1962 funds will be used to simplify the basic design and qualify all component parts.

Engine Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Engine Procurement.....	$1,079,000	$140,000	---
Engine Development.....	---	---	$1,100,000
Total, Engine Development..	$1,079,000	$140,000	$1,100,000

Engine Procurement

The procurement of motors for the eight development vehicles was covered by funding in the fiscal year 1960; additional funds were later required in the fiscal year 1961 for replacement of first- and third-stage engines that were expended on preliminary stage testing of the vehicle. The amount now indicated for 1961 will complete the funding of motors required for the eight basic vehicles.

Engine Development

The key factor in achieving a heavier payload capability and larger nose cone diameter is the utilization of recent advancements in propellant state-of-the-art that have been realized under the Minuteman and Polaris programs. By adapting these existing, higher specific impulse propellants to the configuration required on Scout, a significant increase in performance can be achieved with relative economy of time and resources. The Department of Defense is funding approximately one-third of the program during the fiscal year 1961 with the remaining portion to be completed by NASA with fiscal year 1962 funding. As now planned, the new motor configuration will be available for incorporation in the third operational vehicle (Scout No. 11) scheduled for mid-calendar year 1962.

System Support	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1961 Supplemental	Fiscal Year 1962
Ground Support Equipment.....	$84,000	---	$300,000	$200,000
Launch Services.....	225,000	$500,000	200,000	1,000,000
Engineering Coordination.....	---	---	250,000	300,000
Total, System Support..	$309,000	$500,000	$750,000	$1,500,000

Support of the Scout system requires provision for a complete system check-out capability in the contractor's plant, launch services through launching of the basic eight development vehicles, and engineering effort to insure proper reliability and payload coordination.

Ground Support Equipment

A system check-out capability is being provided at the contractor's plant to achieve a higher level of quality control and to minimize the expensive and time-consuming check-out procedures that would otherwise be required at the launch site. The supplemental 1961 funds will cover the special test tooling and equipment necessary to meet this requirement for Scout No. 5 and all subsequent vehicles. The fiscal year 1962 effort will be directed toward the development of a horizontal pre-flight check-out system for use at the launch site. This system will cover the final check-out prior to flight and will be designed to minimize vehicle preparation and count-down time. The horizontal feature of the system will allow more flexible operation of the vehicle and will reduce the cost and complexity of launch operations.

Launch Services

Funds in this area cover costs of contractor launch personnel that must be planned at a constant level to maintain continuity of the crew. Supplemental 1961 funds will cover costs that were underestimated in the original program pricing. Fiscal year 1962 funds will cover all launchings required for completion of the development program.

Engineering Coordination

As part of the total program effort, contractor services are required on a continuing basis for payload and vehicle integration, preparation of trajectories, range safety analyses, failure reporting, data reduction, and preparation of handbooks. These functions, previously performed in-house by the Langley Center on a limited basis, will require supplemental funds for contractor effort in the fiscal year 1961 with a comparable level of effort in the fiscal year 1962.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

DELTA

SUMMARY OF REQUIREMENTS:

	1960	1961	1962	Page No.
Vehicle Development.....	$6,218,297	$3,550,000	----	RD20-2
Engine Development.....	300,000	50,000	----	RD20-2
System Support.....	5,957,500	8,200,000	$2,900,000	RD20-2
Total.....	$12,475,797	$11,800,000	$2,900,000	

OBJECTIVES:

To provide a reliable space vehicle to replace the Thor-Able, Juno II, Jupiter C, and Vanguard vehicles for medium payload satellites and small payload space probes

JUSTIFICATION:

The Delta vehicle will be used to launch a variety of scientific and operational satellites and space probes until such time as the newer Scout and Thor-Agena B vehicles now under development become available. The Delta is a three-stage vehicle with the first stage a production Thor missile with the nosecone and the guidance unit removed. The second stage is similar to that of Thor-Able and Vanguard with a new engine thrust chamber and an improved radio inertial guidance system. The third stage is a solid propellant rocket motor developed for Vanguard.

Although similar in design to the Thor-Able series, the Delta incorporates a number of changes, including a coast-phase attitude control system that will permit higher injection altitudes and additional flexibility in establishing trajectories. The capabilities of this vehicle were well demonstrated on August 12, 1960 when the second Delta vehicle successfully placed the Echo satellite in a precise, nearly circular orbit, at an altitude of about 1,000 miles; and again on November 23, 1960, when the third Delta placed into orbit the Tiros II meteorological satellite at an altitude of approximately 400 miles. Delta has a payload capability of up to 500 pounds for satellite applications and up to 75 pounds for space probes.

FUNDING REQUIREMENTS:

Vehicle Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Design and engineering.....	$1,600,000	$1,100,000	---
Fabrication.....	4,618,297	2,400,000	---
Thor parts.....	---	50,000	---
Total, Vehicle Development..	$6,218,297	$3,550,000	---

During the fiscal year 1960, the development of the basic Delta vehicle system was essentially completed and procurement of hardware for a number of the test vehicles was well underway. The first launch attempt on May 13, 1960 was unsuccessful due to a failure in the second stage control system. During the fiscal year 1961, the redesign effort generated by this failure was completed and the basic soundness of the design modification was firmly established through the successful firing of Deltas No. 2 and 3. Fabrication of the twelve test vehicles will be completed with 1961 funds; no additional funding for this area will be required in the fiscal year 1962.

Engine Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Engine modification.....	$300,000	---	---
Changes to third stage motors....	---	$50,000	---
Total, Engine Development...	$300,000	$50,000	---

This portion of the Delta program was restricted to the second and third stages. Work on the second stage consisted of the development and substitution of a stainless steel thrust chamber. Changes in the third stage solid propellant motor originally developed for Vanguard were relatively minor and consisted principally of applying closer control over dimensions and performance characteristics. No fiscal year 1962 funds are required to complete the Delta engine development effort.

System Support	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Guidance services.....	$625,000	$1,000,000	---
Shipping costs.....	125,000	200,000	---
Range support services.....	707,500	1,200,000	---
Contractor launch services.....	4,500,000	5,800,000	$2,900,000
Total, System Support.....	$5,957,500	$8,200,000	$2,900,000

Funding for all system support services except launch services will be completed in the fiscal year 1961. Guidance services are procured through the Air Force and cover utilization of the radio guidance systems during each

of the Delta launches. Funds required for shipping costs are transferred to the Air Force which supplies airlift services in the transportation of Delta stages from the West Coast to the Atlantic Missile Range. Range support services include such items as the purchase of propellants, range overtime compensation, provision of telemetry support services, and direct work orders issued to the Atlantic Missile Range. No funding for these items will be required in the fiscal year 1962.

Funding is required in the fiscal year 1962 for contractor launch services to receive, assemble, check out, and launch the vehicle. The requested funding will complete all requirements for contractor launch services for the twelve-vehicle Delta program. The last development vehicle launch is expected late in the fiscal year 1962.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

CENTAUR

SUMMARY OF REQUIREMENTS:

	1960	1961	1961 Supplemental	1962	Page No.
Vehicle Development..	$19,344,203	$28,700,000	$13,394,000	$32,800,000	RD21-3
Engine Development...	16,300,000	16,100,000	---	19,500,000	RD21-4
System Support.....	1,000,000	2,200,000	2,181,000	4,100,000	RD21-6
Total.....	$36,644,203	$47,000,000	$15,575,000	$56,400,000	

OBJECTIVES:

To develop a general purpose launch vehicle of high-performance and reliability for Earth satellite, lunar, and planetary exploration missions.

JUSTIFICATION:

The NASA mission requires launch vehicles capable of injecting, on a wide variety of space trajectories, scientific spacecraft differing extensively in weight and volume. In order to cover the range of NASA mission requirements at minimum cost of time and money for launch vehicle development, procurement, and operations, NASA has settled on a relatively few different multi-purpose launch vehicles ranging from the Scout to the Saturn. These launch vehicles will be used repeatedly by the NASA and in most cases by the Department of Defense as well, in order to build reliability, which is a dominant factor in the cost and rate of progress in space exploration. Composed of an Atlas first stage and a new liquid-hydrogen liquid-oxygen second stage, the Centaur is a vitally important and urgently needed member of this launch vehicle family. On a low Earth-orbit mission, the Centaur will have a payload-carrying capacity of 8,500 pounds, thus filling the need for a vehicle capable of carrying payloads which are too heavy for the Thor or Atlas-Agena B vehicles (up to 5,000 pounds) and too light to warrant the use of the more expensive Saturn vehicle (payload 19,000 pounds). There is no other vehicle currently in existence or under development which can perform this role.

It is planned to launch ten Centaur vehicles between late-calendar year 1961 and mid-calendar year 1963 as part of the vehicle development program. An early and successful completion of this flight program is essential for the following reasons:

1. Centaur is the first rocket vehicle to utilize liquid-hydrogen and liquid-oxygen as propellants. This combination promises more than one-third greater performance than the conventional kerosene liquid-oxygen propellant combination. Successful solution to the many problems associated with the use of this advance propellant combination will constitute a substantial technical breakthrough in rocket performance, an area in which the United States space program most needs improvement.

2. The Centaur second-stage engine will be used to power the S-IV and S-V stages of the Saturn vehicle, the development of which carries the highest national priority.

3. All the upper stages of Saturn will utilize liquid-hydrogen as fuel. The success of the Saturn program, therefore, depends upon the early solution of hydrogen problems encountered in the Centaur program.

4. The Rover nuclear rocket engine will use liquid-hydrogen, and is, therefore, similarly dependent upon Centaur's early success.

5. The lunar and planetary exploration programs of NASA and the Department of Defense Advent 24-hour communication satellite program, cannot proceed effectively until a vehicle of Centaur's capability is available.

In view of the many developmental problems to be overcome and the need for adequate time to construct the necessary facilities for ground testing, launching, tracking and data handling, late-1961 was selected as the earliest date that a first launch of Centaur could be scheduled. The budget amounts and time phasing are considered the minimum to enable meeting the time schedule for the technical objectives established for the Centaur development program. A delay in providing funds on the time schedule indicated will necessitate either delaying the flight program and thus the important programs cited above which depend upon Centaur's early success, or attempting a flight program without having completed the minimum level of preliminary ground testing and reliability assurance work which sound engineering dictates, thus hazarding a failure of the flight program and consequent damage to our international prestige. Both of these alternatives are unacceptable.

The amount requested as a 1961 supplemental estimate is a critically important element of the minimum funding plan. It is required to help finance the pre-launch efforts without which the success of the first

Centaur launch, and follow-on launches, would be in considerable jeopardy. It will provide funding for:

1. Procuring and installing a television system for in-flight observation of propellant behavior in the first three Centaur flights. Non-visual instrumentation for this purpose has not been developed.

2. Procuring and launching four Aerobee rockets carrying zero-gravity test articles. These tests are necessary to give data on the behavior of liquid-hydrogen in the air-less, zero-gravity environment to be encountered later by actual Centaur flight vehicles.

3. Extending the amount of component ground testing necessary to improve our confidence in the adequacy of vehicle components and launch site equipment to perform their intended function.

4. Emergency overtime at contractors' plants to help meet the very tight schedule of events leading to first launch.

5. Engineering changes necessary in system components to make them reliable for first flight.

6. Additional ground instrumentation to adapt the existing NASA world-wide instrumentation network for use with Centaur.

The fiscal year 1962 estimates provide for a continued and strengthened Centaur development program. Recent technical difficulties with the development of the Centaur engine and its associated equipment have given evidence of insufficient strength in the development phase. It has been decided to extend the development period approximately four months and to strengthen it substantially by increased vehicle ground tests and increased engine ground tests prior to and during the flight program. It is considered essential that this strength be added to insure vehicle success in flight and to help avoid the very high costs of development flight failure.

FUNDING REQUIREMENTS:

Vehicle Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1961 Supplemental	Fiscal Year 1962
Second-Stage Design and Engineering.....	$4,444,203	$3,940,000	$3,810,000	$5,750,000
First-Stage Procurement and Modification.....	800,000	5,600,000	---	8,400,000
Fabrication of Second-Stage Test Vehicles.....	11,900,000	6,160,000	6,984,000	6,460,000
Ground Testing.....	2,200,000	10,350,000	1,800,000	5,640,000
Reliability.....	---	2,650,000	800,000	6,550,000
Total, Vehicle Development.....	$19,344,203	$28,700,000	$13,394,000	$32,800,000

This portion of the program includes the design, engineering, fabrication, ground testing, and reliability testing for the Centaur second stage (less engines), and the design of modifications to, and fabrication of, the first stage (Atlas). Two Centaurs have been assembled. The first Atlas-Centaur has been erected on a stand at the Atlantic Missile Range for compatibility checks. Three guidance sets have been delivered. Ground tests are proceeding at the contractors' test facilities, and at the Langley Research Center. Hot static firings will soon begin at a contractor's facility and at the Lewis Research Center.

Second-Stage Design and Engineering

This item includes engineering services for the design of the Centaur second stage, engineering studies of various flight trajectories, and technical reports. Extensive design work is necessary to improve the performance of tank insulation, tank vents, propellant acquisition system, boost pumps and cooldown system. Component re-design will be necessary as the testing program progresses.

First-Stage Procurement and Modification

This item includes design of modifications necessary in the Atlas ICBM to adapt it for use with the Centaur second stage, and the fabrication and check-out of the modified Atlas. Ten such Atlases are provided for in the program.

Fabrication of Second-Stage Test Vehicles

This item includes the manufacture of Centaur second-stage vehicles (less engines) and their check-out. Ten such vehicles are provided for in the program. New vehicle components must be fabricated to reflect the redesigns necessitated by the results of ground and flight tests.

Ground Testing

This item includes preparation of a special test vehicle and other vehicle components, and the carrying out of tests to obtain data on storage, pumping and heat transfer characteristics of liquid-hydrogen, operation of integrated attitude control systems, jettisoning of heat insulation panels, and on the operation of integrated second-stage flight propulsion systems. The program includes the estimated costs of ground systems-tests of a complete flight-type second stage vehicle in an altitude-simulation facility. These tests, or their equivalent, are considered a prerequisite to adequate flight reliability.

Reliability

This item includes environmental testing, on the ground and in flight, of multiple samples of vehicle components (such as guidance components), statistical analysis and reporting of the results of such tests, and feedback of test results to the component designer to aid in re-design of the component, if necessary.

Engine Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Engine Design and Engineering.....	$14,700,000	$8,400,000	$800,000
Fabrication of Prototype and Production Engines.....	1,600,000	6,000,000	5,160,000
Ground Testing.....	---	1,200,000	13,240,000
Ground Support Equipment.....	---	500,000	300,000
Total, Engine Development.....	$16,300,000	$16,100,000	$19,500,000

The Centaur second-stage engine is the first flight-configured rocket engine utilizing liquid-hydrogen and liquid-oxygen as propellants. It features a tubular-walled combustion chamber fed by a turbo-pump assembly that is powered on the "boot-strap" principle, i.e., the turbine derives its power solely from the heat that is transferred from the combustion chamber to the liquid-hydrogen coolant. This portion of the program includes the design, engineering, fabrication, and ground testing of the Centaur second-stage engines and the auxiliary ground equipment necessary to support the transportation, checkout, and firing of Centaur engines in ground tests and in the flight program. Preliminary flight rating tests of the Centaur hydrogen engine are currently under way and will be completed soon. Twelve ground test engines and sufficient flight engines for the ten Centaur development vehicles, plus spares, are provided for in the program. Ground tests at the West Palm Beach test facility are currently under way in support of the coming flight program.

Engine Design and Engineering

This item includes engineering services for the design of the Centaur second-stage hydrogen engine, engineering studies of the engine's adaptability to operation under off-design conditions, and technical reports. This design work will continue into the fiscal year 1962 to improve the engine ignition, thrust control and cooldown systems, sufficiently to qualify for flight.

Fabrication of Prototype and Production Engines

This item includes the manufacture of Centaur second-stage engines and their checkout prior to delivery. Twelve ground test engines embodying the design improvements currently under investigation are required to

support the Centaur ground testing program at the engine contractor's plant, in the altitude facility, at Edwards Air Force Base and at the Lewis Research Center.

Ground Testing

This item includes the fabrication of non-deliverable developmental engines, their installation in the West Palm Beach test facility, and the conduct of the tests in that facility. It also includes technical services provided by the engine contractor during engine-vehicle tests at the vehicle contractor's test facilities. Considerable effort is required to improve the safety and utilization of contractor test stands and to give heavy emphasis to reliability by extensive engine ground tests. Over 100 additional engine runs on the ground are scheduled prior to flight.

Ground Support Equipment

This item includes the design, fabrication, and check-out of auxiliary equipment necessary to support the second-stage engines. Engine ground handling dollies, and engine testing and check-out equipment for use at ground test sites are required.

System Support	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1961 Supplemental	Fiscal Year 1962
Ground Instrumentation.....	---	---	$1,981,000	---
Launch Services.....	---	$1,500,000	---	$4,100,000
Test Ground Support Equipment..	$1,000,000	700,000	200,000	---
Total, System Support.....	$1,000,000	$2,200,000	$2,181,000	$4,100,000

This portion of the program includes the design, engineering, fabrication, ground testing, and installation of tracking, telemetry and communications equipment of existing down-range tracking stations to adapt these stations to their intended use for Centaur flights. Included are test ground support equipment at the Centaur launching site at the Atlantic Missile Range and the services required at the launch site to prepare the first-stage and second-stage vehicles for launch and to launch them. Launching services for the ten Centaur development vehicles are provided.

Ground Instrumentation

This item provides for the procurement and installation of new ground equipment required at existing tracking stations to track, recieve data, and transmit the data received from the Centaur vehicles in flight.

Launch Services

This item provides for services by the Centaur contractors required at the launch site to prepare the first-stage and second-stage vehicles for launch and to launch them.

Test Ground Support Equipment

This item provides for the design, fabrication, checkout and installation of the specialized test and operating equipment at the Atlantic Missile Range necessary to support the launches of the Centaur vehicle.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

SATURN

SUMMARY OF REQUIREMENTS:

	1960	1961	1962	Page No.
Vehicle Development.....	$33,755,000	$67,253,000	$157,770,000	RD22-6
Engine Development.....	14,938,000	33,800,000	34,070,000	RD22-9
System Support.....	8,627,000	17,005,000	32,320,000	RD22-10
Total.....	57,320,000	$118,058,000	$224,160,000	
DOD.....	47,870,000			
NASA.....	9,450,000			

OBJECTIVES:

To develop a multi-purpose vehicle system using a "building-block-approach" for the upper stages to achieve a variety of configurations and capabilities. This concept will provide a family of vehicles to meet future space requirements for large payloads on a sound basis of reliability, safety, timeliness, and economy.

JUSTIFICATION:

The Saturn vehicle development, which carries the highest national priority, involves the development of vehicle stages, a guidance system, engines, and the development of special support equipment for handling, check-out, transportation, and launching. Saturn will be a multi-purpose vehicle, capable of sending large payloads into interplanetary space and even larger payloads (3 to 5-man crew) into orbits near the Earth.

The Saturn project was initiated by the Advanced Research Projects Agency (ARPA) of the Department of Defense (DOD) in August of 1958. The first-stage concept, based on the utilization of multiple "off-the-shelf" engines to obtain a thrust of 1,500,000 pounds has remained relatively unchanged since that time. The use of multiple engines in each stage will provide the capability of carrying out the desired space mission with one engine inoperative. After the President, in early November 1959, announced his intention of transferring the Saturn program from the DOD to NASA, a joint NASA-DOD committee recommended that all the upper stages of Saturn should utilize high-energy propellants (specifically liquid hydrogen and liquid oxygen). The configurations now planned are the two

or three-stage C-1 (stages S-I + S-IV + S-V) and the two, three- or four-stage C-2 (stages S-I + S-II + S-IV +S-V). It is significant to note that the Saturn stages S-I, S-II, and S-IV are each physically larger than any missiles previously developed in the United States, and also the latter two are pioneering developments using the new cryogenic fuel, liquid hydrogen. The planned launch schedule for the ten Saturn development vehicles is one in calendar year 1961, two in 1962, five in 1963 and two in 1964.

The Saturn C-1 is being reconfigured to accommodate design changes evolving from the S-IV stage development program (i.e., the incorporation of six engines instead of four.) With the increased thrust available from the S-IV stage, the Saturn C-1 vehicle, when comprised of two stages (S-I and S-IV), will put increased payloads into low orbit with higher reliability than can be accomplished with the three-stage configuration (S-I, S-IV and S-V). Refined mission analysis has indicated that the primary role of the Saturn C-1 vehicle will be orbital missions for such space programs as Apollo.

The additional stage (S-II) in the second version of Saturn (the C-2) will provide approximately 2 times the payload capability of the C-1 and will add to this country's vehicle capability by making possible more difficult missions, such as manned circumnavigation of the moon and orbiting of other planets. The primary role for the Saturn C-2 will be escape missions with early application to hyperbolic reentry testing for the Apollo program. The planned developmental launch schedule for the C-2 version provides for one launch in calendar year 1964, four in 1965, and two in 1966.

A more detailed discussion of the various developments which make up the whole Saturn program follows.

Vehicle Development

The configuration of Saturn currently under development (the C-1) is a two-stage or a three-stage vehicle. The first stage (S-I) is under development as an in-house project at the Marshall Space Flight Center, utilizing engines manufactured by the Rocketdyne Division of North American Aviation, Inc. The second stage (S-IV) and the third stage (S-V) are being developed by the Douglas Aircraft Company and by the Convair-Astronautics Division of General Dynamics Corporation, respectively. The latter two stages will utilize engines provided by the Pratt & Whitney Division of United Aircraft Corporation. An all-inertial guidance system will be employed with the C-1. The two-stage configuration will be capable of placing approximately ten tons of payload into orbit about the earth, and the three-stage version will send about three tons beyond the earth's effective gravitational field. Assembly of the first and second flight vehicles (SA-1 and SA-2), each consisting of a live booster and dummy upper stages, is now underway. Both static and dynamic tests of the first stage (S-I) are being made in 1961.

The planned growth version of Saturn (the C-2) will be used in two-stage, three-stage, and four-stage configurations. For the C-2, a large new second stage (S-II), also using hydrogen and oxygen, must be developed. The former C-1 second stage (S-IV) becomes the new third stage and the former C-1 third stage (S-V) becomes the new fourth stage. An advanced all-inertial guidance system is planned to be used with the Saturn C-2. Two-stage or three-stage vehicles will be used for most earth orbit missions; the three-stage version also will be used for lunar and interplanetary missions. Extremely high energy missions, i.e., probes to Jupiter or Mercury, will require the four-stage version. It is significant to note that the heavy payload launching potential of the Saturn cannot be attained unless the new second stage (S-II) is provided.

S-I stage: The first stage (S-I) of Saturn employs eight Rocketdyne H-1 engines, each delivering 188,000 pounds of thrust at sea level, for a total thrust of 1.5 million pounds. The stage is about 21-1/2 feet in diameter and 80 feet long. Liquid oxygen and RP-1 (kerosene) form the propellant combination; they are carried in a cluster of eight elongated tanks, of the same diameter as the Redstone missile tank, surrounding one elongated tank of the same diameter as the Jupiter tank. The engines can be individually shut off on command when an incipient malfunction is detected. Since the engines are simplified adaptations of the well-proven engines used in Atlas, Thor, and Jupiter, the number of malfunctions during flight is expected to be low.

S-II stage: This new second stage, to be used only in the Saturn C-2 configuration, will be the same diameter as the S-I stage (21-1/2 feet), will contain over 300,000 pounds of liquid hydrogen and oxygen, and will be powered by four engines. Present plans call for the initiation of S-II stage development in the first half of the fiscal year 1962.

S-IV stage: The second stage (S-IV) of the Saturn C-1 configuration utilizes the liquid-hydrogen liquid-oxygen propellant and a cluster of six Centaur engines built by Pratt & Whitney Aircraft to provide a total thrust of 90,000 pounds. This stage is about 18-1/2 feet in diameter with a length of over 40 feet and a propellant capacity of 100,000 pounds. A preliminary study contract followed by a development contract late in July 1960, initiated the development of this stage; its first flight is planned for early 1963.

S-V stage: The third stage (S-V) of the Saturn C-1 is a Centaur upper stage, modified to fit Saturn launch equipment. Two of the same engines which are to be utilized in the S-IV are to be used to power this stage. It will be 10 feet in diameter, and will contain about 28,000 pounds of usable hydrogen/oxygen propellant. Coasting, attitude control, and engine restart capabilities will be incorporated in this stage, as in Centaur, to permit the attainment of more difficult orbits and deep space trajectories. A preliminary study contract was awarded in October 1960. Due to primary emphasis on orbital missions for the first Saturn vehicles, the S-V development will be limited to engineering design studies in the fiscal year 1962.

Guidance: The guidance system will be physically located above the upper stage of each C-1 and C-2 configuration, and will send commands to the control systems of all vehicle stages to ensure that the proper trajectory is flown. An all-inertial system will be used, in order that a number of ground guidance stations spread around the world will not be required. It is planned to use a digital computer linked to the required sensors, so that a greater storage capacity for trajectory information will be available. The trajectory changes associated with engine-out flight capability will require this greater guidance flexibility.

System integration: The Marshall Space Flight Center is responsible for the over-all design and development of the Saturn vehicles, including the system check-out and launching and the integration of the various developments to ensure that all pieces are compatible with each other and with the planned launching technique. The Marshall Center is also responsible for the design and development of the S-I stage. The Douglas Aircraft Company has the responsibility for the S-IV stage, and Convair-Astronautics for the S-V stage. The guidance system development responsibility will be a partnership effort between the Marshall Center and industry. The Goddard Space Flight Center, the Jet Propulsion Laboratory and the Space Task Group will have the responsibility for the design and development of the payloads to be placed atop Saturn.

Engine Development

The rocket engines to be used in Saturn are developed under separate contracts and are supplied to the respective stage contractors as government furnished equipment. This procedure helps to minimize the number of engine developments required; one engine can thus be used in more than one stage. Described herein are the so-called H-1, J-2, and RL-10 engines. The H-1 and J-2 engines are used in the Saturn S-I and S-II stages, respectively, and the RL-10 engine is used in both the S-IV and S-V stages. A series of static tests, using eight clustered H-1 engines for a total firing time of more than 500 seconds at the 1,320,000-pound thrust level, has been completed.

H-1 engine: The H-1 engine is the logical outgrowth of the engines already developed for the Atlas, Thor, and Jupiter missiles. The engine burns liquid oxygen and kerosene. It is a simplified version of the missile engines previously mentioned which is being uprated from 165,000 to 188,000 pounds thrust. Because of the simplifications incorporated in this engine, its development history, thus far, has been outstandingly good. With the presently achieved record of reliability the use of eight of these engines in the Saturn S-I stage should provide a rocket power plant which is considerably more reliable, at any given point in time, than any other of comparable thrust rating.

RL-10 Engine: The RL-10 engine is to be used in both the S-IV and S-V upper stages of Saturn and is basically the same engine that will be used in the Centaur vehicle. This 15,000-pound thrust engine will be the first flyable engine to utilize the high-energy propellant combination of liquid hydrogen and liquid oxygen. Changes to the basic Centaur engine for adaptation to the six-engine cluster to be used in S-IV Saturn will be kept to a minimum.

J-2 Engine: Four J-2 engines will be used to power the S-II stage. This engine, capable of producing 200,000 pounds of thrust, is the largest engine currently under development that uses liquid oxygen and liquid hydrogen for propellants. Since the S-II stage development is being advanced in conjunction with the Saturn C-2 schedule acceleration, experimental hardware procurement must be funded for Saturn in fiscal year 1962.

System Support

A number of areas of developmental effort are required to bring a space launching vehicle to such a level of reliability that expensive payloads can reasonably be assigned to it. Some of these areas of effort do not result in hardware which flies with the operational vehicle, yet they are nevertheless necessary if the hardware developments are to be successful. Such areas are grouped under System Support. In the case of the Saturn program, the System Support effort includes the development of ground support equipment, the development of appropriate system instrumentation, the development of satisfactory launching operational techniques, and the procurement of the necessary propellant components. The ground support equipment necessary to permit the transportation of the large first stage and to provide for the fueling, check-out, and launching at the Atlantic Missile Range will be complete in 1961.

Ground support equipment: This encompasses the development of those items of equipment which are used for the handling and check-out of the Saturn vehicle. Any such equipment which is related to the construction of facilities for the Saturn program are budgeted in the Construction of Facilities appropriation. The development of equipment items not related to facility construction, but to the Saturn vehicle itself, are budgeted here. Examples of these latter items are road transporters for the various stages, handling slings and dollies, and electrical and pneumatic check-out panels. In general, these items may be used either at the Marshall Center, supporting either the static firing effort or the pre-shipment mating and check-out, or at the Atlantic Missile Range, supporting either the hangar checks or the on-pad checks. Some items, such as the transporters, will stay with the vehicle, and hence be used at both locations.

System instrumentation: During a rocket vehicle development, obtaining knowledge of the environment to which the vehicle is exposed during flight is essential to the development team, if they are to know what made the vehicle perform as it did. Internal pressures,

external pressures, vibration levels, compartment temperatures, the activation of essential electrical relays, valve operations, and the response of the guidance sensors all serve as examples of the type of information which is needed. An extensive set of vehicle-born instruments is required to measure these parameters and to telemeter the information back to the ground. Also needed, of course, are telemetry receivers and decoders, to present this information in usable form. Since Saturn is larger and more complex than missiles previously developed, more extensive and more sophisticated system instrumentation is needed to gather, transmit, and present the necessary information. It is noteworthy that this system instrumentation is primarily used during the vehicle development flights; far less vehicle instrumentation will be required during Saturn's operational phase.

Launch operations: This support area includes the supply of material for general use at the launch complex, the supply of replacement parts for the launch complex, the transport of the various stages, and studies concerning possible improvements of either the launching equipment or the launching techniques.

FUNDING REQUIREMENTS:

Vehicle Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Development Engineering:			
S-I stage	$14,940,000	$13,110,000	$16,000,000
S-II stage	---	---	12,900,000
S-IV stage	805,000	13,150,000	14,600,000
S-V stage	---	700,000	2,000,000
Guidance system	1,460,000	1,370,000	3,200,000
System integration	850,000	2,485,000	9,740,000
	18,055,000	30,815,000	58,440,000
Flight and Expendable Hardware:			
S-I stage	13,950,000	25,018,000	53,100,000
S-II stage	---	---	9,300,000
S-IV stage	---	6,110,000	23,400,000
S-V stage	370,000	1,200,000	---
Guidance system	1,380,000	3,387,000	7,670,000
System integration	---	723,000	5,860,000
	15,700,000	36,438,000	99,330,000
Total, Vehicle Development	$33,755,000	$67,253,000	$157,770,000

Development Engineering

S-I stage: The first flight test vehicle of the Saturn first stage has already been designed, fabricated, and is undergoing static tests. Additional research and development work will consist primarily of testing of a modified control system; study of trajectories and interactions with structural dynamic effects in first stage; launching of the first and second Saturns (SA-1 and SA-2) with dummy upper stages; static tests to obtain feedback information from flights; simplification of assembly and checkout; proof of the structural and dynamic integrity of the booster; and major efforts on reliability proof of components. Additional effort will be required to determine the structural modifications required for the C-2, S-I configuration.

S-II stage: With the President's decision to accelerate the Saturn C-2, preliminary design of the S-II stage will be conducted and more detailed analysis made of higher payload escape missions. A contract for the development of the S-II stage will be initiated during the first half of fiscal year 1962. The remainder of the year's effort will be concentrated primarily on vehicle design and development facility modification.

S-IV stage: Initial design work on the S-IV stage was based on a planned engine of higher thrust than the RL-10 used in the Centaur vehicle. In order to take advantage of the engine already developed for Centaur and to avoid another expensive engine development program, a decision has been made to use the RL-10 engine for the Saturn S-IV stage. This engine should provide maximum reliability at an early date. However, in order to provide adequate thrust, six engines will be required for the S-IV design instead of the four advanced design engines that had been planned. Although some of the initial design work of the S-IV will have to be modified to accommodate the six RL-10 engines, no schedule slippage will be incurred by these modifications. During much of the fiscal year 1962, "battleship" testing of the S-IV propulsion system will be carried out. In "battleship" testing the flight vehicle system is made simpler and more rugged, in order to accommodate possible developmental mistakes. During the same interval, an experimental determination will be made of the interactions between the S-IV tank structure and the insulation. The insulation is needed to keep hydrogen from vaporizing excessively and the liquid oxygen in proximity to the hydrogen from freezing. Late in the year, static testing of a fully instrumented flight stage will be initiated, to assure that the S-IV is satisfactory for flight testing. Other development programs which will be carried on include the development of the S-IV control system and reliability testing of the major flight components.

S-V stage: Although most missions for Saturn can be accomplished with the stages defined above, the addition of another stage (S-V) may prove useful when certain high-energy missions must be performed. It is planned that for these missions the S-V stage will be obtained by using

a Centaur that has been modified to the minimum extent possible. Investigations into the operational requirements of these high-energy missions will be made and design analyses will be initiated to investigate the adaption of Centaur for these purposes.

Guidance system: During the fiscal year 1962, the development of a high-accuracy, digital-type guidance system will be continued, with emphasis on the flexibility which must be obtained in order that the Saturn may achieve all the varied types of planned missions. Extensive evaluation of improved sensor and computer equipment must be vigorously pursued. The initial guidance will be modified as required by evaluation of the results of the first Saturn flight tests. The Centaur guidance system will be analyzed to determine the modifications necessary to satisfy Saturn requirements.

System integration: The problem of system integration is expected to grow larger as more types of payloads are assigned to Saturn. The planned program includes resolution of all interface problems arising between stages, the determination of the various systems effects due to the interactions expected during flight (propellant, aerodynamic, thermodynamic, and trajectory problems) and detailed integration efforts on the initial Saturn payloads.

For maximum economy and reliability of the Saturn vehicle, recovery methods must be examined. Also, in later phases of the program, increased launching rates will require that the current barge transportation method must be augmented, possibly through modification of an existing transport aircraft such as the C-133. The reliability of both the C-1 and C-2 configurations can only attain its highest potential value if existing propulsion, structural, aerodynamic, guidance and control subsystems and components are adequately proven in flight environments obtained from the actual flight test program. Accordingly, analysis and synthesis of reliability programs for specific equipment will be conducted.

Flight and Expendable Hardware

S-I stage: In the early stages of the Saturn development program a lead time of 23 months is required for most of the components which are assembled to form the S-I stage. During the fiscal year 1962 components will be ordered to satisfy the requirements of five boosters (flights SA-5 through SA-9). Also during this period, the assembly for four boosters will be completed (those to be used in flights SA-4 through SA-7), as well as the check-out for the four boosters which will fly in flights SA-3 through SA-6. Other components will be obtained to serve as flight spares, to support the reliability testing program, and to aid in the program of general development testing. For the acceleration of the Saturn C-2 vehicle, earlier delivery of hardware will require additional funding for the S-I stage contractor to cover advanced engineering planning, test facility modification, assembly, inspection and check-out equipment as well as hardware and assembly manufacturing labor.

S-II stage: Sufficient components and equipment will be procured in 1962 to insure the feasibility of the preliminary design proposed and to insure that the first flight test components will be available on time.

S-IV stage: Components for five stages (SA-4 through SA-8) will be ordered during the fiscal year 1962. Assembly of the two stages to fly in SA-4 and SA-5 will be completed and the pre-flight static firing and Government acceptance of the S-IV stage for SA-4 are scheduled to occur. Also to be obtained in this period are spare flight components and components to support both the general development testing and the reliability testing programs.

Guidance system: The guidance system for Saturn operates on the same lead time schedule as the S-I stage. During the fiscal year 1962 components will be ordered to support guidance systems for five Saturn flight vehicles (SA-5 through SA-9) as well as components to support general development testing, reliability testing, and to serve as flight spares. Guidance systems will be assembled and checked out to support flights 3 through 6. The Centaur guidance system will be modified for test flights in SA-5 and SA-6; flight spares and checkout equipment will be required.

Systems integration: Components and subsystems, which are necessary to solve, experimentally, the various propellant, aerodynamic, thermodynamic and trajectory problems will be purchased as required. Engineering analyses, including model testing of transportation of Saturn stages by aircraft will be conducted. Investigations, including model testing, will be performed on techniques for recovery of Saturn launch vehicles. Reliability testing of components and subsystems will be undertaken to improve the reliability of both the Saturn C-1 and C-2.

Engine Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Development Engineering:			
H-1 engine.....	$6,775,000	$5,325,000	$4,500,000
RL-10 engine.....	300,000	12,100,000	3,000,000
	7,075,000	17,425,000	7,500,000
Flight and Expendable Hardware:			
H-1 engine.....	7,365,000	11,475,000	11,570,000
RL-10 engine.....	498,000	4,900,000	12,000,000
J-2 engine.....	---	---	3,000,000
	7,863,000	16,375,000	26,570,000
Total, Engine Development	$14,938,000	$33,800,000	$34,070,000

Development Engineering

H-1 engine: During the fiscal year 1962 the major developmental work on this engine should be completed. The engine will have successfully passed its preliminary flight rating test at the derated level of 165,000 pounds of thrust, and its final qualification test at the 188,000-pound thrust level. Therefore, the engineering effort on this engine will continue to decline. The other developmental effort will include emphasis on reliability and such special developments as are shown to be necessary by the results of the S-I static firing program and of actual Saturn flights.

RL-10 engine: With the reconfiguration of the S-IV stage propulsion to use six RL-10 engines, the RL-10B development program has been terminated. Development funds originally planned have been reduced to a level required to modify the Centaur engine (RL-10) configuration to the Saturn S-IV stage requirements.

Flight and Expendable Hardware

H-1 engine: Sufficient engines and spares will be delivered to support the S-I assembly plan, the S-I static firing program, and the actual Saturn flights. In addition, components will be procured as necessary to support the H-1 development program and the associated reliability program. Included, also, is the provision of instruction manuals and field engineering support for the engine.

RL-10 engine: Engines and spares will be delivered to support the S-IV assembly plan. Reconfiguration of the S-IV, changing the number of engines from four to six, will require additional hardware procurement and the increased production rate for the engine will require augmentation of test facilities. Special components, needed either in the development program or in the associated reliability program, as well as field engineering support and instruction manuals will be provided.

J-2 engine: To support the acceleration of the S-II stage, procurement of long lead time items for ground test engines, to be supplied to the S-II stage contractor, will be required.

System Support	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Development Engineering:			
Ground support equipment.....	$2,555,000	$1,486,000	$2,400,000
System instrumentation.....	2,532,000	1,120,000	1,500,000
Launch operations.....	---	50,000	1,700,000
	5,087,000	2,656,000	5,600,000

Flight and Expendable Hardware:	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Ground support equipment.....	$1,500,000	$5,419,000	$10,960,000
System instrumentation.....	1,090,000	2,280,000	5,900,000
Launch operations.....	---	150,000	600,000
Propellants.....	950,000	6,500,000	9,260,000
	3,540,000	14,349,000	26,720,000
Total, System Support.....	$8,627,000	$17,005,000	$32,320,000

Development Engineering

Ground support equipment: As of the beginning of the fiscal year 1962 all the necessary ground support equipment to support the first three Saturn flights from Launch Complex No. 34 at the Atlantic Missile Range will have been obtained. The major engineering tasks during the fiscal year 1962 will be to incorporate modifications into the equipment designs as dictated by actual field handling and flight experience, and to incorporate additional modifications as required for compatibility with Launch Complex No. 37. Complex No. 37 is being designed to be able to handle both the C-1 and the C-2 configurations of Saturn and hence is not a carbon copy of the Launch Complex No. 34.

System instrumentation: The final proofs of satisfactory operation of the new telemetering and tracking instrumentation will be obtained. There will be incorporated into the various designs whatever modifications to the instrumentation seem required as a result of the experience obtained in the first Saturn flights. Also in this time period will be included an extensive effort on improving component reliability for instrumentation.

Launch operations: Studies will be undertaken during the fiscal year 1962 concerning better water transportation techniques for the Saturn stages, the possible utility of alternate methods of transporting these stages, and possible improvements in launching techniques, particularly from the standpoint of minimizing vehicle time-on-stand. Additional experimental explosive research data will be obtained on liquid-oxygen and liquid-hydrogen to establish the launch structure design parameters.

Flight and Expendable Hardware

Ground support equipment: During the fiscal year 1962 orders will be placed for the procurement of the special ground support equipment required for Saturn. The equipment will be used for fueling, launching,

handling, transport, and field check-outs. Spare check-out equipment and equipment to replace those items which may be destroyed during the launching operations will also be procured. Contractor field support for the check-out of the equipment is included.

System instrumentation: Instrumentation will be ordered for five Saturn flight vehicles (SA-5 through SA-9). It is presently estimated that approximately 1,000 telemetry channels per vehicle will be employed. The assembly and check-out of flight instrumentation for four vehicles will also be carried out in the fiscal year 1962. Spare tracking and field check-out equipment for the instrumentation will be obtained.

Launch operations: The funds under this heading are required for transporting the various Saturn stages to the Atlantic Missile Range, supplying replacement parts for Launch Complex No. 34 resulting from losses during Saturn launchings, and supplying standard materials and equipment required in the launching operations.

Propellants: Propellants must be supplied for the Saturn flights, for the development of the Saturn stages (S-I, S-II, S-IV), and for development and acceptance tests of the H-1 and RL-10 engines. The program will require liquid oxygen, liquid nitrogen, liquid hydrogen, kerosene, and helium. The appreciable rise in the 1962 estimate over the previous year is due to much more extensive testing of the RL-10 engine and of the S-IV stage.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1962 ESTIMATES

VEGA

SUMMARY OF REQUIREMENTS:

	1960	1961	1962	Page No.
Vehicle Development.....	$840,000	---	---	RD23-2
Engine Development.....	1,780,000	---	---	RD23-2
System Support.....	1,380,000	---	---	RD23-2
Total.....	$4,000,000	---	---	

OBJECTIVES:

The Vega program was initiated by the National Aeronautics and Space Administration to provide a space-research vehicle capable of launching earth-satellite and deep-space payloads at the earliest possible date. However, in light of other vehicle developments of similar capability, the Vega program was terminated in December 1959, to reduce the total number of vehicle types required to support the United States space program.

JUSTIFICATION:

The Vega vehicle was planned for use as either a two-stage or three-stage vehicle system. In both versions, the first stage was an Atlas and the second stage a modified Vanguard (first stage), incorporating an altitude start and re-start capability. The third stage employed a 6,000 pound-thrust storable fuel engine under development by NASA's Jet Propulsion Laboratory.

Incrementally funded contracts were initiated in the fiscal year 1959 for the design, development, fabrication, test, and launch of eight Vega vehicles, including modification of the Atlas first-stage and development of the Vega second-stage power plant. Concurrently, the Vega third-stage and the associated lunar instrumentation developments were undertaken by the Jet Propulsion Laboratory. Design of modifications to the first-stage Atlas was completed during the fiscal year 1959; development in all other areas continued into the fiscal year 1960. On December 11, 1959, the Vega program was terminated.

FUNDING REQUIREMENTS:

	Fiscal year 1960	Fiscal year 1961	Fiscal year 1962
Vehicle Development:			
Second stage.....	$700,000	---	---
Third stage.....	140,000	---	---
	840,000	---	---
Engine Development:			
Second-stage engine.....	880,000	---	---
Third-stage engine.....	900,000	---	---
	1,780,000	---	---
System Support:			
Lunar instrumentation development.....	1,380,000	---	---
Total.....	$4,000,000	---	---

NATIONAL AERONAUTICS AND SPACE ADMINISTATION

FISCAL YEAR 1962 ESTIMATES

TRACKING AND DATA ACQUISITION

SUMMARY OF REQUIREMENTS:

	1960	1961	1962	Page No.
Advanced Research.....	$190,600	$3,235,500	$2,862,500	RD24-2
Advanced Technical Development	4,074,600	7,064,900	10,208,000	RD24-7
Flight Program:				
Network Operations.....	7,943,160	12,784,900	14,106,600	RD24-15
Network Communications.....	580,200	6,660,700	9,122,900	RD24-15
Computation and Data Reduction.....	3,400,440	1,910,000	2,350,000	RD24-15
Total.....	$16,189,000	$31,656,000	$38,650,000	

OBJECTIVES:

To continue to operate tracking and data acquisition facilities necessary to support the over-all NASA space flight program; to provide tracking and data acquisition support for space flight operations upon request by other Government agencies; and to provide for research and development on improved tracking and data acquisition systems and equipment. Some major technical objectives included in fiscal year 1962 program are:

1. Provide tracking and data acquisition services for NASA and in support of certain Department of Defense projects.

2. Improvement of the over-all operating efficiency and accuracy of existing NASA tracking stations.

3. Development of prototype tracking and data acquisition equipment to provide greater precision and versatility.

4. Development of advanced communications techniques for spacecraft at planetary distances.

5. Speed-up of data handling, data reduction, and on-site data computing to reduce time lag between the conduct of the experiment and the results.

JUSTIFICATION:

In all cases of space flight operations, whether a scientific satellite, a space probe, a sounding rocket, or a manned vehicle, there is a need for tracking stations capable of providing orbital data or position time histories, and a need for telemeter receivers for data acquisition. These stations must be properly integrated by a communications network to permit the data to be transmitted to a suitable computing center, where it may be rapidly reduced to a form in which it can be studied and analyzed by the scientists. The data represent the raw material from which the scientific experimenters will gain their new knowledge of space. The quantity and quality of these data will largly determine the rate of progress made in space research.

While the NASA network of stations is designed to afford the maximum amount of operational flexibility, there are special conditions associated with particular projects which may require equipment modifications, or in certain cases, the temporary installation of new items of equipment at new locations. In order to minimize the requirements for new stations, or to compensate for temporary deficiencies, the NASA proposes to provide support to cooperating non-NASA stations which are suitably equipped to perform a useful function for the purposes of a particular experiment.

In addition to providing tracking services, a continuing effort must be maintained to advance the state-of-the-art in tracking systems and methods, in data reduction and analysis techniques, and in methods of telemetry and data transmission to keep pace with increasingly complex spacecraft programs.

FUNDING REQUIREMENTS:

Advanced Research	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Theoretical Analysis, Tracking and Data Systems:			
Comparative analysis, tracking and data acquisition systems	---	$31,000	$60,000

Advanced Research	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Study of orbit computation and data reduction methods	---	$100,000	$94,000
Computing services.....	---	---	14,000
	---	131,000	158,000
Experimental Studies; Tracking, Data Acquisition, and Timing Systems:			
Components for development.....	$28,100	64,000	62,000
Solid state devices studies.....	10,000	65,000	62,800
Low-noise pre-amplifier studies..	10,000	85,000	50,000
Precision propagation delay measurements.....	---	75,000	---
Sytems studies - tracking systems drives.....	---	110,000	---
Study of on-site reduction systems.....	---	30,000	---
Synchronoms demodulation studies.....	---	35,000	---
Telemetry coding and modulation studies.....	---	32,800	25,000
Very low frequency timing studies.....	---	87,000	100,000
Precision ranging systems studies	---	35,000	100,000
Study on calibration of parabolic antennas.....	---	30,000	50,000
Reduction of sun tracking data...	---	---	20,000
	48,100	648,800	469,800
Optical and Electric-Optical System Studies:			
Optical test and research equipment components.....	---	100,000	50,000
Optical techniques development...	---	100,000	100,000
Electronic-optical test equipment and components.....	---	88,500	80,000
Electronic-optical sensors and recorders.....	---	100,000	120,000
Infrared tracking contract.....	---	124,000	150,000
Component testing.....	---	25,000	50,000
	---	537,500	550,000

Advanced Research	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Pre-prototype Development; Tracking, Data Acquisition, and Timing Systems:			
Calculations at David Taylor Model Basin.....	$25,000	---	---
Other data acquisition analysis..	22,100	$32,000	$30,000
High-speed paper tape punch.....	---	15,000	---
Vacuum equipment and other special instrumentation for maser testing.....	---	15,000	---
Pre-prototype ranging tramsmitter	---	25,000	---
Wide-band magnetic tape recorder.	---	35,000	---
100 megacycle test equipment.....	---	108,000	---
Transmitter modulator.....	---	62,000	---
Tracking receiver development....	---	60,000	---
Satellite antenna development....	---	60,000	---
Beacon L band development.....	---	30,000	---
Rubidium vapor frequency standard equipment development contract.	---	75,000	80,000
Timing system study.....	---	16,500	70,000
Special research equipment-wide-band oscilloscopes, counters and printers.....	---	12,000	10,000
Ultra-high frequency wide-band airborne transponder.....	---	40,000	30,000
Ultra-high frequency wide-band receiver.....	---	10,000	30,000
Components and electronic material for laboratory use.....	---	229,200	123,600
High-power interrogation transmitter and ranging equipment...	---	---	135,000
Low-frequency range antenna.....	---	---	45,000
Installation and evaluation of pre-prototype equipment.....	70,400	127,200	165,000
	117,500	951,900	718,600
Calibration System Development:			
Punching of star catalogs.....	25,000	25,000	---
Airborne calibration equipment...	---	5,000	---
Multi-channel portable recorder..	---	15,000	---
Calibration system component procurement and evaluation.....	---	40,800	---
	25,000	85,800	---

Advanced Research	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Basic Research; Lunar and Interplanetary Telecommunications:			
Communication systems theoretical studies.....	---	$215,000	$235,000
Analytical and experimental communications studies.....	---	214,500	230,300
Circuit elements research.....	---	251,000	290,000
Antenna elements basic research..	---	200,000	200,800
	---	880,500	955,100
Total, Advanced Research....	$190,600	$3,235,500	$2,862,500

A program description by individual projects best defines the scope and direction of the Advanced Research effort. Pre-prototype equipment referred to in connection with Advanced Research denotes bread-board or experimental improvisations to make empirical tests to confirm studies.

Theoretical Analysis, Tracking and Data Systems

As out knowledge of the space environment increases, and as more practical use of satellites is made, such as in communications and meteorology, our needs for precise tracking and data handling will increase. The NASA Goddard Space Flight Center will have primary technical cognizance of this work for satellite payloads. Comparative analysis of existing and proposed tracking and data acquisition systems is necessary in order to insure that future systems are developed to meet our increasing requirements. Orbit computation and data reduction methods are, of course, an integral and very important part of this problem. Systems must be analyzed in terms of their efficiency, accuracy, and information handling capacity. These basic studies may eventually generate new concepts and will be aimed at indicating the types of tracking and data systems, development of which should be pursued in the future. Some of these studies in the fiscal year 1962 will be a continuation of work started the previous year, while others represent new efforts.

Experimental Studies; Tracking, Data Acquisition, and Timing Systems

Work in this area will include experimental studies of modulation and coding techniques directed toward increasing the amount of information transmitted per watt of spacecraft power; the feasibility of increasing the effective capacity of data transmission facilities by partial on-board or on-site data reduction; and the development of more efficient data editing techniques. Precise systems for time-correlating tracking data, obtained at the stations distributed at distant points around the world,

must be developed. This is necessary for accurate orbit determinations. Work in this line will be directed toward more stable time and frequency standards, toward support of very low frequency timing research, and toward development of precise methods of determining propagation delays between a frequency standard transmitter and a receiving site. Research and experimental analysis will be directed toward the development of improved low-noise electronic receivers to increase the range and data handling capacity of our systems as satellites become more complex and transmit more data.

Optical and Electronic-Optical System Studies

Basic theoretical and experimental systems studies will be undertaken in the field of optical systems and electronic optics. Application of these studies to optical tracking systems will make possible fast and precise readout of data and detection of fainter satellite objects by optical means, when required, or when the object is not radiating signals for electronic tracking. The development of several promising basic sensing devices developed by contractors will be supported as well as integration of these devices into an over-all system for in-house evaluation.

Pre-prototype Development; Tracking, Data Acquisition, and Timing Systems

Included here is the development and evaluation of pre-prototype equipment for more detailed practical analysis of systems chosen by the earlier theoretical and experimental studies. Certain components will, after construction and laboratory tests, be installed at one of the tracking stations for further analysis. This work in the satellite instrumentation area generally takes place at the readily accessible Blossom Point, Maryland satellite tracking site.

Calibration System Development

This item includes the study of calibration systems for use with advanced tracking systems and the development of improved calibration techniques for those presently in use. Periodic calibration of our electronic stations is necessary to insure that the data obtained during operations is accurate. New techniques will be investigated from both a theoretical and operational viewpoint. Pre-prototype equipment will be produced and evaluated for such applications as automation of the photographic plate data reduction procedures used with the photographic plates obtained from optical tracking systems. Optical detection of an object whose position can be accurately defined by photographic means, when compared with simultaneous electronic tracking detection, serves as one calibration method now commonly used. Available fiscal year 1961 funds are adequate to fund this work through the fiscal year 1962.

Basic Research; Lunar and Interplanetary Telecommunications

The planned lunar and interplanetary research programs will require information to be returned from greater distances (millions of miles) and at ever increasing rates. These communications and tracking requirements under the primary technical cognizance of Jet Propulsion Laboratory are unprecedented. Although the new and more efficient systems now being developed within the present state-of-the-art will appreciably increase our capabilities, future requirements can be met only by continuing support of advanced research efforts. Advanced information theory will be applied to the development of more efficient radio modulation and coding techniques for improving tracking accuracy and communications capability. Experimental investigations to be carried out in-house and under contract will include evaluation of selected communication and control systems; studies of circuit elements, including thin-film techniques, parametric and molecular devices; means of generation of energy for communications; and investigations of factors affecting large antenna operation.

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Prototype Equipment for Evaluation of Advanced Tracking Systems:			
Servo-evaluation instrumentation system.....	---	---	$20,000
Servo equipment, gears, amplifiers and prime movers.....	---	$20,000	30,000
Procurement of operational instrumentation.....	$12,100	21,000	50,000
Tracking filters and data instrumentation system for improved tracking system.....	---	---	100,000
Oscillographs.....	22,900	50,000	22,100
Antenna prototype development and construction.....	44,000	---	---
Preamplifier.....	7,500	---	---
Data reduction.....	68,800	50,000	---
400-megacycle receiver converter development.....	---	36,900	---
Ranging equipment development....	48,900	50,000	---
Commercial receivers and special test equipment.....	---	30,000	---
Evaluation, test and development.	69,100	103,100	103,100
Frequency synthesizer.....	9,600	---	---
Precision tracking system (1400 megacycles).....	---	100,000	---
	282,900	461,000	325,200

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Prototype Development of Data Acquisition and Timing Sub-systems:			
Digital data handling breadboard type system.....	---	---	$30,000
Procurement of components for development and evaluation.....	$105,800	$247,200	267,200
Special purpose module equipment for special analog data system.	---	---	75,000
Oscilloscopes.....	---	8,000	---
Parametric amplifiers.....	5,000	112,400	52,800
Analog to digital converters.....	---	10,000	---
400-megacycle preamplifiers.....	---	40,000	20,000
400 and 1430-megacycle small ground telemetry dish.....	---	155,000	155,000
Comb filter spectrograph.....	---	70,000	---
Phase locked discriminators.....	---	40,000	---
Tracking filters.....	50,000	35,000	10,000
Recorders.....	45,000	10,000	---
Tracking receivers.....	---	90,000	35,000
Maser development.....	---	---	100,000
Feeds for 400 and 1780-megacycle parabolic antennas.....	---	---	100,000
Prototype minitrack Mod-I 135-137 megacycles.....	47,100	---	---
Prototype coordinate transfer director system.....	---	---	240,000
Frequency multipliers and oscillators.....	7,900	10,000	---
Timing equipment prototype evaluation	21,500	17,500	50,000
Development of very low frequency receivers.....	---	10,000	50,000
Portable atomic resonance frequency standard system.....	---	---	50,000
	282,300	855,100	1,235,000
Optical Systems Prototype Development:			
Special research equipment and test equipment.....	7,400	37,500	---
Prototype portable optical tracking system.....	---	100,000	150,000
Components for development and evaluation.....	6,600	25,000	5,000
	14,000	162,500	155,000

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Advanced Data System Development:			
Tracking filters	$42,000	$50,000	$50,000
Video terminal equipment	---	50,000	190,000
Comb filters	38,700	100,000	100,000
Digital tape decks	---	140,000	50,000
Magnetic memory and controls	---	50,000	50,000
Printed circuit equipment	---	10,000	10,000
Recorders	---	70,000	70,000
Video recorders	---	---	200,000
Oscillographs	44,600	---	---
Digital conversion equipment	---	---	200,000
Plot boards	---	70,000	100,000
Video display and equipment	---	100,000	100,000
Spectrum analyzer	---	10,000	---
Tape search and control equipment	25,200	40,000	50,000
High-speed punch	---	15,000	---
Station's data reduction equipment	---	150,000	150,000
Power supply pulse generators	49,300	---	---
Tape loop transports	---	50,000	---
Misc. display control and data reduction equipment	209,700	215,600	286,600
Comparative data system analysis	110,700	100,000	100,000
Study of computer characteristics	---	200,000	---
Control center design study	---	100,000	---
Component and sub-system development, high-speed data terminal	---	---	625,000
	520,200	1,520,600	2,331,600
Calibration System Development:			
Airborne calibration equipment	---	15,000	---
Ground station equipment improvement	---	10,000	40,000
Astrographic camera	---	25,000	---
Calibration equipment for development and evaluation	31,900	13,200	10,000
Evaluation of Minitrack calibrating antenna	6,300	---	---
	38,200	63,200	50,000
System Development for Advanced Satellite Programs	1,500,000	500,000	675,000

Advanced Technical Development	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Communications Systems Development:			
Earth-based continuous wave radar system development.....	$200,000	$500,000	$800,000
Advanced telemetry and command systems development.....	---	400,000	600,000
Exploitation of new elements and techniques.....	---	158,600	300,700
	200,000	1,058,600	1,700,700
Communications Elements Development:			
Antenna technical systems design and development.....	500,000	130,000	250,000
Structural and optical evaluation of antenna design concepts.....	---	380,000	350,000
Servo systems advanced development	---	154,000	250,000
Acquisition aids for large aperture antennas.....	---	105,000	400,000
New circuit elements fabrication and evaluation.....	---	310,600	381,600
	500,000	1,079,600	1,631,600
Ground Systems Development:			
Calibration and test equipment development.....	500,000	150,000	200,000
Prototype construction and evaluation of ranging apparatus	---	400,000	500,000
Prototype construction and evaluation of command apparatus	---	94,700	249,700
Prototype construction and evaluation of telemetry apparatus	---	28,800	34,800
	500,000	673,500	984,500
Data Reduction Systems Development:			
Data handling instrumentation and computer development.....	237,000	373,500	591,400
Tracking system data analysis....	---	203,000	289,100
Data reduction program development	---	114,300	238,900
	237,000	690,800	1,119,400
Total, Advanced Technical Development.....	$4,074,600	$7,064,900	$10,208,000

In general, the advanced technical development required by the tracking program includes the design, construction, test and evaluation of prototype systems and sub-systems to meet the requirements of future flight missions. Descriptions of the individual tasks being undertaken follow:

Prototype Equipment for Evaluation of Advanced Tracking Systems

A moderate level of effort will be continued in the fiscal year 1962 in the development and evaluation of prototype sub-systems for an advanced tracking system. The effort will be directed towards providing a detailed concept of an improved radio tracking system in order to expedite its implementation when the specific and foreseen requirements arise. As presently envisioned, the system will consists of a high-frequency extension of our present tracking system, probably combined with a ranging capability to measure accurately the distance and direction of spacecraft with respect to the earth station.

Prototype Development of Data Acquisition and Timing Sub-systems

A number of sub-systems must be developed in order to utilize properly the 85-foot antennas for wide-band telemetry reception from satellites at moderate ranges. An 85-foot antenna is currently being installed at College, Alaska for initial use with the meteorological satellite. The time schedule has made it necessary to use essentially off-the-shelf sub-systems, whose limitations still require changes and improvements in the servo drives, the dish feed system, and the basic data and tracking acquisition electronic receivers. Improved systems must also be developed for driving such antennas from program tapes and for slaving them to other antennas. Extremely precise time standard systems will be developed to meet requirements at selected stations expected to arise late in the fiscal year 1962. More accurate timing is a necessity, both in use of tracking information and in correlation of telemetry data with respect to the position in space to which the data refers.

Optical Systems, Prototype Development

A portable optical tracking system is needed as a calibration aid to insure the accuracy of radio tracking stations and as a prime data source for meeting certain tracking requirements. For example, such accuracy requirements may arise in measuring specific portions in the flight of developmental spacecraft such as Apollo and in development of vehicles such as Centaur and Saturn. A portable optical system will be developed and used both for the calibration task mentioned above and for engineering evaluation of one or more simple electronic optical systems. In one type of electron optical system, a highly sensitive photo-electric detector replaces the photographic plate, and will permit use of faint satellites for calibration. This would provide greater accuracy than now possible by use of high-altitude aircraft to simulate a satellite.

Advanced Data System Development

This necessary developmental work is directed towards providing adequate capability to transmit large quantities of data from ground stations to a control and data reduction center, and the development of an adequate data reduction and processing capability. The art of satellite telemetry is gradually becoming more stabilized, making practical the very desirable development of high capacity automatic equipment for reduction and presentation of data. The advent of wider band-width satellites, such as meteorological television systems, requires development of special methods to reduce such data efficiently and avoid building up a large backlog of data.

Calibration System Development

Work will continue on the development of prototype apparatus, including both airborne and ground station units, for the more accurate and efficient calibration of tracking stations.

System Development for Advanced Satellite Programs

These funds provide for the development of special tracking and data acquisition apparatus unique to a particular program. Typical are special command systems, abnormal band-width requirements, special telemetry links, and non-standard frequencies. The bulk of the funds in the fiscal years 1960 and 1961 were applied to contracts for advanced development and technical support during the implementation of the Mercury network. In the fiscal year 1962, the funds will be used primarily for determining ground instrumentation requirements for the Apollo and other advanced programs. The work will include both analytical and hardware studies.

Communications Systems Development

Work in this area will be directed toward designing and testing prototype communications systems for use in the lunar and planetary programs. Results of supporting research in information theory and coding techniques will be exploited in increasing our capability to communicate with and measure positional coordinates of spacecraft. The earth based continuous-wave radar system, using an advanced modulation technique, will eventually make possible the unambigious determination of range within the solar system to a resolution of 15 meters. The system will use a high-powered ground-based transmitter and a modestly powered spacecraft transponder. Recent experiments in connection with Echo I combined this range measuring system with range-rate (Doppler) measurements to demonstrate the practicality of the proposed deep space tracking system. Further development of the transmitters, receivers, range coders, and other components of the system will be carried out in the fiscal year 1962. Current plans call for full

implementation of the precision deep space tracking system by 1965. In the meantime, the Goldstone transmitter-receiver installation, operating in a coherent CW reflection radar mode should prove an invaluable research instrument for studying satellites, the moon and the planets.

Equal in importance to the tracking system development for deep space is the application of new coding techniques and new communications elements to improvement of telemetry and command systems, thus providing better control and more data transfer from distant spacecraft. This will include the exploitation of new circuit elements and techniques such as masers, parametric amplifiers, and other solid state devices to increase the sensitivity of receiving systems. Telemetering goals will include high reliability, sustained performance for long periods, increased flexibility (possibly including on-board determination of data usefulness), fractional percentage accuracy when required, minimum power consumption, and compatibility with automatic ground data processing.

Communications Elements Development

Fiscal year 1961 and 1962 work in the area will be directed toward the development of low-noise circuit elements and high-gain, low-noise antenna facilities to increase the effective communications capability of the deep space program. This advanced development effort will include experimental evaluation of new antenna feed systems, structural design approaches, servo systems, and acquisition aids. The problem of acquisition of a signal with the very narrow acquisition beam of a high-gain large antenna is a serious one; a number of possible solutions to this problem will be evaluated. One promising approach is indicated by studies showing that proper application of early tracking information obtained from lower gain and smaller antenna facilities will provide sufficiently accurate pointing data for acquisition at greater ranges with the large antennas. Masers and cooled parametric amplifiers using presently known techniques will soon have completed their advanced development phase. However, recent discoveries have shown that considerable simplification of these low-noise devices may well be possible and that further effort is clearly worthwhile. Low-noise amplifiers using the present techniques are bulky and quite impractical for spacecraft operation because of size and weight. If they could be used, they would enhance the communications range capability of the entire space program.

Ground Systems Development

Funds are required for development and engineering of calibration, ranging command, and telemetry systems which have previously been proven suitable for use in the deep space instrumentation facilities. Prototype apparatus will be developed including the necessary instrumentation and test equipment for calibration, adjustment and performance evaluation of the various systems. Included will be such items as telemetry decoding and antenna

collimation equipment, the necessary test beacons, integration and evaluation of new command facilities, and integration of prototype ranging facilities. In most instances work included under this item will be of a prototype nature, developed by the Jet Propulsion Laboratory or by contractors, and tested at Goldstone tracking station prior to acceptance for use in the complete deep space network.

Data Reduction Systems Development

With the much greater quantity of data to be transmitted back from lunar and planetary probes, and the more precise tracking information which is to be required by these probes, the development of improved data programming and data analysis methods is a definite necessity. Work under this item will include analysis and computer programming necessary for most efficient and accurate use of tracking data and the development of the necessary systems for telemetry data handling and reduction.

Flight Program	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Network Operations:			
Satellite (Minitrack) Network.....	$3,675,400	$5,283,000	$5,287,000
Deep Space Network.....	1,341,000	2,996,900	3,322,300
Smithsonian Astrophysical Observatory Network.....	1,450,000	2,160,000	2,250,000
Non-NASA Stations.....	800,000	1,500,000	1,850,000
Special Operations and Services....	400,000	500,000	500,000
Space Parts, Repairs, and Maintenance.....	276,760	345,000	897,300
	7,943,160	12,784,900	14,106,600
Network Communications:			
Satellite (Minitrack) Network.....	480,200	1,113,900	2,584,800
Deep Space Network.....	---	371,100	838,100
Smithsonian Astrophysical Observatory Network.....	100,000	140,000	200,000
Mercury Network.....	---	5,035,700	5,500,000
	580,200	6,660,700	9,122,900
Computation and Data Reduction.....	3,400,440	1,910,000	2,350,000
Total, Flight Program.....	$11,923,800	$21,355,600	$25,579,500

Flight Program	Operated By	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Satellite (Minitrack) Network Operations:				
Blossom Point, Md.	Bendix Corp.	$276,000	$286,000	$330,000
Fort Myers, Fla.	Bendix Corp.	254,000	260,000	297,000
San Diego/Goldstone	Bendix Corp.	214,000	220,000	297,000
Antigua, British West Indies	RCA/Pan American	55,000	200,000	---
Quito, Ecuador	Bendix Corp.	411,000	415,000	429,000
Lima, Peru	Bendix/Geophysical Institute, Huancayo	325,000	325,000	325,000
Antofagasta, Chile	Bendix/Univ. of Chile	380,000	370,000	435,000
Santiago, Chile	Bendix/Univ. of Chile	380,000	382,000	435,000
Woomera, Australia	Australia	50,000	185,000	185,000
Esselen Park, South Africa	South Africa	50,000	175,000	175,000
East Grand Forks, Minn.	Bendix Corp.	---	185,000	297,000
Fairbanks, Alaska	Univ. of Alaska	---	105,000	517,000
St. John's, Newfoundland	Canada	---	70,000	121,000
Winkfield, England	England	---	234,000	234,000
Microlock Stations	Bendix Corp.	---	50,000	---
Space control center operational support	Bendix Corp.	43,000	200,000	220,000
Calibration operations of airplane	Bendix Corp.	320,000	450,000	450,000
Call order services	Bendix Corp.	200,000	206,000	220,000
Special logistic support	Various	90,800	150,000	150,000
Calibration of field stations:				
New Mexico State University calibration data reduction		60,000	55,000	50,000
Ambiguity resolving slide rules		---	5,000	---
Aircraft modifications for parabolic antenna calibrations		---	15,000	---
Calibration equipment		---	20,000	10,000

	Operated By	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Replacement of electronic equipment:				
Magnetic tape recorders		$229,100	$560,000	---
Telemetry data recorders		---	110,000	$110,000
Timing oscillators		---	25,000	---
Communications transmitter		---	25,000	---
Fixed transmitter		143,600	---	---
Tunable discriminator		71,400	---	---
Switchable antenna		122,500	---	---
		3,675,400	5,283,000	5,287,000
Deep Space Network Operations:				
Goldstone, Calif	Jet Propulsion Lab.	1,341,000	1,371,500	1,431,800
Woomera, Australia	Weapons Research Establishment, Australia	---	193,400	72,100
South Africa (Hartebeesthock - near Krugersdorf)	Union of So. Africa	---	339,400	486,700
Mobile tracking station	Not selected	---	432,200	331,400
Reimbursement for foreign stations	Foreign Govts.	---	300,000	600,000
System tests and operations	Jet Propulsion Lab.	---	167,400	179,100
Logistic support	Jet Propulsion Lab.	---	193,000	221,200
		1,341,000	2,996,900	3,322,300
Smithsonian Astrophysical Observatory (SAO) Network Operations:				
Jupiter, Florida	SAO			
Organ Pass, New Mexico	SAO			
Haleakala, Maui, Hawaii	SAO			
Curacao, North West Indies	SAO			
Arequipa, Peru	SAO			
Villa Dolores, Argentina	SAO	1,200,000	1,910,000	2,000,000
Olifontsfontein, South Africa	SAO			

	Operated By	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
San Fernando, Spain.....	SAO			
Shiraz, Iran.....	SAO			
Woomera, Australia.....	SAO, Weapons Research Establishment, Australia			
Mitaka, Tokyo, Japan	SAO, Japan			
Naini-Tal, India.....	SAO, India			
Moon-Watch 110 active stations.....	Volunteer teams	$250,000	$250,000	$250,000
		1,450,000	2,160,000	2,250,000
Non-NASA Station Operations:				
Jodrell Bank Station.....		100,000	250,000	300,000
Fort Churchill Station.....		650,000	1,000,000	1,200,000
Phototrack optical stations.....		50,000	50,000	50,000
Reimbursement for Department of Defense stations and other agencies.....		---	200,000	300,000
		800,000	1,500,000	1,850,000
Special Operations and Services for Flight Missions:				
Special items of equipment to meet ground instrumentation requirements, such as for Explorer VII, Centaur, and Agena projects.....		400,000	500,000	500,000
Spare Parts, Repairs and Maintenance:				
For network tracking stations.....		276,760	345,000	897,300
Total, Network Operations.....		$7,943,160	$12,784,900	$14,106,600

	Operated By	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Satellite (Minitrack)Network Communications:				
Naval Station, Cheltenham, Md. - GSFC	Commercial	$1,800	$2,400	$2,400
Ft. Monmouth - GSFC.....	"	2,500	7,500	11,000
NASA Headquarters - GSFC - MSFC - AMR.	"	---	39,600	42,400
Newfoundland - GSFC.....	"	---	36,000	38,000
NWL Dahlgren - GSFC.....	"	2,400	3,000	3,000
Pentagon (Terminal for South American stations) - GSFC.....	"	9,500	18,500	18,500
South Africa - GSFC.....		110,400	114,000	480,000
Blossom Point - GSFC.....	"	3,000	3,000	3,000
San Diego - JPL - STL - PMR - GSFC....	"	39,600	132,000	240,000
Woomera - GSFC.....	"	170,000	182,400	190,000
Ft. Myers - GSFC.....	"	20,400	21,600	52,000
Grand Forks Links - GSFC.....	"	---	32,400	59,000
Alaska - GSFC (high speed data).....	Military	---	60,000	660,000
Computing Center, Wash., D. C. - GSFC.	Commercial	7,500	14,700	---
Cape Canaveral - Antigua.....	Military	18,000	21,600	22,000
Cape Canaveral - GSFC.....	Commercial	7,200	12,000	12,000
Weather Bureau - GSFC.....	"	600	2,400	2,400
Wallops Island - 2 lines - GSFC.....	"	---	19,200	19,200
Special relocations.....	"	1,200	2,400	3,000
Terminal charges.....	"	2,400	120,000	120,000
2 lines to teletypewriter exchange....	"	---	3,600	3,600
Special internal circuits.....	"	---	8,400	9,000
Panama terminal (for South American stations).....	Military	28,600	50,000	50,000
Operational traffic.....	Commercial	10,000	20,400	22,000
Operational equipment and material costs.....	"	21,900	72,600	114,700
Short term lease costs for operational periods.....	"	23,200	114,200	407,600
		480,200	1,113,900	2,584,800

	Operated By	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
Deep Space Network Communications:				
JPL to Cape Canaveral (2 Teletype)....	Commercial			
JPL to Cape Canaveral (3 Voice).....	"			
JPL to Goldstone (3 Teletype).....	"			
JPL to Goldstone (4 Voice).....	"		$371,100	$838,100
JPL to Australia (1 Teletype).....	"			
JPL to Africa (1 Teletype).....	"			
JPL to Huntsville (1 Teletype).....	"			
		---	371,100	838,100
Smithsonian Astrophysical Observatory Network Communications:				
Communications Center at Cambridge (5 Teletype).....	Commercial			
SAO to International Western Union (N.Y.) (1 Teletype).....	"	$100,000	140,000	200,000
SAO to Domestic Western Union (Cambridge) (1 Teletype).....	"			
		100,000	140,000	200,000
Mercury Network Communications:				
GSFC to Cape Canaveral.....	Commercial	---	257,800	311,300
GSFC to Bermuda.....	"	---	336,400	370,200
GSFC to Mid-Atlantic ship.....	"	---	166,500	80,400
GSFC to Canary Islands and Zanzibar..	"	---	1,189,700	1,266,000
GSFC to Kano.....	"	---	158,700	196,400
GSFC to Indian Ocean ship, Muchea and Woomera.....	"	---	586,600	1,000,000
GSFC to Muchea, Woomera and Canton (via Vancouver).....	"	---	423,800	410,000

	Operated By	Fiscal Year 1960	Fiscal Year 1961	Fiscal Year 1962
GSFC to Hawaii.....	Commercial	---	115,000	152,700
MAS to Canary Islands.....	"	---	39,300	72,600
GSFC to Muchea, Woomera, Hawaii and Canton.....	"	---	480,900	651,200
GSFC to Arguella.....	"	---	60,600	85,600
GSFC to Guaymas.....	"	---	66,100	93,300
GSFC to White Sands.....	"	---	39,600	68,000
GSFC to Corpus Christi.....	"	---	32,500	59,500
GSFC to Eglin AFB.....	"	---	23,700	40,400
Eglin AFB to Cape Canaveral.....	"	---	22,900	39,300
Switching Center - GSFC.....	"	---	250,000	240,000
Switching Center - Hawaii.....	"	---	50,000	72,000
Switching Center - Muchea.....	"	---	35,000	24,000
Switching Center - Woomera.....	"	---	50,000	24,000
Input-output converter GSFC.....	"	---	60,000	30,000
Short term leased costs for operational periods.....	"	---	590,600	213,100
		---	5,035,700	5,500,000
Total, Network Communications.....		$580,200	$6,660,700	$9,122,900
Computation and Data Reduction:				
Data reduction services.....		44,600	60,000	---
Computing services:				
IBM contract for Space Computing Center		1,220,040	550,000	---
CEIR - computing service.....		225,000	---	---
BuStandards - computing services.....		433,000	---	---
Contract services for Computing Center		58,800	100,000	100,000
SAO computation, data, reduction and analysis.....		1,419,000	1,200,000	2,250,000
Total, Computation and Data Reduction		$3,400,440	$1,910,000	$2,350,000
Total, Flight Program.....		$11,923,800	$21,355,600	$25,579,500

Satellite (Minitrack) Network Operations

These stations, operated under contract or by foreign agreements, employ radio interferometers and are used primarily for tracking satellites which send our radio signals, where real-time data is not required. They have all weather capability. They cannot track passive satellites (ones which do not emit signals) nor can they provide the precise orbit data available from optical systems. They have the advantage of being able to detect the angular direction of a satellite with respect to the station without prior information as to precisely where to look. These stations must be located in areas free of extraneous electrical disturbances. From a number of observations from different stations, a reasonable orbital determination can be made. The stations are so located that several observations will be obtained each time a satellite orbits the earth, regardless of its orbital path.

Each station also receives and records telemetry data on magnetic tape. Data from these stations are fed to a central control, communications, and computing center at the Goddard Center. Teletype operators are furnished by the operations contractor at the Center. Automatic data read-out equipment is being provided at stations to speed up data collection and to permit tracking a greater number of satellites. The operating costs are defined in considerable detail. The increase in cost for the fiscal year 1962 for Alaska is due to the addition of new facilities for the Nimbus program. The over-all cost in the fiscal year 1962 is not increased as cost increases in utilities and services are offset by economies in other cost factors.

Deep Space Network Operations

During the fiscal year 1962 the JPL station at Goldstone, California, the Woomera, Australia station, and the South Africa station will be operational. These stations will be under the technical direction of the Jet Propulsion Laboratory, but in Australia and South Africa they will be operated by technical groups in the country concerned.

The deep space stations are used primarily for tracking and data acquisition from vehicles penetrating deep into space, since they have great sensitivity to very faint signals, not detected by ordinary electronic receiving systems. They may also be adapted for gathering larger amounts of data, such as may be involved in the transmission of television pictures from space vehicles, and are capable of transmitting command signals to distant spacecraft. They are not suitable for satellites in low orbits because of low tracking rates of the antennas which cannot move as fast as the satellites. The transmitters may also be used for communications satellite experiments which are in a relatively high orbit. The stations are so located as to permit one station to always be in position to see the moon or far out spacecraft. Funds are included under this heading for the contractual services required in the operation of the auxiliary mobile ("gap-filler") tracking and command station to

meet operational requirements for specific projects. Funds are also included to cover the government-to-government agreements, which involve reimbursement for foreign services to be performed for NASA, beyond those under the cognizance of the NASA technical directing activity.

Smithsonian Astrophysical Observatory (SAO) Network Operations

The existing twelve Baker-Nunn optical stations will continue in operation during the fiscal year 1962 under the technical and administrative direction of the Smithsonian Astrophysical Observatory. A prime purpose of the observations under this program is directly related to scientific studies performed by SAO in connection with learning more about the density of the upper atmosphere, the gravitational field of the earth, and the geometric shape of the earth to help define more exactly the location of continents and islands. The optical observations are also backup for the electronic tracking systems, both as a check of their accuracy and in event of failure of transmission signals from the satellite.

The optical stations can photograph relatively faint space objects (satellites) against star backgrounds to provide a precise determination of the angular position of the object. Observations can only be made when the visibility is good and by virtue of sunlight reflected from the object. Therefore, observations can only be made in periods of clear twilight. Moreover, the camera can see a small segment of the sky at a time, and it must have a prior knowledge of where to look or the satellite will pass out of range before the camera can search any appreciable segment of the sky. Information on where to look is obtained from electronic tracking stations which do not have the acquisition limitations of optical systems, or from one of the Moonwatch observation stations mentioned below.

It is theoretically possible from three or more optical observations to obtain the most precise orbital data of any technique known. For certain geophysical experiments, such as in geodetic and air drag experiments, the maximum precision of optical techniques is necessary. The optical stations must be located at sites where the weather conditions are such that good visibility generally prevails. This site limitation is not necessarily compatible with the site locations of electronic systems, which have other criteria governing their best location. About 800 satellite positions are precisely reduced each month, which is several fold increase in out-put over 1959. To date over 6000 precision positions are available for research and analysis.

In addition to the cost of operating the optical stations is the cost of data transmission, data reduction and analysis and data interpretation which is performed by the Smithsonian Astrophysical Observatory at Cambridge, Massachusetts. Funds are included for the cost of the 110 Moonwatch teams which are volunteer groups assisting the Smithsonian Astrophysical Observatory in securing observations of satellites at different places in the world, using simple telescope equipment. The compensation to the Moonwatch teams merely defrays expenses for materials and for certain items of equipment. There is no compensation for the volunteer services as such. Approximately 2500 volunteer observers participate on a world-wide basis. Since October 1957, more than 24,000 observations have been obtained from the Moonwatch stations.

Non-NASA Station Operations

The NASA will make use on a part-time basis of a number of cooperating non-NASA stations which provide tracking capability. Examples are the facilities at Jodrell Bank, England, and at Fort Churchill, Canada. The extent of the NASA use of these facilities is arrived at by mutual agreements based on the duration and complexity of the particular experiments. In certain cases the NASA will provide funds for reimbursement to Department of Defense and other agencies for special services or items of equipment needed to accomplish particular experiments. Examples of Department of Defense stations used by NASA are the Signal Corps station in Deal, N. J. and the Pacific Missile Range station at San Nicholas for the Tiros meteorological satellite. Funds are also made available to the Commerce Department to continue the Agiwarn service at Ft. Belvoir for the world-wide dissemination of NASA satellite and space probe data in accordance with CoSpar agreements. Phototrack optical stations are operated by the Society of Photographic Scientists and Engineers, who provide useful coverage on projects such as Shotput and Echo.

Special Operations and Services for Flight Missions

While every effort is made to make our ground instrumentation facilities flexible and adaptable to anticipate all space flight programs, there are often unique experiments which impose modification requirements on certain stations. Until the instrumentation plan has been completed, the detailed requirements for ground equipment are not fully known--nor is it possible to predetermine the exact station locations needed. Generally, the work involved consists of adaptations to existing station equipment with, possibly, some minor installations of a temporary nature. This is particularly true where NASA is involved in inter-agency projects and must, as in the case of the Centaur vehicle test project, cooperate to meet certain tracking and data acquisition requirements not required by its own projects.

Spare Parts, Repairs and Maintenance

NASA will have operational cognizance of over 40 tracking and data acquisition sites. An allowance of the order of 5 per cent of the operating cost is made for equipment failures or maintenance and repair problems and to maintain a high order of reliability. In the case of military equipment, an allowance of 10-15 per cent is normal for spares. However it is recognized that ground based equipment at fixed installations is not as subject to damage, and is easier to maintain.

Network Communications

The communication networks for the satellite programs, including the Mercury program, feed into the Goddard Space Flight Center at Greenbelt, Maryland, which is the primary nerve center for all NASA tracking operations. For space probes and for lunar and planetary programs, a communication control center for the three deep space stations is maintained at the Jet Propulsion Laboratory. The Smithsonian Astrophysical Observatory utilizes the available satellite ground communications system to a large extent, as well as a certain amount of commercial facilities and the mails, for its normal traffic. These channels are utilized for transmitting and receiving orbital data to and from various activities, both foreign and domestic, including the Baker-Nunn photographic stations, the Moonwatch teams, observatories, and other installations. Commercial facilities, consisting mostly of radio or cable teletype, are utilized by NASA. Military circuits are used when available and suitable. Voice circuits are used where necessary or critical to operating efficiency.

Computation and Data Reduction

Data reduction services for space flight tracking operations are performed at the Goddard Space Flight Center, the Jet Propulsion Laboratory, and the Smithsonian Astrophysical Observatory. It will be noted that the contract costs for computing services have decreased markedly as a result of the buildup of in-house capabilities in this field. Only the costs in the grant to SAO remain, which include not only the costs of data reduction and computations, but the considerable costs of data analysis and interpretation such as are involved in the experiments to determine air density, effects of solar radiation on orbiting vehicles, and other scientific investigations. The work on SAO goes beyond that of a computing service and includes scientific work. A computing facility is employed in this activity along with programmers and research and analysis personnel who analyze the data for scientific conclusions.