National Aeronautics and Space Administration

BUDGET ESTIMATES

FISCAL YEAR 1972

Volume II

RESEARCH AND DEVELOPMENT

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1972 ESTIMATES

RESEARCH AND DEVELOPMENT

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT

GENERAL STATEMENT

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

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

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

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

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

TECHNOLOGY UTILIZATION: A program that provides for the expeditious public availability of scientific, technological, and engineering information and concepts which flow from NASA's work.

MANNED SPACE FLIGHT:

The Manned Space Flight budget request provides for continuing progress in this area of space operations as the program evolves from an emphasis on lunar exploration to focus on earth orbit missions that produce direct and practical benefits for man.

The Apollo 11 and 12 lunar landings have resulted in much new knowledge about the moon. The moon has been discovered to be a fascinating and complicated body, and it has preserved its history well. Scientists now expect that exploration of the moon could provide keys to the chronology of our solar system since its formation over 4.6 billion years ago. With every major discovery, there is the unanticipated and the unexpected, and scientists are now studying why earth plants thrive in lunar soil, and why some hardy microorganisms rapidly die in it.

The Apollo 13 mission suffered a nearly catastrophic rupture of an oxygen tank while en route to the moon in April 1970. The astronaut crew was able to use the Lunar Module as a lifeboat and through the dedicated efforts of the Apollo team returned to a safe landing in the Pacific.

Four more Apollo landings are scheduled, two in 1971 and two in 1972. The last three landings will have spacecraft and hardware with increased capabilities to provide for greater scientific returns from the missions.

Space Flight Operations is the name applied to that portion of the manned space flight effort directed toward the development of a capability that will allow man to journey into space routinely and economically and to use space flight in a routine manner to increase his knowledge and understanding of the earth and universe. Major elements of Space Flight Operations include Skylab, the space shuttle, the space station and associated experiments, and life sciences.

Skylab, an earth orbit workshop, scheduled for launch in early 1973, will be used during an eight month period to conduct over fifty experiments in a broad range of scientific and technological disciplines, but with special emphasis on earth resources, solar astronomy, and biomedicine.

The space shuttle represents the key element in achieving a low cost space transportation system. As a reusable vehicle, it will be able to carry passengers and cargo into space in an airline type of operation. Preliminary design studies of the space shuttle and its engine are now underway, with design and development of the engine scheduled to begin in mid 1971. Preliminary design studies of the space station are also being conducted. These studies are expected to result in selection of the optional design and operational configuration from the various conceptual alternatives. Life Sciences represents a consolidation of NASA's efforts in the areas of human factors, near earth biology, and biomedicine.

Advanced Missions Studies to examine manned space flight program concepts and the requirements for future systems will be continued. The aim of this effort is to provide technical information upon which to base future program decisions.

SPACE SCIENCE AND APPLICATIONS:

The FY 1972 budget emphasizes Space Applications and Planetary Exploration and continues a strong effort in the area of Physics and Astronomy.

In the Applications area, the first Earth Resources Technology Satellite will be completed, checked out and launched to conduct experiments to test the utility of spaceborne sensors for application to problems related to the earth natural and man made resources. The spacecraft in sun-synchronous orbit will carry instruments designed to meet the requirements of users for spatial and multi-spectral resolution and repetitive coverage. The satellite program will be supplemented by continuation of the aircraft earth resources survey project.

Space applications effort in the field of meteorology will continue. Final preparations will be underway for launch of a Synchronous Meteorological

Satellite to provide an operational prototype of a geostationary meteorological satellite to permit continuous observation of major weather systems. Work will proceed toward launch in late 1972 of the next Nimbus satellite carrying new instrumentation designed to extend determination of the vertical structure of the atmosphere into cloudy areas.

Work will also continue on Application Technology Satellite F and G which will flight test a space erectable parabolic antenna thirty feet in diameter, demonstrate high pointing accuracy and flight test a number of scientific and technology experiments. A Cooperative Applications Satellite will be initiated in conjunction with the Canadian Department of Communications to provide data on the use of frequency ranges above 10 GH_z.

The Lunar and Planetary Exploration program in FY 1972 encompasses an effort which will eventually lead to initial observations of all planets from Mercury to Pluto while continuing to expand our knowledge of Venus and Mars. Two Mariner spacecraft launched in FY 1971 will orbit Mars and return data about a variety of Martian characteristics during FY 1972. Preparation will be underway on the Mariner mission to Venus and Mercury to be launched in 1973, and a major program will be in progress on the Viking spacecraft designed to both orbit and land on Mars in 1975. Pioneer F will be launched and Pioneer G will be in preparation to provide our first observations and measurements beyond the orbit of Mars, flying through the asteriod belt and into the vicinity of Jupiter to provide initial spacecraft observations of that planet. Work will be in progress during FY 1972 on the U.S. experiment to be carried on the West German Helios spacecraft to be launched by the U.S. in 1974 and 1975 to investigate the interplanetary medium two-thirds the distance to the sun. Also during FY 1972, initial development effort will be undertaken on a long duration spacecraft suitable for a variety of missions to the outer planets. Initiation of this effort is intended to take advantage of the unique alignment of the outer planets in the late 1970's which will make possible gravity assisted flybys of three planets with a single spacecraft. A possible Jupiter orbiter mission will also be studied.

In Physics and Astronomy, experimentation with the improved Orbiting Solar Observatory, OSO-H, will continue while a new series of OSO's is under development. An Orbiting Astronomical Observatory, OAO-C, with the primary mission of studying interstellar gasses, will be launched during 1972. Development effort will be initiated on a High Energy Astronomical Observatory, HEAO, with instrumentation for identification and observation of gamma ray, X-ray and cosmic ray sources. Explorer spacecraft, sounding rockets, balloons, airborne instrumentation and ground-based research will supplement the major spacecraft projects.

ADVANCED RESEARCH AND TECHNOLOGY:

The FY 1972 program consists of three major categories of effort: Aeronautical Research and Technology, Space Research and Technology, and Nuclear Power and Propulsion.

Aeronautical Research and Technology involves a continuing program coordinated with other government agencies to expand the technological base in aeronautical research to facilitate the development and production of improved civil and military aircraft. Emphasis is being placed on technology that will increase the safety of aeronautical systems and reduce undesirable environmental effects.

Research will be continued in aerodynamics, flight dynamics, propulsion, operating systems, vehicle systems, life sciences, electronics, materials and structures, and noise reduction for application to future generations of aeronautical vehicles. Program emphasis in 1972 will be on Short Take-Off and Landing (STOL) and Vertical Take-Off and Landing (VTOL) aircraft systems for short-haul transportation and on improvements for medium and long-haul jet transports. Work to be undertaken in 1972 includes design and initial fabrication of experimental STOL turbofan transport research aircraft. The essential objectives of this program are to validate the predicted performance of powered lift, including engine quietness, and to permit the establishment of realistic criteria for en route and terminal operations and criteria for certification of STOL jet transport type aircraft.

In Space Research and Technology, research will be conducted in the areas of materials and structures, power and propulsion, machine intelligence, information sciences, guidance, control and communications. Effort will continue on laser communications and on reliable, long-life and high-speed/density components for space electronics systems. Research effort will also focus on advancing the technology needed to produce large amounts of electric power in space and to develop high specific impulse propulsion systems. Specific technology requirements for near-term objectives, including the space shuttle and planetary flight programs, will continue to be supported in the critical areas of thermal protection, aerothermodynamics, configuration development, entry technology and long-life componentry.

Nuclear power research will investigate advanced reactor and isotopic power systems. Research will continue on advanced nuclear propulsion concepts offering high performance potential. Work will continue on selected long-lead time components for the Nuclear Engine for Rocket Vehicle Application (NERVA) flight weight engine.

TRACKING AND DATA ACQUISITION:

The objective of this program is to provide the tracking and data acquisition support required by the NASA space flight programs. As the direction of the program has evolved from one of implementing a global support capability, to one primarily of maintaining and operating this world-wide capability, recent budget requests have reflected the operational nature of the program. Support of the Apollo missions will continue during FY 1972. Activity in support of the planetary program will increase in preparation for the workload in the early to the mid-seventies.

The FY 1972 funding request for purchase of equipment reflects emphasis on maintaining current capabilities, completing current procurement, and purchasing only the additional equipment necessary to support the increase in the planetary and applications program. Supporting Research and Technology will continue to emphasize studies for a Tracking and Data Relay Satellite System (TDRSS).

TECHNOLOGY UTILIZATION:

The Technology Utilization program provides for expeditious public availability of scientific, technological and engineering information and concepts which result from NASA programs. This promotes a maximum return from public investment in NASA's research and development to the non-aerospace sector of the economy as well as benefiting the aerospace industry. To assure fulfillment of this objective, the program provides for establishing effective mechanisms for assuring that all new knowledge is identified, collected and evaluated; and announcing and disseminating this new knowledge to assure its wide application and utilization.

The FY 1972 Research and Development program plan discussed in this budget totals $2,517,700,000, a reduction of $37,300,000 below the FY 1971 program of $2,555,000,000.

Research and Development expenditures for the current fiscal year are estimated at $2,610,000,000, and at $2,411,000,000 for FY 1972, a reduction of $199,000,000.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1972 ESTIMATES

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

BUDGET ACTIVITY	OFFICE/PROGRAM	Fiscal Year 1970	Fiscal Year 1971	Fiscal Year 1972
	MANNED SPACE FLIGHT.....	$2,029,967,000	$1,431,100,000	$1,286,475,000
1a	Apollo.....	1,684,367,000	914,400,000	612,200,000
1b	Space flight operations	343,100,000*	515,200,000	672,775,000
1c	Advanced missions.....	2,500,000	1,500,000	1,500,000
	SPACE SCIENCE AND APPLICATIONS.....	519,529,000	565,700,000	750,400,000
2a	Physics and astronomy..	112,851,000	116,000,000	110,300,000
2b	Lunar and planetary exploration.....	150,900,000	144,900,000	311,500,000
2c	Bioscience.....	19,655,000	12,900,000	---
3	Space applications.....	128,304,000	167,000,000	182,500,000
**	Launch vehicle procurement.....	107,819,000	124,900,000	146,100,000
	UNIVERSITY AFFAIRS			
6b	Sustaining university program.....	7,000,000	---	---
	ADVANCED RESEARCH AND TECHNOLOGY.....	270,931,000	264,200,000	212,825,000
5	Aeronautical research and technology.....	95,685,000	102,000,000	110,000,000
4	Space research and technology.....	119,977,000	107,000,000	75,105,000
4	Nuclear power and propulsion.....	55,269,000	55,200,000	27,720,000
6a	TRACKING AND DATA ACQUISITION.....	278,000,000	290,000,000	264,000,000
6c	TECHNOLOGY UTILIZATION...	5,000,000	4,000,000	4,000,000
	TOTAL BUDGET PLAN.....	$3,110,427,000	$2,555,000,000	$2,517,700,000

*Includes application of $117,473,000 reserved from apportionment in 1969 pursuant to the Revenue and Expenditure Control Act of 1968 (P.L. 90-364, 82 Stat. 251).

**In the Budget Appendix, page 835, the vehicle hardware portion of Launch Vehicle Procurement is statistically distributed to unmanned flight programs (e.g., Physics and Astronomy, Space Research and Technology) and the undistributed portion is identified as Activity 2d.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1972 ESTIMATES

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

(Thousands of dollars)

PROGRAM OFFICE	Total	Kennedy Space Center	Manned Spacecraft Center	Marshall Space Flight Center	Goddard Space Flight Center	Jet Propulsion Laboratory	Wallops Station	Ames Research Center	Electronics Research Center	Flight Research Center	Langley Research Center	Lewis Research Center	Space Nuclear Systems Office	NASA Headquarters
Office of Manned Space Flight														
1970	2,029,967	267,040	996,790	714,441	200	869	30	457	7	---	1,762	800	---	47,571
1971	1,431,100	179,585	592,275	599,875	200	470	---	6,525	---	---	650	25	---	51,495
1972	1,286,475	193,400	445,890	595,405	---	175	175	8,380	---	300	5,970	---	---	36,780
Office of Space Science and Applications														
1970	519,529	---	14,166	2,663	217,916	87,328	1,682	32,566	596	---	49,477	48,773	---	64,362
1971	565,700	2,995	13,812	4,655	251,731	68,382	2,894	40,485	---	---	43,400	67,664	---	69,682
1972	750,400	3,075	12,000	15,740	251,506	133,779	3,300	24,410	---	---	154,445	78,587	---	73,558
Office of University Affairs														
1970	7,000	---	---	---	---	---	---	---	---	---	---	---	---	7,000
1971	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1972	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Office of Advanced Research and Technology														
1970	270,931	---	8,705	13,683	9,540	20,938	1,734	31,644	6,651	8,980	54,632	62,075	33,568	18,781
1971	264,200	---	6,282	13,644	6,753	18,854	100	34,288	---	10,720	58,553	64,758	35,300	14,948
1972	212,825	---	1,300	13,095	4,535	18,890	---	34,265	---	18,750	45,105	56,005	13,325	7,555
Office of Tracking and Data Acquisition														
1970	278,000	---	---	1,560	204,367	52,258	6,456	---	---	1,875	880	---	---	10,604
1971	290,000	---	---	400	205,200	64,300	6,250	---	---	1,850	1,250	---	---	10,750
1972	264,000	---	---	300	189,200	55,000	6,250	---	---	1,500	950	---	---	10,800
Office of Technology Utilization														
1970	5,000	---	---	---	---	---	---	---	---	---	---	---	---	5,000
1971	4,000	---	---	---	---	---	---	---	---	---	---	---	---	4,000
1972	4,000	---	---	---	---	---	---	---	---	---	---	---	---	4,000
Total Budget Plan														
1970	3,110,427	267,040	1,019,661	732,347	432,023	161,393	9,902	64,667	7,254	10,855	106,751	111,648	33,568	153,318
1971	2,555,000	182,580	612,369	618,574	463,884	152,006	9,244	81,298	---	12,570	103,853	132,447	35,300	150,875
1972	2,517,700	196,475	459,190	624,540	445,241	207,844	9,725	67,055	---	20,550	206,470	134,592	13,325	132,693

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1972 ESTIMATES

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

(Thousands of dollars)

PROGRAM		TOTAL	Kennedy Space Center	Manned Spacecraft Center	Marshall Space Flight Center	Goddard Space Flight Center	Jet Propulsion Laboratory	Wallops Station	Ames Research Center	Electronics Research Center	Flight Research Center	Langley Research Center	Lewis Research Center	Space Nuclear Systems Office	NASA Headquarters
OFFICE OF MANNED SPACE FLIGHT, TOTAL	1970	2,029,967	267,040	996,790	714,441	200	869	30	457	7	---	1,762	800	---	47,571
	1971	1,431,100	179,585	592,275	599,875	200	470	---	6,525	---	---	610	25	---	51,495
	1972	1,286,475	193,400	445,890	595,405	---	175	175	8,380	---	300	5,970	---	---	36,780
Apollo	1970	1,684,367	258,350	873,393	513,047	200	869	30	50	7	---	960	---	---	37,461
	1971	914,400	170,000	454,500	259,400	200	470	---	---	---	---	440	---	---	29,390
	1972	612,200	170,900	230,040	191,725	---	---	---	---	---	---	---	---	---	19,535
Space flight operations	1970	343,100	8,690	122,007	200,634	---	---	---	407	---	---	802	800	---	9,760
	1971	515,200	9,485	137,275	339,775	---	---	---	6,525	---	---	210	25	---	21,905
	1972	672,775	22,400	215,250	403,080	---	175	175	8,380	---	300	5,970	---	---	17,045
Advanced missions	1970	2,500	---	1,390	760	---	---	---	---	---	---	---	---	---	350
	1971	1,500	100	500	700	---	---	---	---	---	---	---	---	---	200
	1972	1,500	100	600	600	---	---	---	---	---	---	---	---	---	200
OFFICE OF SPACE SCIENCE AND APPLICATIONS, TOTAL	1970	519,529	---	14,166	2,663	217,916	87,328	1,682	32,566	596	---	49,477	48,773	---	64,362
	1971	565,700	2,995	13,812	4,655	251,731	68,382	2,894	40,485	---	---	43,400	67,664	---	69,682
	1972	750,400	3,075	12,000	15,740	251,506	133,779	3,300	24,410	---	---	154,445	78,587	---	73,558
Physics and astronomy	1970	112,851	---	400	1,534	84,906	875	650	2,773	25	---	523	---	---	21,165
	1971	116,000	---	220	2,940	85,659	335	1,674	3,820	---	---	1,080	---	---	20,272
	1972	110,300	---	200	14,050	68,290	350	2,000	4,860	---	---	1,055	---	---	19,495
Lunar and planetary exploration	1970	150,900	---	643	88	4,841	81,618	---	21,636	2	---	28,904	---	---	13,168
	1971	144,900	42	685	400	4,438	64,659	---	34,471	---	---	23,166	---	---	17,039
	1972	311,500	---	100	800	6,800	131,500	---	17,900	---	---	133,500	---	---	20,900
Bioscience	1970	19,655	---	328	364	50	1,614	30	7,774	---	---	122	---	---	9,368
	1971	12,900	---	197	85	100	1,501	---	1,519	---	---	28	---	---	9,470
	1972	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Space applications	1970	128,304	---	12,795	150	92,450	2,731	1,002	383	277	---	6,265	1,320	---	10,931
	1971	167,000	---	12,710	280	128,346	1,087	1,220	675	---	---	5,085	1,390	---	16,207
	1972	182,500	---	11,700	200	140,450	1,300	1,300	1,650	---	---	3,650	3,700	---	18,550
Launch vehicle procurement	1970	107,819	---	---	527	35,669	490	---	---	292	---	13,658	47,453	---	9,730
	1971	124,900	2,953	---	950	33,188	800	---	---	---	---	14,041	66,274	---	6,694
	1972	146,100	3,075	---	690	35,966	629	---	---	---	---	16,240	74,887	---	14,613
OFFICE OF UNIVERSITY AFFAIRS	1970	7,000	---	---	---	---	---	---	---	---	---	---	---	---	7,000
	1971	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	1972	---	---	---	---	---	---	---	---	---	---	---	---	---	---
OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY, TOTAL	1970	270,931	---	8,705	13,683	9,540	20,938	1,734	31,644	6,651	8,980	54,632	62,275	33,568	18,781
	1971	264,200	---	6,282	13,644	6,753	18,854	100	34,288	---	10,720	58,553	64,758	35,300	14,948
	1972	212,825	---	1,300	13,095	4,535	18,890	---	34,265	---	18,750	45,105	56,305	13,325	7,555
Aeronautical research and technology	1970	95,685	---	---	1,223	---	741	---	18,708	3,095	7,291	27,355	27,396	---	9,276
	1971	102,000	---	---	1,369	---	715	---	21,586	---	8,665	32,863	30,300	---	6,502
	1972	110,000	---	---	1,725	---	750	---	26,355	---	17,750	29,200	30,725	---	3,495
Space research and technology	1970	119,977	---	8,605	10,641	9,190	16,513	1,734	12,686	3,556	1,689	26,927	19,501	---	8,935
	1971	107,000	---	6,282	10,675	6,540	14,545	100	12,362	---	2,055	25,125	21,788	---	7,528
	1972	75,105	---	1,300	10,370	4,475	14,940	---	7,435	---	1,000	15,380	16,145	---	4,060
Nuclear power and propulsion	1970	55,269	---	100	1,819	350	3,684	---	250	---	---	350	14,578	33,568	570
	1971	55,200	---	---	1,600	213	3,594	---	340	---	---	565	12,570	35,300	918
	1972	27,720	---	---	1,000	60	3,200	---	475	---	---	525	9,135	13,325	---
OFFICE OF TRACKING AND DATA ACQUISITION	1970	278,000	---	---	1,560	204,367	52,258	6,456	---	---	1,875	880	---	---	10,604
	1971	290,000	---	---	400	205,200	64,300	6,250	---	---	1,850	1,250	---	---	10,750
	1972	264,000	---	---	300	189,200	55,000	6,250	---	---	1,500	950	---	---	10,800
OFFICE OF TECHNOLOGY UTILIZATION	1970	5,000	---	---	---	---	---	---	---	---	---	---	---	---	5,000
	1971	4,000	---	---	---	---	---	---	---	---	---	---	---	---	4,000
	1972	4,000	---	---	---	---	---	---	---	---	---	---	---	---	4,000
TOTAL BUDGET PLAN	1970	3,110,427	267,040	1,019,661	732,347	432,023	161,393	9,902	64,667	7,254	10,855	106,751	111,548	33,568	153,318
	1971	2,555,000	182,580	612,369	618,574	463,884	152,006	9,244	81,298	---	12,570	103,853	132,447	35,300	150,875
	1972	2,517,700	196,475	459,190	624,540	445,241	207,844	9,725	67,055	---	20,550	206,470	134,592	13,325	132,693

SUM 8

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1972 ESTIMATES

RESEARCH AND DEVELOPMENT BUDGET PLAN FOR

MANNED SPACE FLIGHT PROGRAMS

Program	1970	1971	1972
Apollo.....	$1,684,367,000	$914,400,000	$612,200,000
Space flight operations....	343,100,000*	515,200,000	672,775,000
Advanced missions.....	2,500,000	1,500,000	1,500,000
Total.....	$2,029,967,000	$1,431,100,000	$1,286,475,000

* Includes $117,473,000 of FY 1969 funds applied to FY 1970 budget plan.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1972 ESTIMATES

OFFICE OF MANNED SPACE FLIGHT APOLLO PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

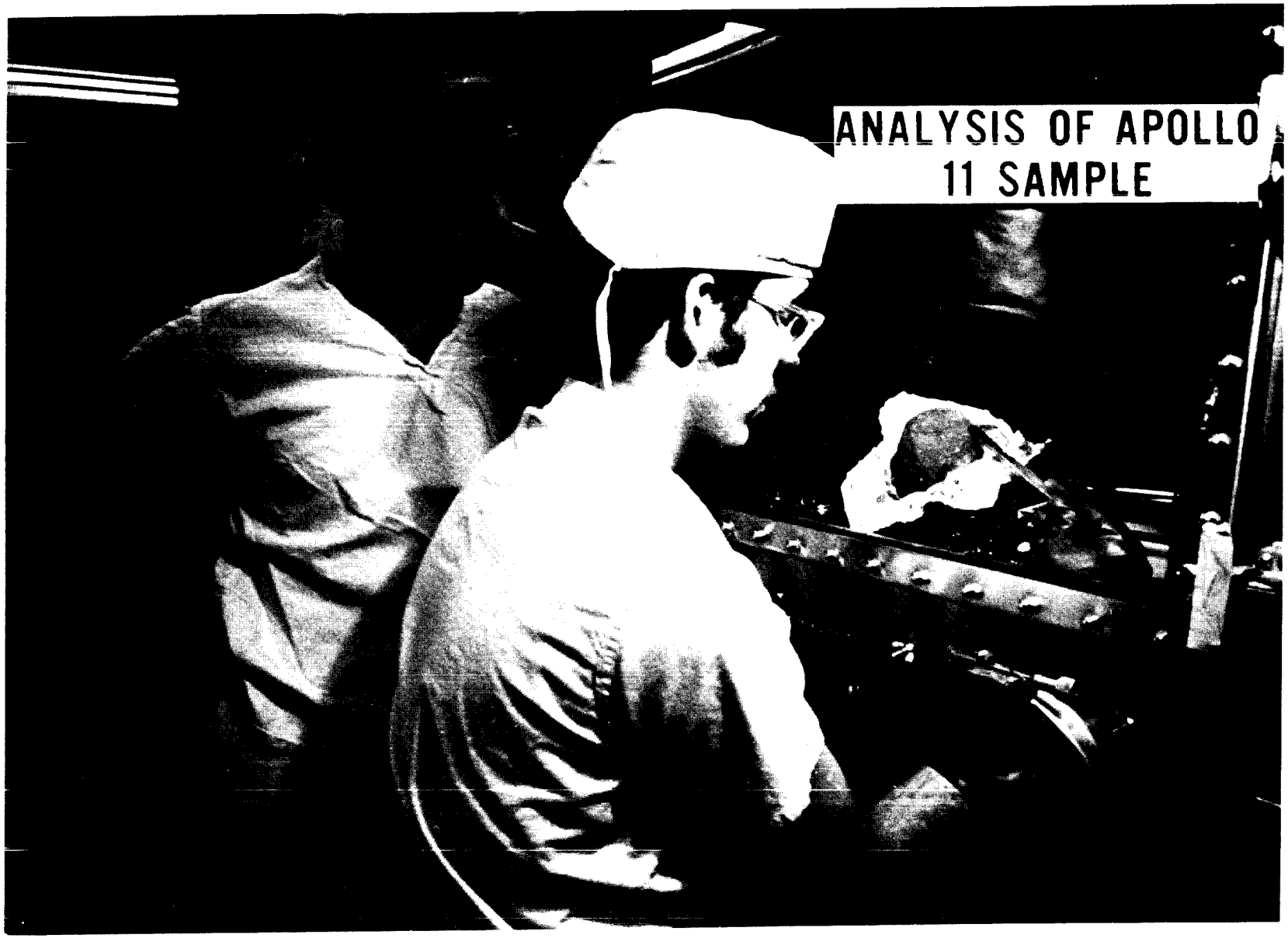
Americans have walked on the moon, deployed scientific experiments, collected and returned to earth samples of lunar rocks and soil that seem to date from the very beginning of our solar system.

As a result of the analysis of the lunar samples, present indications are that the moon was formed more than 4.5 billion years ago, approximately the same time as that estimated for the formation of the earth.

During the first billion and a half years in its history, the moon's surface became partially molten at least once and perhaps several times. As yet, because of the limited exploration of the moon, there has been no determination of the extent of area that was melted or the cause of the melting--whether it was from meteoritic impact or from internal heat produced by radioactive decay. The heating had to be on a large scale to accomplish the degree of differentiation found in the rocks, and there is substantial agreement that the lunar seas, or maria, represent lava flows of molten rock that solidified. The maria thus far sampled were filled with lavas approximately 3.4 - 3.7 billion years ago. Age dating indicates that they did not form simultaneously, but came into being as distinct events over a period of several hundred million years.

An important objective of future lunar landing missions will be to date the surface age of the lunar highlands. If the highlands date from the very beginning of the moon, and the maria were formed later during the first billion or more years, scientists should be able to observe a distinct, well preserved record of the events that occurred during the first billion years of the history of the solar system.

There are very few places on earth where any rocks can be found dating back to 3.5 billion years. Most of the earth's surface can be dated as being less than several hundred million years old. The dynamic processes of the earth's environment such as weather, erosion, displacement and movement of land masses, and volcanic activity, have destroyed and altered most of the historical record. Scientists now know that the moon, whose past history has not been significantly affected by such dynamic processes, has preserved its record well, and may become the archival reference as man seeks to understand the history of the earth and the solar system.


ANALYSIS OF APOLLO
11 SAMPLE

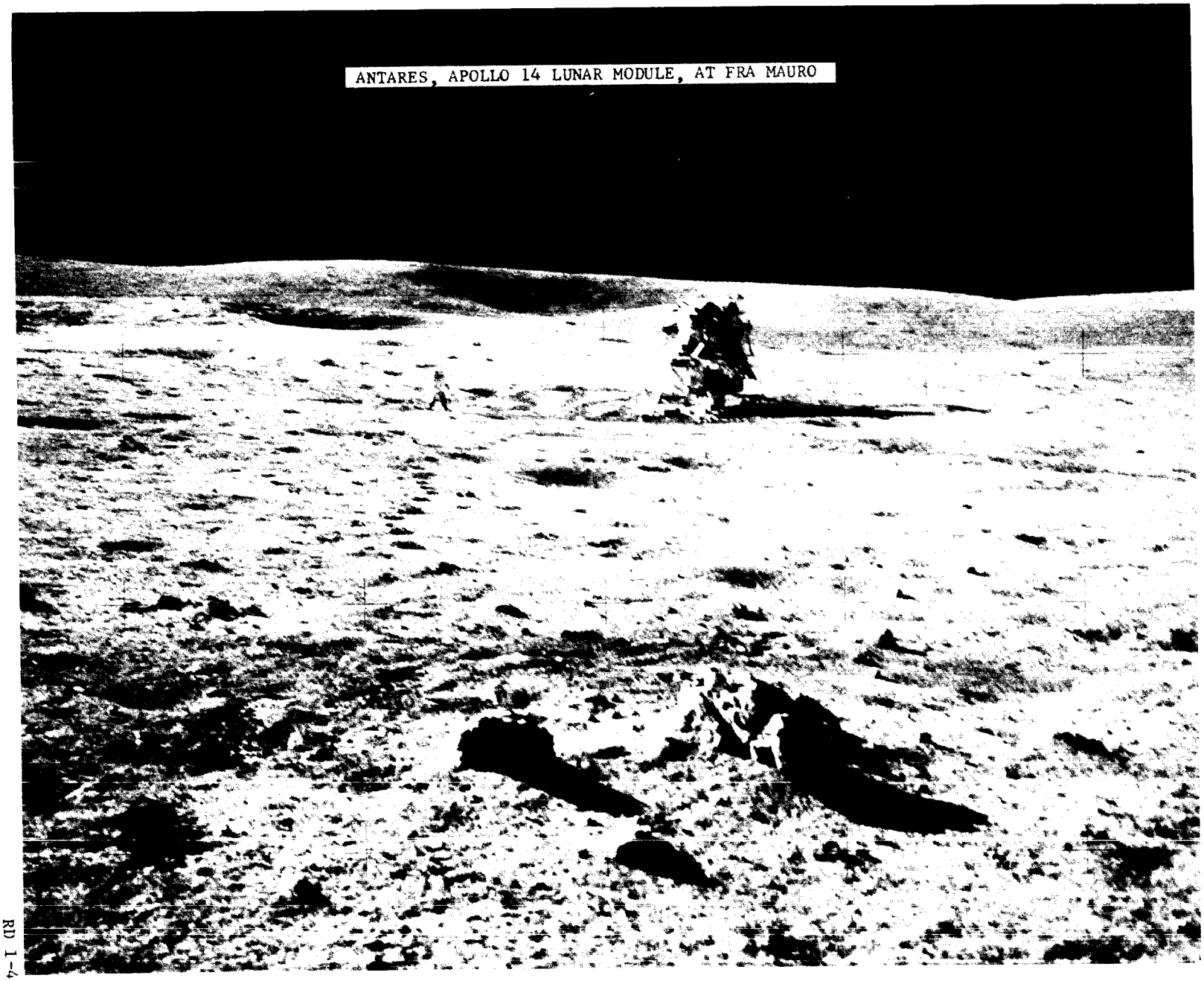
There has been no evidence that water has ever been present at the Apollo 11 and 12 landing sites, and it appears to be increasingly doubtful that water to any significant extent has ever been present on the moon.

No evidence of viable life has yet been uncovered in the analysis of the lunar material. The recently announced discovery of amino acids being present in a meteorite from the Asteroid Belt and the widespread presence of organic compounds detected throughout the universe indicates that the moon may be an invaluable site to search for evidence of early stages towards the beginning of life. This is especially so since the moon is believed by some to contain a relatively high abundance of material from carbonaceous chondrite meteorites, the class in which amino acids were detected. This meteoritic form is quite rare on earth, as it usually incinerates on entering the atmosphere.

There are significant differences in the distribution and relative abundance of elements on the moon as compared to the earth with the moon being relatively rich in refractory metals such as titanium, and relatively depleted in volatile metals such as lead and bismuth. Scientists, in studying the processes of formation for some of the lunar rocks, have searched for analogs here on earth and have found them, their scientific significance unrecognized before this time. This particular phase of study could be exceedingly valuable, for in promoting a greater understanding of the geological processes here on earth, the potential for discovering new ore supplies is present through increased insight into the processes that create them.

A seismometer placed on the lunar surface by the Apollo 12 astronauts has recorded more than 200 events of natural origin during the first eight months of operation. At least 26 were shallow moonquakes that occurred within three days of the time when the moon comes closest to the earth during its monthly orbit cycle. Some of these events may be related to the suggestion that the moon is becoming more circular as it slowly draws away from the earth and its tidal bulge is reduced. A primary source of these events is considered to be in the vicinity of the crater Fra Mauro, near the Apollo 14 mission landing site.

Lunar seismic signals are very complex and different from those on earth. During the Apollo 13 mission, the spent S-IVB stage impacted on the lunar surface at a distance of 85 miles from the Apollo 12 site with an approximate force of 11.5 tons of TNT. The data from this well calibrated signal indicates that the lunar material is fractured to depths of approximately 20 miles and shows no evidence of the major discontinuities which are a striking characteristic of the solid earth. No deep interior moonquakes have as yet been detected and there is no evidence of the kind of crustal movement and mountain building that is so important in the formation of the earth's topography and which is associated with the earth's molten core. The S-IVB stage from the Apollo 14 mission impacted 110 miles from the Apollo 12 site to provide additional reference data on the substructure of the moon. Both Apollo 12 and 14 passive seismometers recorded the impact of the Apollo 14 Lunar Module ascent stage and also a significant lunar seismic event that occurred while the Apollo 14 crew was returning to earth.


ANTARES, APOLLO 14 LUNAR MODULE, AT FRA MAURO

A magnetometer was deployed by the Apollo 12 crew to measure the magnetic field of the moon. A very small lunar magnetic field was anticipated but the Apollo 12 magnetometer showed an unexpected steady field about 10 times the predicted strength. The Apollo 14 astronauts carried a portable magnetometer on their second traverse, and the initial results indicate a significant magnetic field located at the Fra Mauro site. Analysis of the samples indicates that the moon was subjected to, or possessed a much stronger magnetic field in its early days, a field one-tenth as strong as that of the earth. Studies of the lunar magnetic data indicates that the moon may have a small central core with a temperature of from 800° to 1,000° centrigrade. This core is not believed to be liquid as is the earth's center.

The Laser Ranging Retro-Reflector deployed at Tranquility Base by the Apollo 11 astronauts, continues to perform satisfactorily. It serves as a target for point to point distance measurements from earth. These measurements are performed by recording the round trip travel time of short pulses of laser radiation transmitted from a telescope, reflected from the device, and received approximately two and one-half seconds later by the same telescope. Several measurements per week, with a precision of less than a foot in the earth-moon distance, are being made by the McDonald Observatory staff in the Davis Mountain area in Texas. Measurements to date have significantly improved our knowledge of lunar motion and expected results from longer periods of monitoring will relate not only to lunar motions, but to fluctuations in the earth's dynamics, including measurements of continental drift. It is hoped that the distance between the earth and moon can be calculated as precisely as one inch. This precision would be helpful in assessing the hypothesis that the moon is pulling away from the earth at a rate of one inch a year, and that the moon is becoming more circular as it does so. These laser measurements may also assist in determining the nature and extent of the hypothesis known as the Chandler Wobble of the earth's axis. It is suggested that this wobble is related to major earthquakes, and that during 1971 there will be a cyclic peaking of the wobble. A fuller understanding of such a phenomenon could help in making earthquakes predictable. The Laser Ranging Retro-Reflector deployed on Apollo 14 and planned for Apollo 15 will establish a network of instruments which will allow scientists to continue the study of dynamics of the earth-moon relationship. Since many observatories do not have telescopes of sufficient size to range on small arrays, the reflecting surface of the Apollo 15 array will be three times larger than the reflectors deployed on Apollo 11 and 14 and its optical efficiency will be increased to four times that of the Apollo 11 lunar reflector. The full exploitation of these reflectors will permit extended lunar ranging measurements from a number of observing stations around the world.

Some scientists who have studied the lunar rocks believe they have discovered indications of the existence of new very heavy elements in the transuranic series, unknown or extinct on earth. These naturally occurring elements would be more complex than the heaviest elements known on earth which are artificially created using nuclear research facilities. These indications are the product of unusual tracks found in the lunar samples. Other scientists have suggested that these tracks are the result of magnetic

monopoles, whose existence has been hypothesized. If monopoles do exist and could be controlled, this would produce a revolutionary development in the areas of high energy physics and power sources.

The moon's surface appears to have preserved a record of the sun's activity for many hundreds of millions of years. The sun's effect upon the earth's weather is well known and a historical correlation between changes in the earth's weather and fluctuations in solar activity could allow man to make better predictions of the long term climatic trends. Analysis of the returned Surveyor parts, which absorbed radiation from the sun for nearly three years, has been of great assistance in determining the relative intensity and composition of particles given off by the sun.

The Apollo 12 astronauts visited the Surveyor III spacecraft during their second EVA on November 19, 1969, and returned portions of the spacecraft which had been on the lunar surface and exposed to solar and cosmic radiation for a period of 31 months. Engineers and scientists have been evaluating the effects of space environment on the Surveyor parts at facilities in the United States and Europe. Most of the components, materials, optics, and other devices far exceeded design requirements and survived the extremes of vacuum, radiation, and temperature to which they were subjected. One type of terrestrial bacterium also survived this long exposure on the moon. The detailed results will be used to reduce the performance uncertainties associated with the effects of operation and lengthy storage of hardware in space, and to help in reducing the cost of space hardware. One conclusion from these studies is that no part failed as a result of exposure, but failures occurred as a result of prelaunch production and checkout activities.

Exploration into a new world or new area often produces unexpected and surprising results. One unexpected result from the analysis of lunar material has been that terrestrial plants thrive in it, growing significantly larger and greener than their counterparts planted in earth soil. Additional studies by NASA in collaboration with the Department of Agriculture are underway to investigate this phenomenon. These studies may lead to a new understanding of the chemistry of plant growth, or into the use of selected minerals as a stimulus to growth.

A second discovery has been that certain very hardy microorganisms, including staphylococcus, are quickly killed when put in contact with certain lunar soil samples. The reason for this is under study, but the results could lead the way to the control of harmful bacteria and viruses.

Analysis of the lunar samples has been undertaken in the spirit of international cooperation. Scientists from 16 foreign countries have already studied the Apollo 11 and 12 samples, and the applications of scientists in many other countries are being reviewed. The United States and the Soviet Union have just concluded an agreement to exchange lunar samples, with this country to receive lunar soil from the Sea of Plenty, returned to earth by the unmanned Soviet spacecraft Luna-16.

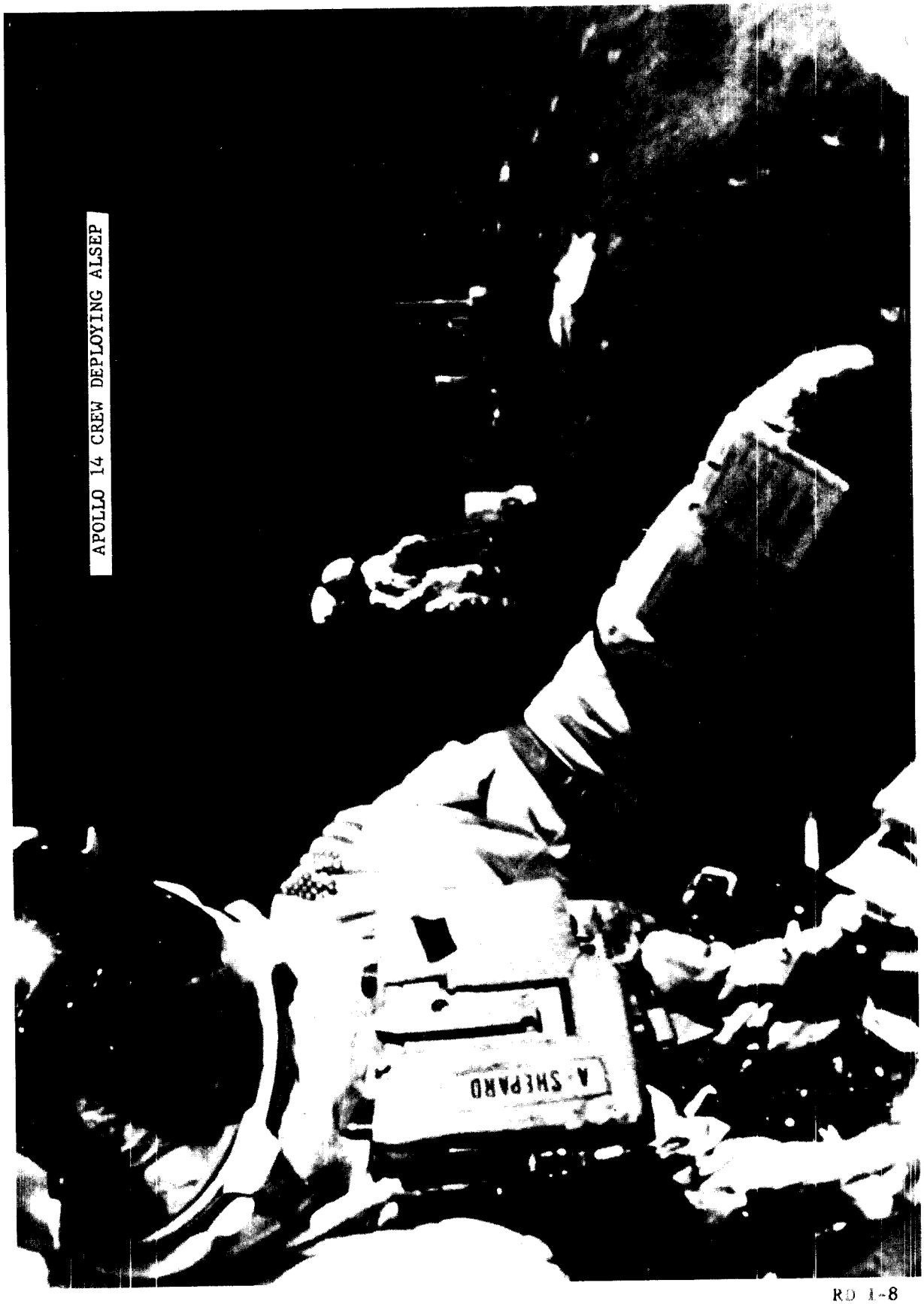
In September 1970 NASA reduced the number of remaining lunar missions from six to four. All approved experiments unique to the deleted flights will be flown on the remaining missions, and those Apollo 13 experiments not carried on the Apollo 14 mission are planned for other lunar landings. The decision makes Apollo hardware available for possible use in future national programs requiring manned operations or a very heavy payload capability. The present plan is to complete Apollo missions in 1972.

Two lunar landing missions were initially planned in 1970; however, after the aborted Apollo 13 mission, the scheduled launch of Apollo 14 was changed to January 1971 to incorporate modifications to the Command and Service Modules required as a result of the major problem that occurred during the Apollo 13 flight. The three remaining CSM's to be flown in the Apollo program include modifications to minimize the probability of a recurrence of the oxygen tank problem. Modifications include adding another oxygen tank; changing the in-tank wiring insulation; using stainless steel, rather than aluminum for the quantity sensing gauges; removing the heater assembly thermal switch; adding a temperature sensor and a third heater element; replacing fuel cell reactant shut-off valves with valves having isolated electrical circuits; and changing the caution and warning system.

To further utilize the experience recorded on the Apollo 13 mission, a study was undertaken to identify the spacecraft modifications that could be made to provide additional consumables and emergency equipment and increase the potential of the CSM and LM serving in a "lifeboat" mode. Two approaches were studied--retention of the LM ascent stage, and improvement of the return capability of the CSM. An analysis was made of each approach based on overall operational considerations, landing site opportunities, additional consumables required, and the weight factors. It was concluded from these analyses that modifications of the CSM to improve the return capability offered the most advantage in terms of safety. The major modifications to the CSM include the addition of a battery, isolation of the newly installed third cryogenic oxygen tank in the Service Module, and addition of more consumable water containers in the Command Module. The LM was provided with additional emergency capabilities should a failure occur during the mission when the LM could be used.

Another lunar landing mission, Apollo 15, is scheduled in 1971, with the final two, Apollo 16 and 17, in 1972. The Apollo 17 mission is planned for December 1972, five months later than the previous plan, to insure that scientific experiments that were originally to be flown on the now cancelled Apollo 18 and 19 missions will be fully available. This delay also helps minimize the FY 1972 funding requirement.

The Apollo 14 mission with Alan Shepard as Commander, Stuart Roosa as Command Module Pilot, and Edgar Mitchell as Lunar Module Pilot was launched on January 31, 1971. The landing site was Fra Mauro, which was the intended site for Apollo 13. This landing was the first Apollo landing at other than a lunar mare. The major objective of the mission was to investigate the Fra Mauro formation, an extensive geological unit, which lunar geologists believe is composed of material ballistically ejected and carried by a surge of gas and debris produced by the giant impact that created the Imbrium basin. It is



APOLLO 14 CREW DEPLOYING ALSEP

hoped that rocks found in the Fra Mauro formation will predate the general age of rocks from previous missions, and will date from the time of formation of the moon and perhaps from the origin of our solar system. The Apollo 14 astronauts returned approximately 100 pounds of lunar material which is presently undergoing preliminary analysis.

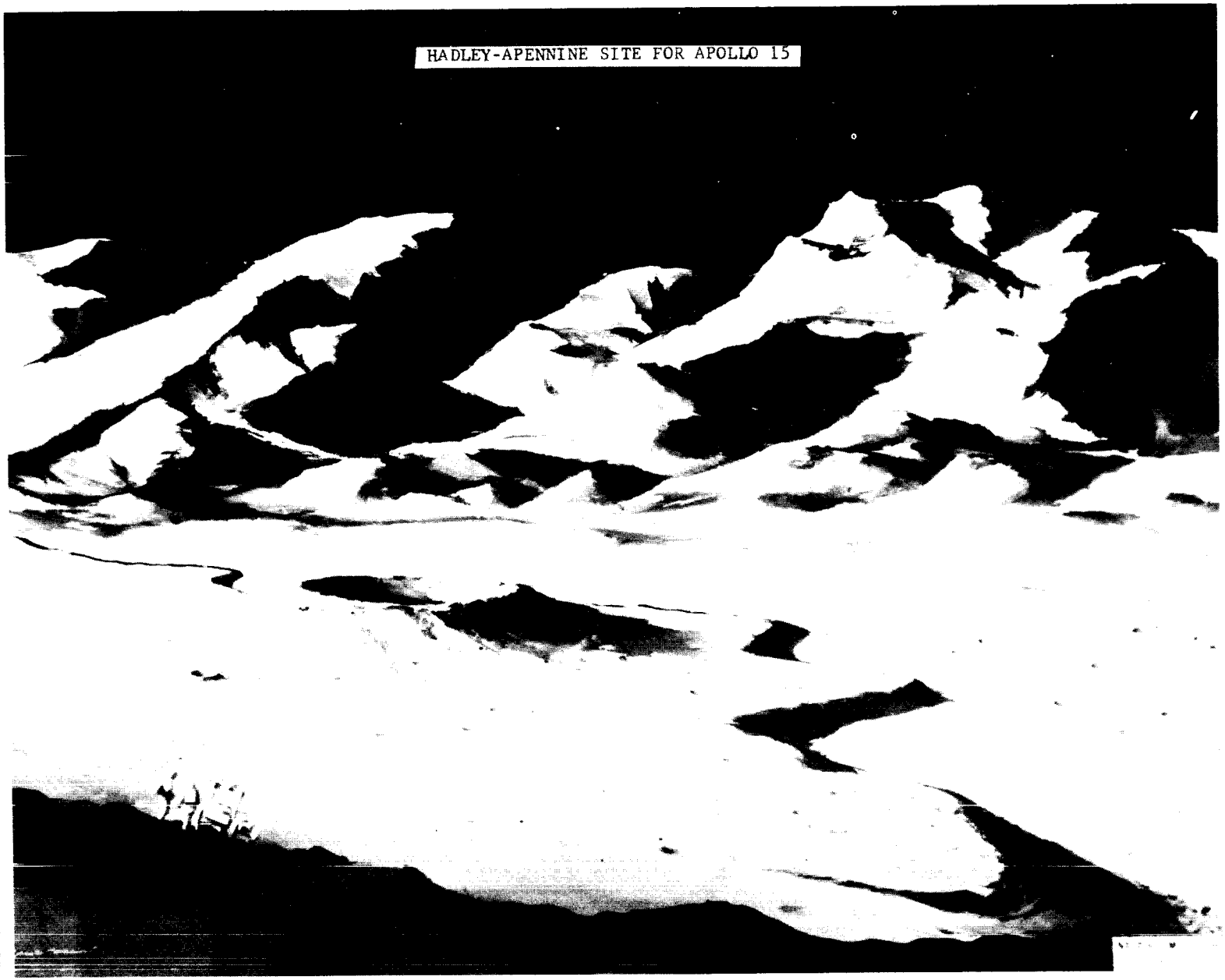
The Apollo 14 crew deployed an Apollo Lunar Surface Experiments Package (ALSEP) similar to the one previously placed at the Ocean of Storms. Two new experiments were added to that package. One was an active seismic experiment which generated and monitored artificially stimulated seismic waves in the lunar surface and near subsurface. The other is a low energy solar wind experiment to record proton and electron flux data for evaluation of solar wind and cosmic rays.

The astronauts, while on the lunar surface, deployed the following: a laser ranging retro-reflector to enable precise earth-to-moon measurements; a Passive Seismometer similar to that in use at the Apollo 12 site; a solar wind composition experiment to determine the isotopic composition of noble gases in the solar wind at the lunar surface; a portable magnetometer to measure the magnetic field of the moon at the landing site; a cold cathode ionization gauge to measure the density, temperature, and changes in the lunar atmosphere; and a suprathermal ion detector to study changed particles in the lunar atmosphere. The ALSEP package at the Fra Mauro site is working as designed, and complements the ALSEP operating on the Ocean of Storms. These two experiment stations represent the beginnings of a geophysical network of experiments providing information over long periods of time on physical phenomena and conditions on and near the surface of the moon.

A mobile equipment transporter, a light weight two wheel vehicle resembling a Chinese rickshaw, was used to carry cameras, hand tools, and sample bags for use by the astronauts and to assist in the use of the portable megnetometer.

During the mission, orbital science photography and remote geophysical sensing was conducted from the CSM. Photographic subjects included candidate landing sites, specific segments of the lunar surface in earth shine and in low level light near the terminator, and other lunar surface areas of prime scientific interest. A radar experiment examined the lunar surface bulk electrical properties as well as determining the average regolith depth and surface roughness.

The last three Apollo missions are the most sophisticated and comprehensive of the entire series. A whole new array of exploration procedures and instrumental concepts open new opportunities for research on the moon to scientists from all over the world. A total of 62 surface and orbital experiments will be conducted on the Apollo 15-17 missions. Of these, 18 will be new experiments. In addition, three new photographic tasks will be conducted from lunar orbit, and these tasks will be performed on each mission. Changes in the LM and lunar surface hardware will allow the astronauts to remain on the lunar surface for up to 66 hours; the landed scientific payload will be doubled to approximately 1,000 pounds; and the range and efficiency of surface operations will be increased through improved suit mobility, improved life support system, and a lunar roving vehicle.


HADLEY-APENNINE SITE FOR APOLLO 15

Further, CSM changes are being made to add nearly 1,000 pounds of cameras, other remote sensing scientific equipment, and additional consumables to increase the capability to study the moon from orbit. Findings from the widely separated landings can then be tied together and fitted into a total picture of the moon.

Many of the orbital experiments to be conducted during the last three Apollo missions will be operated from an integrated instrument package located in the Service Module. Instruments scheduled include a mapping camera system which will provide a capability for high resolution panoramic metric photography, laser altimetry and reference stellar photography. The information obtained will permit a more detailed study of the moon's size, shape, surface topography, and the interrelationship between the gravitational field and lunar surface features. Other orbital experiments include a variety of sensors for examining the geochemical and physical properties of large areas of the lunar surface, and for studying the fields and particles environment of the moon.

Apollo 15 and 17 missions will each deliver small, self-powered subsatellites to lunar orbit. The subsatellites will monitor the variation of magnetic fields and interplanetary charged particle streams in the vicinity of the moon to determine the electrical body properties of the moon and infer internal physical characteristics. The subsatellites are equipped with transponders which will provide for refinement and extension of mass concentration and mass deficiency data.

Of particular interest in the latter missions is the increased surface mobility which will be provided to the astronauts by the lunar roving vehicle. This vehicle will greatly increase the mobility and range of the astronauts. It can carry both astronauts, their equipment and the collected surface samples. A wide variety of samples will be collected during each of the three EVA's to be conducted during each mission to provide a more complete understanding of the characteristics and features of the landing site.

The Apollo 15 crew will have David Scott in Command, Alfred Worden as Command Module Pilot, and James Irwin as Lunar Module Pilot. It is scheduled for launch in July 1971, and will land in the Hadley-Apennine mountain region on the edge of the Sea of Rains. Near the landing point, the Apennine Mountains rise up to 8,000 feet above the mare floor which includes sinuous Hadley Rille, a canyon 600-1,000 feet, 1/2 mile wide and 50 miles long.

At the Hadley-Apennine site, another ALSEP will be emplaced. A new experiment to be employed during this mission will be the heat flow experiment which will be placed in holes drilled about ten feet into the surface. The measurement of heat flow from the interior of the moon is a fundamental geophysical measurement needed to interpret the present internal constitution of the moon as well as its history and evolution. This experiment was originally scheduled on Apollo 13. In addition, another passive seismometer and magnetometer, both of which will provide information about the interior of the moon, along with several instruments that analyze the lunar atmosphere will be deployed to continue the establishment of an instrument network on the moon.

Specific landing sites for Apollo 16 and 17 have not been selected. Three sites are considered primary candidates. They are the Marius Hills, a major ridge system of apparently volcanic origin; Descartes, a highland area; and the 60-mile diameter crater Copernicus with its 2,500 foot high central peak.

A lunar sounder and lunar seismic profiling experiment will be flown on Apollo 17. Data analysis from the Apollo 12 seismometer implies that moonquakes are analagous to earthquakes generated by slippage, but they always appear to slip in the same direction. This is very likely caused by a source of strain accumulating within the moon and being released by the additional tidal forces that occur at the time of close earth-moon proximity. At present, scientists can only speculate as to the source of strain. Further data from the lunar seismic profiling experiment may provide a clearer insight into this phenomenon.

The lunar sounder, a radio sounding device, will be used to probe geological substrata from high altitudes. It will be included as part of the orbital scientific experiment package on Apollo 17. This lunar sounder has a long development time and would not have been available for earlier flight schedules. The device is similar to radar in its transmission of a signal and sensing the return from the target area. However, the use of multiple frequencies and their known penetration variations make it possible to extrapolate the density and makeup of the subsurface.

Completion of the Apollo flight program has been extended five months to December 1972, to improve the science return on the last mission and to enhance the opportunities to incorporate the results of previous lunar flights into this last flight. Experience with previous lunar exploration demonstrates the desirability for additional time for the scientific community to assimilate the data received from each flight. This can be accomplished by a more complete and thorough analysis of the results of each mission and incorporating this knowledge into the investigative plans for the next mission.

Since Apollo 16 and 17 are planned as the last opportunities in this decade for manned exploration of the moon by this country, it is important for the nation to obtain the greatest possible scientific returns from these flights. This rescheduling of Apollo launches increases the interval between missions and a delicate balance must be maintained between the launch intervals and the scientific returns from these flights. Operational efficiency and safety are directly related and depend on a launch rate sufficient to maintain an effective level of competence in the Apollo team. The new Apollo schedule maintains this delicate balance while allowing the scientific returns to be expanded.

SUMMARY OF RESOURCES REQUIREMENTS:

	1970	1971	1972
Spacecraft.....	$775,608,000	$411,086,000	$164,152,000
Saturn V.....	486,691,000	237,700,000	186,003,000
MSF operations.....	422,068,000	265,614,000	262,045,000
Total.....	$1,684,367,000	$914,400,000	$612,200,000

Distribution of Program Amount by Installation:

	1970	1971	1972
John F. Kennedy Space Center	$258,350,000	$170,000,000	$170,900,000
Manned Spacecraft Center....	873,393,000	454,500,000	230,040,000
Marshall Space Flight Center	513,047,000	259,400,000	191,725,000
Goddard Space Flight Center.	200,000	200,000	---
Jet Propulsion Laboratory...	869,000	470,000	---
Wallops Station.....	30,000	---	---
Ames Research Center.....	50,000	---	---
Electronics Research Center.	7,000	---	---
Langley Research Center.....	960,000	440,000	---
NASA Headquarters.....	37,461,000	29,390,000	19,535,000

BASIS OF FUND REQUIREMENTS:

Spacecraft

Spacecraft.....	$775,608,000	$411,086,000	$164,152,000
Total.....	$775,608,000	$411,086,000	$164,152,000

The Command and Service Modules and Lunar Modules required to conclude the Apollo flight program will be essentially complete by the end of FY 1971. The spacecraft contractors, North American Rockwell for the Command and Service Module and Grumman Aerospace Corporation for the Lunar Module, have delivered the Apollo 15 spacecraft to the Kennedy Space Center (KSC). The spacecraft for the Apollo 16 and 17 missions are in checkout, with the Apollo 16 hardware scheduled for delivery before the end of FY 1971.

Work on CSM's and LM's intended for missions now cancelled has been suspended. The CSM's are being placed in long term storage for possible future earth orbital missions. Hardware from the LM's will be used to support the remaining Apollo missions, after which the LM's will be disposed of in accordance with national interests. No follow-on Apollo spacecraft production capability is planned; tooling facilities and other equipment for production will be disposed of in the most economical manner.

The Lunar Roving Vehicle test program is nearly complete, with qualification testing scheduled to be finished in January 1971. Fabrication and assembly of the flight units is underway, with the first flight unit, to be flown on Apollo 15, will be delivered to KSC in March 1971. The final flight unit will be completed early in FY 1972.

The Apollo 11 mission carried four experiments to the lunar surface, and nine lunar surface experiments were carried by Apollo 12. The Apollo 14 crew performed or deployed eleven lunar surface experiments, in addition to conducting four orbital experiments. While the number of lunar surface experiments

will not change significantly for the Apollo 15, 16, and 17 landings, the type of experiment will vary depending upon site characteristics, and to provide the opportunity to take a range of scientific measurements. Among the experiments to be deployed on the lunar surface will be seismometers, heat flow experiments, various geology instruments, gravity experiments, magnetometers and atmosphere and particle detectors.

The ALSEP for Apollo 15 will be delivered to KSC in FY 1971, with the Apollo 16 ALSEP delivery scheduled for early FY 1972. Work is now underway on the Apollo 17 ALSEP which will be delivered to KSC in the latter part of FY 1972. This experiment package contains four new experiments: the seismic profiling, lunar ejecta and meteoroid, atmospheric composition, and surface gravimeter. Other new surface experiments to be carried on Apollo 17 are a traverse gravimeter and a surface electrical properties experiment.

The orbital experiments for the Apollo 15 and 16 missions will be delivered in FY 1971. Work is now underway on the experiments for the Apollo 17 flight. This mission will be the first flight for the ultraviolet (UV) spectrometer, infrared (IR) scanning radiometer, and lunar sounder. These experiments are scheduled to be delivered in FY 1972.

Funding in FY 1972 is required to support the preparation, flight, and post flight analysis of Apollo missions. It also provides for modifications, factory checkout and delivery of spacecraft, and procurement of science payloads and equipment that is required to support the remaining Apollo flights. Included is flight equipment such as the spacesuits, the portable life support systems, and the Lunar Communication Relay Unit (LCRU) which will provide the astronaut with a direct communications link to the earth when he is out of sight of the Lunar Module. The LCRU will be used in association with the Lunar Roving Vehicle, and will also feature a color television camera. The LCRU is a new development and will have its first flight on Apollo 15. The spacesuits and the life support systems have also been upgraded for the last three Apollo missions.

A most essential and critical requirement included in the funding request for FY 1972 is the contractor engineering effort necessary to support the flight program. It is this contractor engineering team that contributed so significantly to the safe return of the Apollo 13 crew. Necessary levels of critical skills will be maintained to assure flight safety and to provide a rapid response in resolving any problems which arise during the launch preparation and flight phases of a mission. Tasks to be performed by contractor personnel at the plants and at Manned Space Flight centers include mission support, field and flight problem resolution, failure analysis, and any necessary repair and subsequent retesting of failed components. In addition, personnel are required to maintain and calibrate special test equipment and maintain required tooling and documentation.

Saturn V

	1970	1971	1972
Saturn V.....	$486,691,000	$237,700,000	$186,003,000
Total.....	$486,691,000	$237,700,000	$186,003,000

All Saturn V launch vehicles stages have completed manufacture and static test. The vehicle for Apollo 15 has been delivered to KSC with the final elements of the Saturn V vehicles for both Apollo 16 and 17 to be delivered to KSC during FY 1972. All the stages for these missions are presently in storage. The S-IC stages manufactured by Boeing Aircraft Corporation are located at the Michoud Assembly Facility and Mississippi Test Facility. The S-II stages were built by North American Rockwell and all the S-II stages are in storage at the Kennedy Space Center. The McDonnell Douglas Corporation S-IVB stages for these two missions are at the Kennedy Space Center, and the Instrument Units assembled by IBM are located at Huntsville, Alabama. Check-out of the Instrument Units for the Apollo 16 and 17 missions will be completed in FY 1971, with manufacturing and checkout of the last Saturn V Instrument Unit scheduled to be completed in FY 1972. This will complete the production of the 15 Saturn V launch vehicles purchased for the Apollo program.

Funding in FY 1972 will provide for transportation of the S-IC stages and instrument units to KSC; systems engineering, integration and configuration support; engineering and technical support at the Marshall Space Flight Center laboratories in support of the flight program; maintenance and operation of the Slidell, La. computer facility; and maintenance of the Mississippi Test Facility and the Michoud Assembly Facility.

As with the Spacecraft, an essential and critical Saturn V requirement included in the funding request for FY 1972 is the contractor in-plant engineering effort necessary to support the flight program. The required levels of critical skills will be maintained to assure flight safety and to resolve problems which arise during the launch preparation and flight phases of a mission. Tasks to be performed by contractor personnel at the plants include mission support, field and flight problem resolution, failure analysis, and repair and subsequent retest. In addition, certain personnel are required to maintain and calibrate special test equipment and maintain required tooling and documentation.

Funding is also included for storage and maintenance of production tooling and facilities so that, if required, Saturn V production could be restarted at some future date. In addition, videotapes and other graphic records of manufacturing techniques, test and checkout procedures, and associated production tasks will be made to facilitate any future restart and to reduce the cost of resuming production. Funding will also be used to inventory and

assess the future usefulness of equipment and materials, and to perform any other necessary tasks related to concluding a production run while preserving the capability for future resumption.

MSF Operations

	1970	1971	1972
Launch, flight and recovery.....	$371,365,000	$230,133,000	$234,745,000
Technical.....	50,703,000	35,481,000	27,300,000
Total.....	$422,068,000	$265,614,000	$262,045,000

In addition to providing for the conduct of actual Apollo missions, MSF Operations funding provides for the basic capabilities in crew training, launch, flight, recovery and program-wide technical and Department of Defense support required for manned space flights regardless of program. These activities are located primarily at the Kennedy Space Center, Florida and the Manned Spacecraft Center, Texas.

The major operational costs of the Kennedy Space Center are associated with the checkout of the spacecraft and launch vehicles, and the launch support requirements. Support is supplied by both NASA contractors and the Air Force Eastern Test Range. Included are the actual prelaunch checkout, assembly and launch of the space vehicles, management and operation of launch complexes; systems engineering services; technical shop operations; propellant services and propellant systems maintenance; laboratory operations; and ordnance storage. Also included are engineering design and fabrication services for the ground support equipment systems that support the launch capability; modification, installation and specialized maintenance of launch facilities; and post launch facility refurbishment.

Other operational costs at KSC include those associated with computation and instrumentation support, involving the operation and maintenance of computing systems, high speed plotters, magnetic tape data transmission equipment, and peripheral computer equipment. Additional operational support provided under this category includes the operation and maintenance of telemetry, antenna, and tracking systems that receive and process data from prelaunch tests and launches of NASA space vehicles.

The Manned Spacecraft Center in Houston is the headquarters for all crew, flight, and recovery operations. The astronauts are based at this center along with most of their essential training equipment. This equipment includes proficiency aircraft, spacecraft mockups, procedures simulator, docking trainer, zero "G" simulator, systems trainer, lunar landing training vehicles and the mission simulators. The Manned Spacecraft Center is also responsible for mission simulation and other astronaut training equipment

located at the Kennedy Space Center. Also at MSC is the Mission Control Center with its computer complex and communications links to the tracking network and other worldwide data sources. The Center controls flight operations from shortly after liftoff to recovery.

In addition to basic expenses in support of these operations, there are requirements that are directly relatable to specific missions such as mission planning, including trajectory analysis; failure analysis and evaluation of operational performance; and the funding of recovery operations which encompasses the planning, development and operational phases of recovery activity including the location and retrieval of the astronauts and spacecraft following touchdown. The DOD provides most of the recovery operation elements required by NASA in this support category. Reimbursement is made for all DOD costs incurred based on the number of ships, aircraft, communications facilities and training personnel deployed, and on the number of days these resources are used.

Technical

Technical operations provides for the systems engineering needed for integrated technical support, review, and analysis; advanced development, contract administration, audit, and property administration provided by the Department of Defense on a reimbursable basis; and for the nonrecurring maintenance and rehabilitation of government-owned industrial plants.

OFFICE OF MANNED SPACE FLIGHT — SPACE FLIGHT OPERATIONS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

Space Flight Operations employs the scientific, technological, and operational capability developed in the Apollo program to exploit space for direct practical benefits, and to further expand man's exploration of that domain. The principal goal of the past decade was to demonstrate this nation's abilities in space by accomplishing a manned lunar landing and return before the end of that decade. This capability can now be directed toward the beneficial utilization of space initially through the eight month flight of Skylab, a precursor space station, and later through the operation of a reusable transportation system, and long duration space station. This reusable transportation system, or space shuttle, will be able to carry scientists, technologists and specialists of different skills and disciplines, as passengers into space without their having to qualify as astronauts. The flight characteristics of the shuttle as a passenger transport system would allow men and women from any interested country to travel into space. The station and shuttle would support a wide range of experiments and experiment disciplines.

Space Flight Operations activities will commence with the Skylab program formerly known as Apollo Applications, in which the S-IVB stage of the Saturn launch vehicle is being modified to serve as an orbital workshop. Skylab is a necessary first step toward developing a capability for long duration manned operations in earth orbit. Three successive teams of astronauts will occupy this experimental laboratory for periods of up to two months. They will use the installed equipment to perform scientific and application experiments, conduct solar observations, and determine the physiological and psychological effects of long duration flight on the health of the astronauts and on crew morale and effectiveness. Exercises, habitability factors, and other ameliorating conditions and activities that reduce any adverse effects will be investigated.

In the latter part of the decade, the space shuttle, a fully reusable vehicle capable of carrying large payloads, composed of passengers, cargo or a combination of the two, to and from earth orbit, will provide an economical space transportation system designed to make near earth space more readily accessible for a great variety of manned and unmanned activities.

The primary objective of the space shuttle program is to develop and place into operation an earth-to-earth orbit and return space transportation

system, with characteristics which not only reduce the direct cost of transportation to earth orbit but permit accompanying reductions in the costs of payloads. It is anticipated that the reduction in the costs of space operations made possible by use of the shuttle will permit far greater use of space than has been previously economically possible, and allow a substantial increase in the scope and range of benefits derived from space operations.

The category, Orbital Systems and Experiments, consists of activity in three areas: space station modules, experiments, and space life sciences.

Space station module and experiment study efforts will continue to define an advanced earth orbital facility, logistically supported by the shuttle, and characterized by routine, long term, flexible, productive operations, with minimum operating costs and increased crew efficiency and safety. The experiments to be conducted in association with station and shuttle operations encompass nearly all the scientific disciplines.

Complementing all space activities, underway and planned, is space life sciences. This integrated medical and biological program provides for the study and investigation of the effects of space on man and other living organisms, and the translation of these effects into meeting man's requirements to survive in space.

SUMMARY OF RESOURCES REQUIREMENTS:

	1970	1971	1972
Skylab	$324,600,000	$405,200,000	$535,400,000
Space shuttle	12,500,000	80,000,000	100,000,000
Orbital systems and experiments	6,000,000	30,000,000	37,375,000
Total	$343,100,000	$515,200,000	$672,775,000

Distribution of Program Amount by Installation:

John F. Kennedy Space Center, NASA	$8,690,000	$9,485,000	$22,400,000
Manned Spacecraft Center	122,007,000	137,275,000	215,250,000
Marshall Space Flight Center	200,634,000	339,775,000	403,080,000
Jet Propulsion Laboratory	---	---	175,000
Wallops Station	---	---	175,000
Ames Research Center	407,000	6,525,000	8,380,000
Flight Research Center	---	---	300,000
Langley Research Center	802,000	210,000	5,970,000
Lewis Research Center	800,000	25,000	---
NASA Headquarters	9,760,000	21,905,000	17,045,000

BASIS OF FUND REQUIREMENTS:

Skylab

The Skylab project has reached an advanced state of development. Its principal objectives are to utilize and apply space for man's benefit and knowledge while demonstrating man's capability to live and work in space for extended periods of time.

The flight phase will commence early in 1973 with the unmanned launch of the Orbital Workshop. Operations will begin one day later when the first of three crews in an Apollo Command and Service Module launched on a Saturn IB vehicle will rendezvous and dock with the Workshop. The Workshop, consisting of laboratories, work areas, control stations, living quarters, earth sensors and a solar observatory, will be used in performing astronomy, space physics, and earth resources studies and experiments; bioscience and medical experimentation; and manufacturing and engineering technology demonstrations.

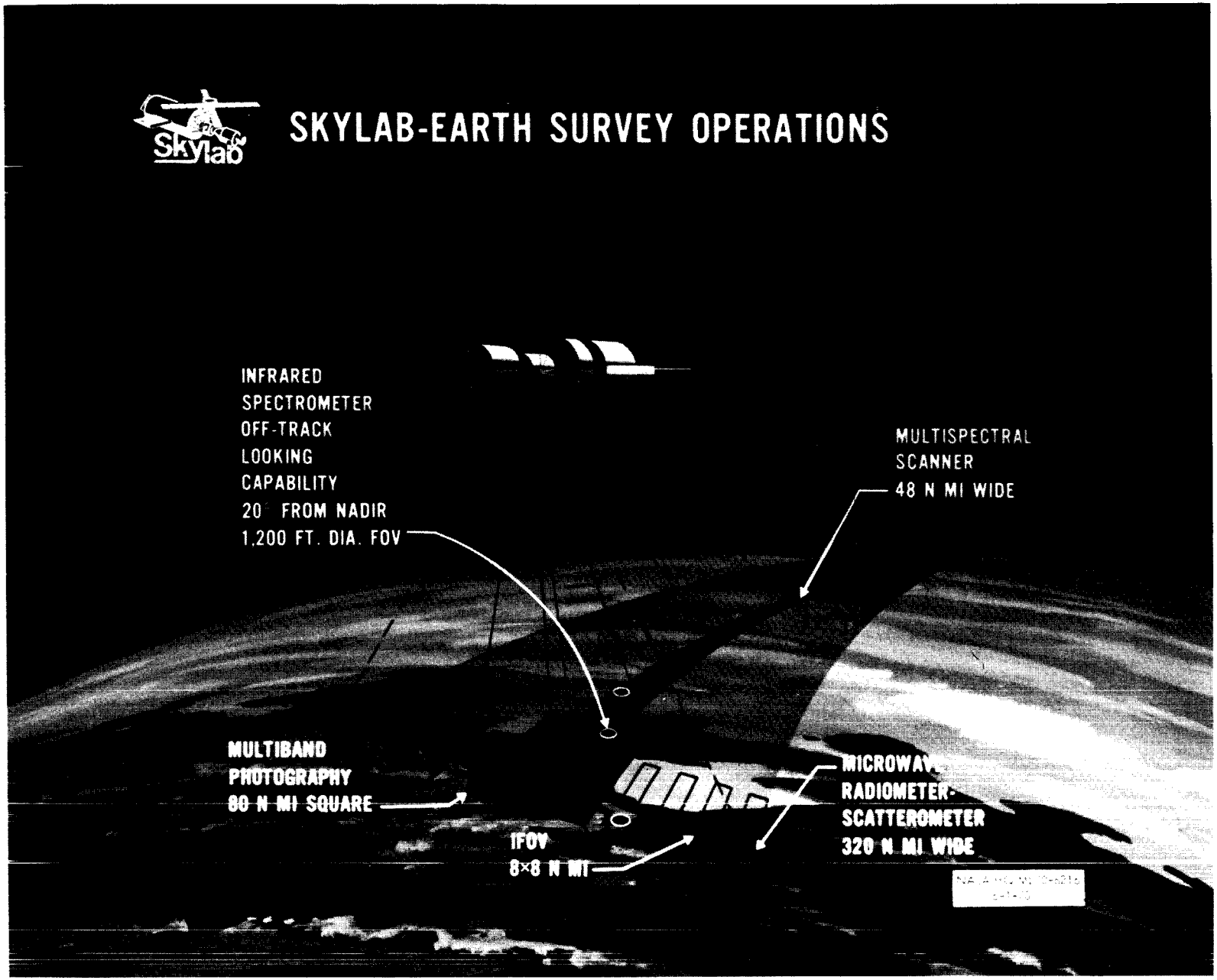
The Workshop with its on-board instruments constitutes an orbital research facility that will be used to advance knowledge in many of the areas that have been identified as appropriate for space operations. Over 2,200 astronaut hours will be allocated to experiment activities, more than three times the amount assigned in all prior U.S. manned earth orbit missions.

Earth Sciences:

The use of sensors and cameras from space to record and monitor the resources of the earth, man's interaction with his world, and the natural processes and interdependencies that characterize and represent our environment, provides an opportunity for improving the quality of life on earth. The Earth Resources Experiment Package, or EREP, to be flown in Skylab will demonstrate the practical application of earth resources surveys in providing the data base for management and conservation of the earth's resources.

Sensors and cameras can be used to study our agricultural and forest resources by seeking and mapping the progress of plant diseases, and by surveying these resources, to provide assessments of projected and potential yield. Land usage can be recorded to provide a comprehensive insight into the ways in which man uses this limited resource. Urban and demographic planners can assess relative population distributions, and examine the structure of metropolitan areas. Cartographers can construct current maps for much of the world's surface and chart areas for which no detailed maps exist. Geologists can locate areas of promise in the continuing exploration for mineral resources to sustain the economy and to replenish diminishing supplies. Hydrologists can survey and catalogue existing water resources while seeking the location of new sources, and will be able to more effectively conserve and manage the supplies that are available. The oceans can be

SKYLAB-EARTH SURVEY OPERATIONS



studied to better understand the dynamics of the sea, its currents, upwellings, and waves, potentially enabling man to more properly and efficiently harvest the resources of the sea, and protect the land from erosion.

High resolution coverage of atmospheric processes and phenomena can enable meteorologists to gain new insights into the nature of weather. Environmentalists can monitor the range and degree of the pollution that seems to permeate the air and waters of the earth, and quantitative assessments of the type and nature of pollution can be made.

The Skylab mission will travel in a high orbital inclination to provide earth survey coverage between 50° latitude north and south. This will cover some 75% of the earth's area, including 80% of food producing areas, and 90% of the population. The coverage encompasses the contiguous United States, and as an example has as its northern boundary a line stretching from central Germany through southern Belgium and the English channel across the North Atlantic to the Gulf of St. Lawrence and across the southern tier of western Canadian provinces. The southern boundary circles the oceans north of Antarctica and crosses land only at the southern tip of Chile and Argentina.

To take maximum advantage of this high inclination, the earth-looking capabilities of the Workshop have been increased by improving the quality of the multispectral camera array to provide for higher resolution over an expanded range of wavelengths. A second experiment, the infrared spectrometer, will analyze the spectral characteristics of earth phenomena without serious atmospheric interference. A 10-Band multispectral scanner will measure radiation in various regions of the spectrum reflected or emitted from selected test sites. The remaining two experiments are a microwave scatterometer, altimeter, and radiometer, and a L-Band microwave radiometer and will study the use of radar and passive microwave systems. These two experiments can operate day or night and are not affected by weather and clouds. Their primary objectives will be to examine ocean surfaces and temperatures; and on land to record the presence and extent of water or snow.

The earth sensing Skylab instruments will complement those flying in polar orbit on the unmanned Earth Resources Technology Satellite (ERTS) during this period. The ERTS satellites can supply continuous coverage on a dedicated basis, while the Skylab viewing will be performed in conjunction with other experiment priorities and with different spectral coverage. This will permit coordinated measurements of the same area by different systems. Aircraft and ground measurements of specific test sites, both in the United States and other countries which are cooperating in this activity, will also be made for the purposes of calibrating and interpreting the data from the Workshop and ERTS.

Astronomy and Space Physics:

The Apollo Telescope Mount (ATM) will be this country's first manned

astronomical observatory in space. It carries instruments associated with five experiments: a white light coronagraph to monitor the brightness, form and polarization of the solar corona in white light; an X-ray spectrographic telescope for studying solar flare emissions in the soft X-ray wavelengths; an ultraviolet spectrometer for photoelectrically recording high resolution solar images and surveying spectral emissions of selected areas of the sun; a dual X-ray telescope for obtaining time-histories of the dynamics of the solar atmosphere in selected X-ray ranges; and an ultraviolet spectrograph and heliograph for recording high resolution images in the ultraviolet wavelength.

Man has been limited in his study of the sun because our atmosphere obstructs observation of the ultraviolet, extreme ultraviolet, X-ray, and most infrared radiation from the sun and distorts optical images. Further, clouds and atmospheric pollution often interrupt and preclude viewing. Operating above the atmosphere at an altitude of 235 miles, the manned observatory will be free from this interference and will have the capability for selective pointing. These ATM observations will provide a far greater understanding into the dynamic processes that take place in and around the sun, which can be of direct practical application. While the effect of solar flares in creating aurora's and in disrupting the ionosphere and the earth's magnetic field has been observed for many years, little is known of the effects of high energy solar particles on the earth's upper atmosphere and therefore on the weather.

Another potential practical benefit is that a better insight into the energetic processes of the sun may yield an understanding of the interactions of magnetic fields and high energy plasmas that could in turn lead to improved nuclear power sources for large scale use on earth. The increased demand for electrical power coupled with a potential shortage of fossil fuels and the growing concern for environmental pollution could make this a matter of major importance before the end of the century.

The crews will also conduct other astronomical and space physics experiments. A complementary experiment to the ATM will photograph the sun and obtain ultraviolet and solar spectra for prediction of solar flares and the quality of radio communication at various frequencies during solar storms. Nuclear emulsions will intercept cosmic rays, whose physical and chemical characteristics can be measured and observed. A series of boxes will collect small micrometeoroids for analysis in laboratories back on earth. Sky surveys will be made by photographing large areas of the sky in the ultraviolet wavelength, and surveying it for X-ray sources. One of these is the ultraviolet panorama experiment, being flown for the Laboratoire d'Astronomic Spatiale (CRNS) of France which will measure the UV color index of stellar objects in our galaxy.

The requirement for a better knowledge of spectrophotometric criteria of

early-type stars is recognized as fundamentally important data for future studies of early-type stars common to regions in the spiral arms of a galaxy.

The brightness in the night sky will be measured in an evaluation of the phenomena known as Gegenschein and Zodiacal light. Also a study of the light and twilight earth horizon light and atmospheric airglow will be undertaken.

Space Medicine and Bioscience:

This third major experiment area primarily applies to the conduct of future space activities, although it can provide new insight into basic physiological processes of men and animals, and certainly some of the instrumentation developed for measurements of body processes in space will find use in earth applications.

The Skylab missions will permit, for the first time in this country's program, the conducting of extensive real time, controlled, sequential, inflight biomedical and behavioral measurements. This program will also provide the first opportunity for a scientist-astronaut physician to participate in on board observations and experiments as a member of the flight crew.

Man's physiological responses and aptitudes in space will be measured and assessed under zero gravity conditions. His post mission adaptation to the terrestrial environment will be examined through a series of progressively longer missions, and the increments by which mission duration can be increased will also be determined.

In addition to space medicine, several biological experiments will be conducted. These are a study of the effect of zero gravity on living human cells in a tissue culture, and two experiments examining biological rhythms. Living organisms possess periodic rhythms, influenced by unknown factors, which govern their life processes, activities, and behavior. If these rhythms are altered, a condition may develop among the different functions of the organism, resulting in metabolic confusion that may induce discomfort and illness. Vinegar gnats and mice will be studied for the effect of the space environment on these rhythms.

Engineering and Manufacturing Technology:

The final set of Skylab experiments is in the area of engineering and manufacturing technology. Among the experiments to be performed are: an analysis of aerosol dispersion in zero gravity; an evaluation of various thermal control coatings; a study of the effects of crew motion on the dynamics of a space vehicle; precision optical tracking; and the nature and propagation of flame in zero gravity.

An important experiment will be the evaluation of the feasibility of manu-

facturing selected materials in space utilizing the space vacuum and zero gravity conditions. This will include investigations into the melting of metals, brazing techniques, composite and spherical casting, and crystal growth. Much of this work shows great promise and may provide the basis in future years for using space stations as commercial facilities for use in manufacturing either perfectly formed products or unique materials.

Mission Description:

The Skylab missions will begin in early 1973 with the unmanned launch of the Workshop into a 50° orbit of 235 miles altitude using a two stage version of a Saturn V vehicle. The Apollo Telescope Mount (ATM) will be covered by a payload shroud forward of the Workshop, in the area occupied during Apollo missions by the Lunar Module and Command and Service Modules. The shroud will also protect the Airlock and Multiple Docking Adapter during launch. The payload shroud will be jettisoned, the ATM will swing out to the side, and the solar arrays will be deployed. On the day following launch of the Workshop, a Saturn IB vehicle will launch a modified Apollo Command and Service Module whose three man crew will rendezvous and dock with the Workshop to allow completion of the orbital assembly and commencement of operations.

The initial manned mission will be primarily directed toward the accomplishment of medical experiments related to providing assurance for the well-being of astronauts during the three Skylab missions. Other areas of focus will be the solar astronomy, earth resources, and technical experiments which will be conducted concurrently with the medical activity. This mission is planned to last up to 28 days, beginning with the launch of the manned flight.

At completion of the first mission, the crew, before leaving, will prepare the Workshop for an unmanned period of two months, during which it will be maintained in a semi-active condition.

The second manned mission, with a new crew, will be launched approximately 3 months after the first manned launch. This revisit mission is planned for a duration of up to 56 days. The mission will reoccupy the Skylab Workshop and gather much greater amounts of data from medical, technical, scientific, earth resources, and solar astronomy experiments, with the focus on these latter two areas.

The rendezvous profile, Skylab Workshop activation, mission operations sequence, and CSM deorbit and recovery will be similar to those in the first mission.

The third and final crew will be launched approximately 3 months after the second manned launch. This mission is also planned for a duration of up to 56 days from launch. Again, the crew's activities will emphasize the

scientific and applications objectives of the experiments. After completion of the experiments and mission activities, the Workshop will be prepared for orbital storage in the solar-inertial attitude (pointing toward the sun). The CSM will undock from the Workshop and then deorbit for a planned recovery in the mid-Pacific area. There are no present plans for any further revisits to the Workshop.

A change in program plan was made in May 1970 to provide for launching the Skylab Saturn IB vehicles from Launch Complex 39. The transfer of Saturn IB launch operations to Complex 39 was undertaken to reduce costs, to streamline Kennedy Space Center (KSC) operations by consolidating all manned space flight launches at one complex, and to improve reliability through use of the newer complex and its facilities for indoor assembly of the space vehicle.

Backup hardware, including a Workshop, Multiple Docking Adapter Airlock, Apollo Telescope Mount, and other experiments, will be brought to the point of completion of manufacturing and systems installation, so that final checkout and delivery can be expeditiously accomplished to conduct a backup mission if required.

Skylab

	1970	1971	1972
Space vehicles.....	$63,330,000	$77,300,000	$194,000,000
Payloads and experiments.....	243,120,000	302,300,000	306,900,000
Operations.....	18,150,000	25,600,000	34,500,000
Total.....	$324,600,000	$405,200,000	$535,400,000

Space Vehicles

Four Apollo Command and Service Modules are being modified for Skylab use. CSM modifications are required because the unique operational and support requirements of Skylab result in a longer mission duration, new orbital rendezvous requirements, Workshop support requirements, mission attitude contraints, and increased return payload capability. Skylab spacecraft will operate in a traditional manner during ascent, rendezvous, and docking to the Workshop. When docked, however, much of the equipment in the Command and Service Module will be shut off to conserve power and consumables. Modifications to the Command and Service Module include: changes to the on board computer to reflect mission differences and to permit attitude control while docked; altering the environmental control system to allow it to be shut down while docked, as the CM's cabin humidity, temperature, and gas levels will be controlled by the Workshop; providing for an additional entry battery and electrical umbilical connectors with the Workshop, while removing one fuel cell; installing heaters and control wiring in the Service

Module to permit long duration propellant storage at low temperatures; deleting two Service Module propellant tanks to save weight, while adding propellant tanks for one stabilization and control system to provide a greater attitude control capability. Other changes will be made to the caution and warning and communications subsystems.

Manufacturing and assembly of the Command and Service Module to be used in the first manned Skylab mission was completed in FY 1970. During FY 1971, manufacturing and assembly will be completed on the remaining three spacecraft, and systems installation will be in process for all four.

During FY 1972, checkout at North American Rockwell's Downey, California plant will be completed on the first spacecraft and delivery will be made to KSC. The remaining three Command and Service Modules will be in various phases of systems installation and checkout at the end of the fiscal year.

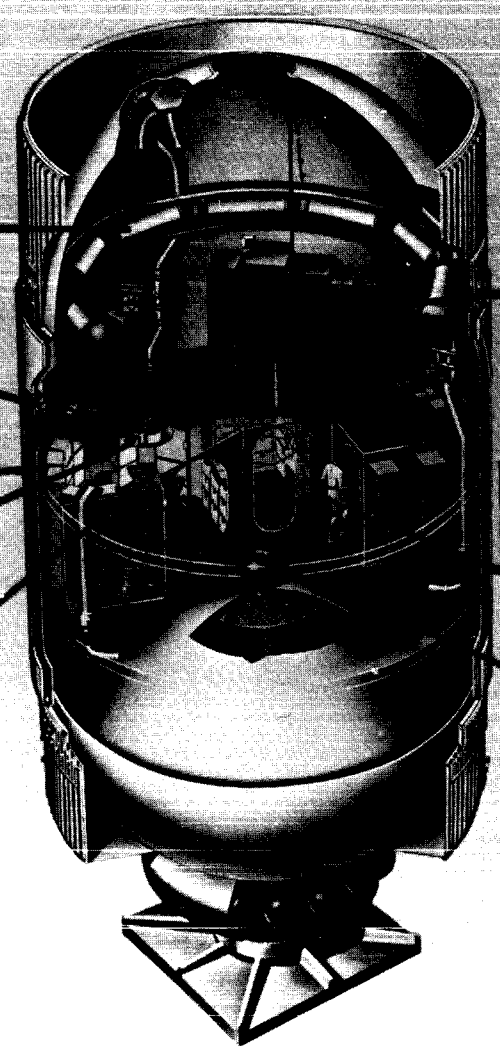
The four Saturn IB launch vehicles, which will be used to launch the Command and Service Modules, have been in storage at contractor locations. The Skylab S-IB first stages are at the Michoud Assembly Facility. Fiscal Year 1972 funds will be provided to the Chrysler Corporation, builder of the stages, for removing these from storage and beginning the necessary refurbishment, modifications, and checkout. The second stage, the S-IVB, has been stored in California. Refurbishment, modifications, and checkout of the initial S-IVB stages is currently in process by the McDonnell-Douglas Corporation and near the end of FY 1971, the first of the four stages will be shipped to KSC for additional storage until required for prelaunch operations. Fiscal Year 1972 funding supports completion of inplant activities on the remaining three stages and for delivery to KSC. During FY 1972, modification and checkout of the Instrument Units (IU) for the Saturn IB will be performed with the first IU delivery to KSC near the end of the fiscal year.

In addition to the funding required to support the hardware for the manned launch phases of the Skylab program, funding is also required in FY 1971 and FY 1972 for modifications to the Saturn V launch vehicle, which launches the Workshop. The primary vehicle, Saturn 513, will receive required modifications and will be available for shipment near the end of FY 1972.

Payloads and Experiments

The Orbital Workshop is a modified S-IVB stage which has been transformed to provide for long-duration manned habitation in space. It is divided into two levels which contain the necessary crew provisions, living quarters, and food preparation and waste management facilities to support a crew of three men for three periods of up to 56 days each. Some of the experiments to be conducted during the mission and the necessary support facilities for their operation are also installed in the Orbital Workshop. Other subsystems associated with the Workshop are the propulsive cold gas thruster attitude

ORBITAL WORKSHOP (OWS)



EQUIPMENT NOT
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22 SKYLAB
EXPERIMENTS

control system, which receives control commands from either the Instrument Unit or solar telescope electronics, and maintains the proper direction and attitude for the cluster; and the solar array panels which generate nearly 12,000 watts in the sunshine. The Workshop is also capable of unmanned on-orbit storage, reactivation, and reuse.

The Airlock Module provides a pressurized passageway between the Multiple Docking Adapter and the Orbital Workshop. It contains an airlock to enable astronauts to perform extra-vehicular activity and is also the supply, distribution, and control center for the cluster atmosphere and thermal control. In addition, it contains the equipment for electric power control and distribution to all elements of the cluster. The Airlock Module also provides support for cluster communications and data handling, including delayed-time voice communications with the ground. Other functions include thermal control of the Apollo Telescope Mount control and display console and support for selected experiments.

The Multiple Docking Adapter provides the docking interface for the Command and Service Module to the Skylab Workshop. It has two docking ports - an axial port for normal CSM docking and a radial port for contingency use.

The Multiple Docking Adapter is pressurized and contains the Apollo Telescope Mount control and display console, and the Earth Resources Experiment Package experiments and equipment. There is also provision for internal storage of hardware and experiments that are carried and operated in the MDA.

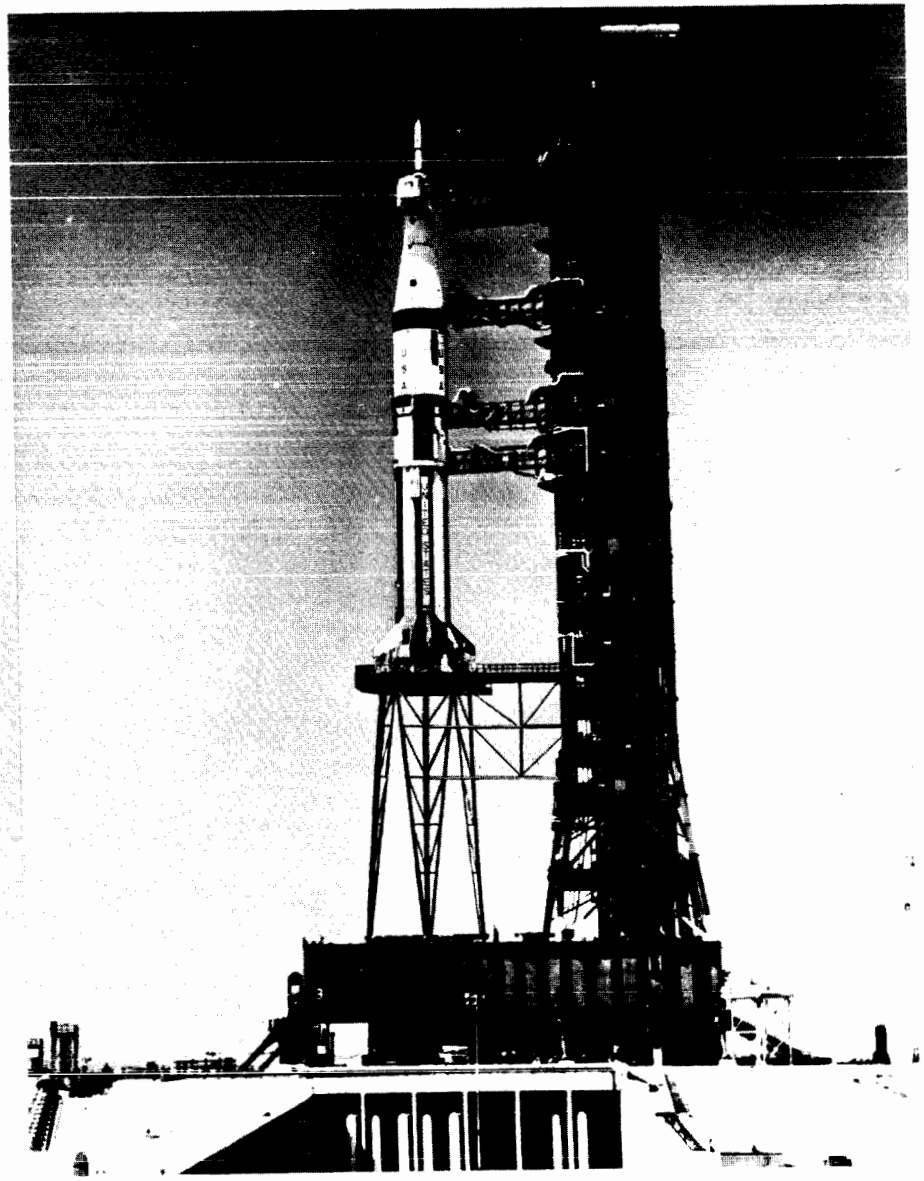
The Apollo Telescope Mount is the first use by the United States of a manned scientific telescope in space. The ATM is a solar observatory with the capability to observe, monitor and record the structure and behavior of the sun, particularly during periods of solar flare activity. The system is designed to provide attitude control and experiment pointing for the entire group of five ATM experiments. Power is provided through a solar panel array and battery systems. There is provision for retrieval and installation of the film used for the ATM by astronaut extravehicular activity. The ATM will be positioned while in orbit by a deployment assembly.

In FY 1971, much of the fabrication of the Workshop will be completed and most of the subsystem and experiment installation will have been accomplished by the end of the year. Fiscal Year 1972 funding provides for the completion of fabrication, installation, systems checkout, testing, and shipment of the flight hardware to the Kennedy Space Center where it will be mated to the Saturn V launch vehicle to begin prelaunch checkout.

Manufacturing of the Multiple Docking Adapter structure was completed at the Marshall Space Flight Center in October 1970 and was delivered to the Martin-Marietta Corporation, Denver, Colorado for installation and integration of operating systems and experiments. These activities will be completed

SKYLAB

SATURN IB ON LAUNCH COMPLEX 39



in FY 1972. In FY 1972, the flight unit will be delivered to the McDonnell-Douglas Corporation, St. Louis, Missouri for integrated testing with the Airlock Module. Fabrication and major structural assembly of the Airlock Module was also completed late in 1970 and final assembly operations are now underway. In FY 1972, the final assembly will be completed, experiments will be installed, and the flight unit will be mated with the Multiple Docking Adapter. Integrated testing of the Multiple Docking Adapter and the Airlock is designed to verify the combined performance of these two major modules and will include an altitude chamber test. At the completion of the St. Louis activities, near the end of FY 1972, the combined Airlock Module/ Multiple Docking Adapter will be delivered to the KSC for premate checkout.

The Apollo Telescope Mount is being manufactured at the Marshall Space Flight Center. Fabrication and assembly, and installation of experiments and subsystems are underway and are scheduled for completion in FY 1972. Funding requirements, in addition to those for completion of installation, includes checkout and vibration testing at MSFC. The unit will then be shipped to the Manned Spacecraft Center for thermal-vacuum testing, and then delivered to Kennedy Space Center for premate checkout near the end of FY 1972.

Funding in Fiscal Year 1971 and 1972 also provides for the completion and delivery of the more than 50 major experiments in the Skylab program and for the final efforts related to the payload shroud. In addition, requirements exist throughout FY 1972 for payload integration and program support requirements of the total Skylab program.

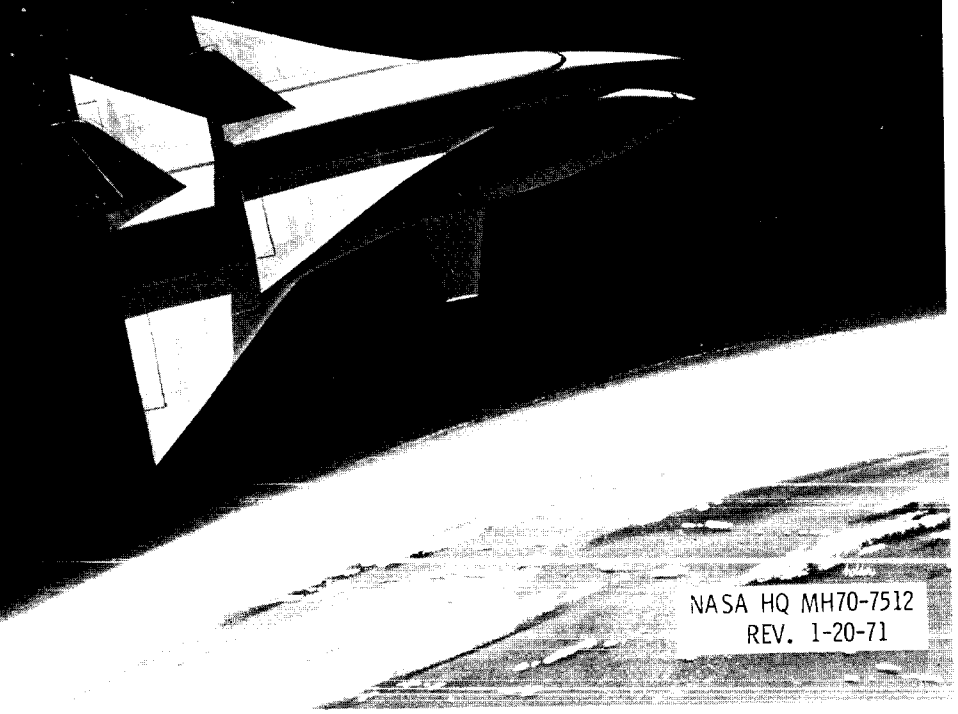
Operations

Funds in this category will support unique requirements of the Skylab program at the Kennedy Space Center and the Manned Spacecraft Center that are directly involved with Skylab prelaunch, launch, flight, crew, and recovery activities. Basic support underlying these requirements and common to all manned flight activities will be funded by the Apollo program. Specific Skylab requirements include mission planning and analysis, Saturn Workshop simulator design and development, trainer/simulator modifications to Apollo and Skylab equipment, development of Saturn IB launch capability from Pad 39; modification of launch checkout equipment to accommodate Skylab unique hardware; test planning and procedures for checkout of Skylab unique hardware; and space vehicle prelaunch operations. Also included are the Skylab program technical operations activities which involve systems engineering efforts required for program integration and technical evaluation, systems specifications, mission planning, trajectory analysis, checkout review, and technical documentation and support. In addition, this category provides for contract administration and audit, and property administration services provided for the Skylab program by the Department of Defense on a reimbursable basis.

In FY 1972 the Kennedy Space Center will complete modification efforts

GENERAL CHARACTERISTICS

- AIRLINE-TYPE OPERATIONS
- TWO MAN CREW
- REUSABLE - 100 MISSIONS
- LARGE CARGO BAY
- 7 DAY SELF SUSTAINING
- SHIRTSLEEVE ENVIRONMENT



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required to provide a Saturn IB launch capability at Launch Complex 39; modifications to Launch Complex 39 to accommodate the checkout and launch of the Workshop hardware; for integration and checkout of the ground and flight systems; and for the support and training equipment assembly required for training of Skylab launch crews.

The Manned Spacecraft Center will receive delivery of the Saturn Workshop Simulator which will functionally simulate many of the workshop on-orbit systems and experiments, including the ATM solar experiments. FY 1972 funds are required for support of mission planning and analysis, flight planning and flight crew procedures development which will continue to receive heavy emphasis during the premission time frame.

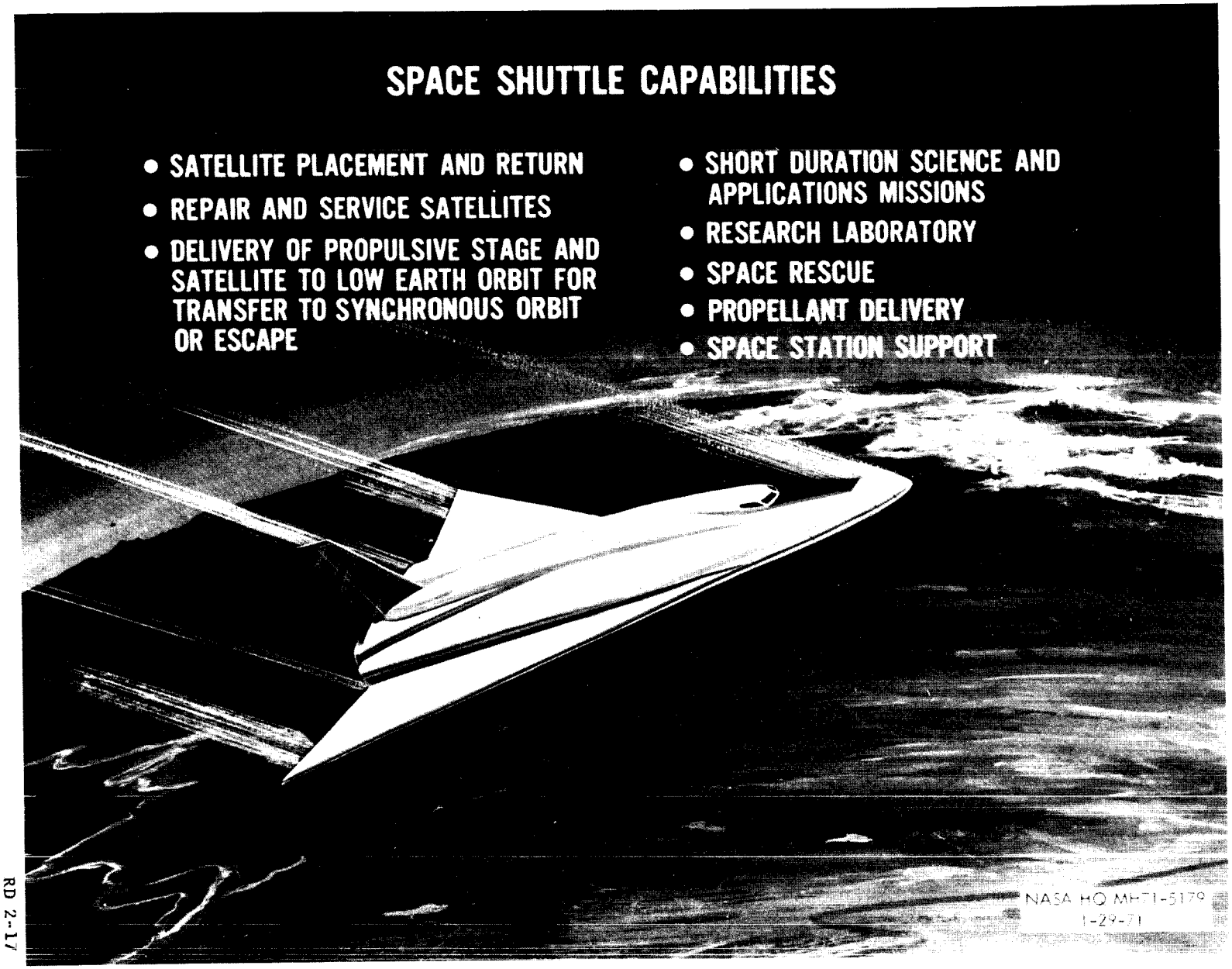
Space Shuttle

The key to economical space operations in the forthcoming decades of space exploration is the space shuttle, a reusable space transportation system. It can revolutionize present day space operations by providing an airline-type accessibility to space at low operational costs.

Costs to support planned applications, scientific, and defense satellites could be reduced substantially below those associated with current expendable systems. Two major sources of cost reduction are associated with the use of the shuttle system. In addition to the substantial operational savings generated by having reusable hardware, there are significant economies that can be realized in payload design, development, procurement, and testing which result from relaxed weight and volume constraints, the capability to return payloads that have malfunctioned or for refurbishment, and in-flight checkout of payloads to assure their proper operation before their long term deployment.

The shuttle is planned as a two stage vehicle, comprised of an orbiter and booster. It will possess an all azimuth capability and have an operational availability such that it can be launched on short notice within two hours if necessary. The shuttle will take off vertically under rocket power with the booster accelerating the orbital stage to the outer fringe of the earth's atmosphere where separation will occur. The booster will then decelerate and cruise to a designated landing field. The orbiter will proceed to orbit, powered by its own rocket engines, to deliver the payload and perform the assigned missions. After spending up to seven days in orbit, the orbiter will re-enter and return to a conventional airport runway and also land horizontally. After a short turnaround period of approximately two weeks both shuttle stages will be ready for another mission.

The shuttle will be designed for 100 or more flights with a minimum of ground maintenance. Payload transportation will be similar to commercial airline practice. The orbiter will contain a large compartment of about 10,000 cubic feet to accommodate a varying payload mix of satellites,


SPACE SHUTTLE CAPABILITIES
• SATELLITE PLACEMENT AND RETURN
• REPAIR AND SERVICE SATELLITES
• DELIVERY OF PROPULSIVE STAGE AND SATELLITE TO LOW EARTH ORBIT FOR TRANSFER TO SYNCHRONOUS ORBIT OR ESCAPE
• SHORT DURATION SCIENCE AND APPLICATIONS MISSIONS
• RESEARCH LABORATORY
• SPACE RESCUE
• PROPELLANT DELIVERY
• SPACE STATION SUPPORT
NASA HQ MH71-5179
1-29-71

passengers, and cargo. In a passenger mode, ten people plus a crew of two can be accommodated. Moderate G loads and a shirt sleeve environment will allow average people in good health to fly into space without extensive flight training.

Once developed, the shuttle can replace essentially all the present day launch vehicles except for very small vehicles of the Scout class, and the Saturn V. Its low operational cost and its versatile capability make it suitable for a wide variety of missions including:

1. Satellite Placement and Return - Satellites will be transported to low earth orbit in the cargo bay where they will be given a final checkout at the desired orbit before beginning their assigned mission. Satellites can also be retrieved by the shuttle and returned to earth for modification or servicing.

2. In-Orbit Repair and Servicing Satellites - The shuttle will be able to visit orbiting satellites for periodic servicing including film retrieval, component replacement, and consumable replenishment.

3. Delivery of Propulsive Stages and Satellites - Propulsive stages and payloads for high energy missions can be delivered by shuttle to low earth orbits. After a final on-orbit checkout the propulsive stage and its payload are removed from the cargo bay and positioned for launch. The propulsive stage will transport the payload to a geosynchronous orbit or escape mission.

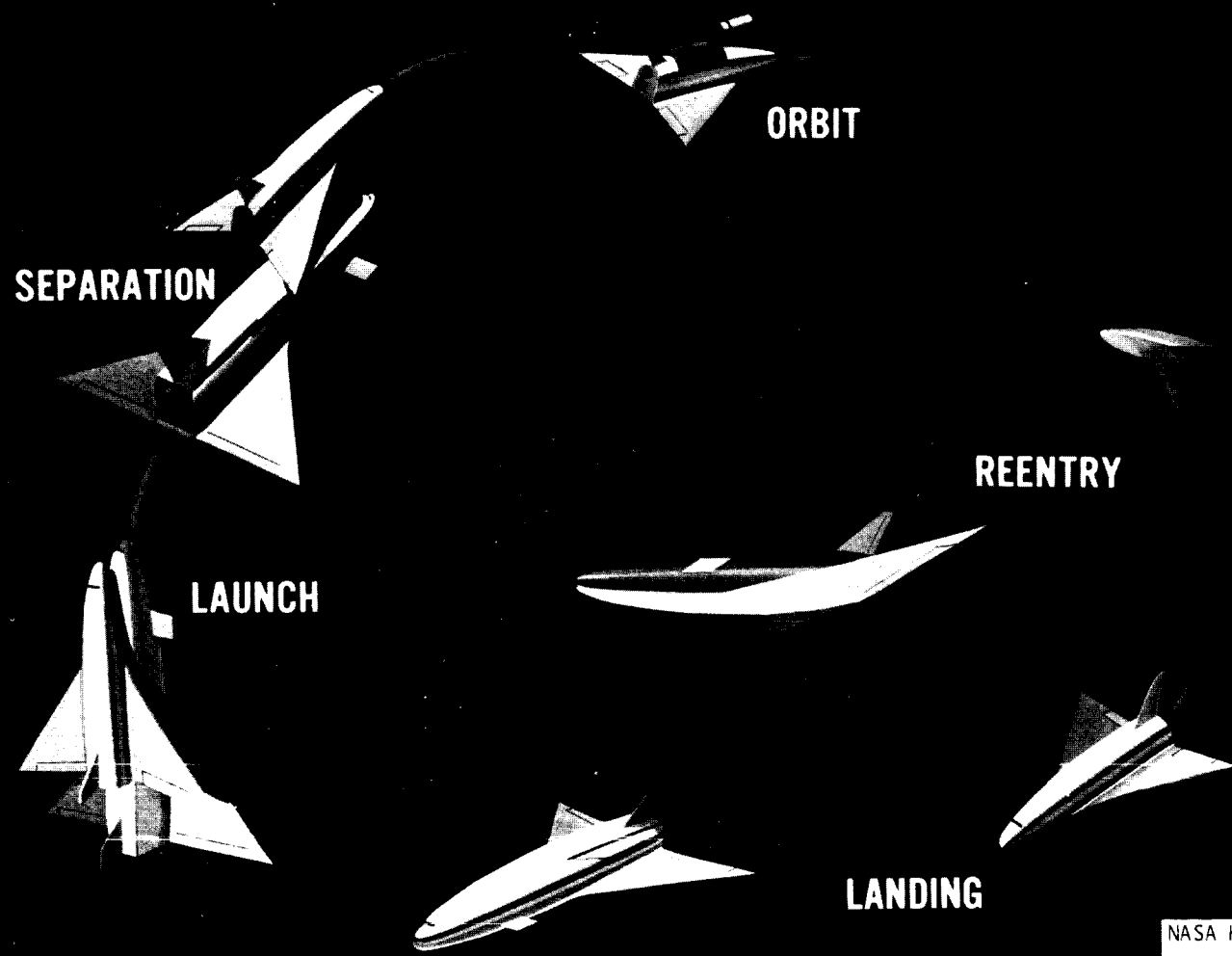
4. Short Duration Science and Applications Missions - The space shuttle can be outfitted to conduct special purpose short duration missions. In this manner the shuttle could augment the space station for unique earth or skyviewing mission opportunities.

5. Research Laboratory - The shuttle can also serve as a space research laboratory. The development and testing of new components and space systems can be enhanced by using the shuttle to check them out in the environment of space.

6. Space Rescue - The shuttle will make ground based space rescue possible with its quick response capability and operational flexibility. In some instances the shuttle may eliminate the need for space rescue by the timely delivery of replacement components and equipment.

7. Space Station Support - Personnel and cargo will be routinely transported from earth to the space station and returned. The low acceleration experienced on these flights will permit personnel who have no astronaut training to visit the station. Cargo in the form of equipment, experiments and consumables will be carried. Return cargo will consist of such items as film, tape and other experiment data.

MISSION PROFILE



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In each of the areas discussed, special consideration has been given to the identification and pursuit of opportunities for international cooperation in space. With the approval of the President, and working closely with the State Department, NASA has launched a major effort during the past year to increase the level of international participation in major space exploration of the 1970's. The focus of this effort, and one area in which foreign countries, particularly in Europe, have expressed a great interest is the space shuttle system. European countries are now reviewing the nature and degree of participation, including financial, they wish to propose. A number of European firms are presently working as members of U. S. contractor teams now engaged in shuttle definition studies.

Current plans for the shuttle propose a beginning of horizontal flight testing in the mid '70s, with a full operational capability by the end of the decade. The FY 1972 budget request provides for the detailed design and development of an engine -- the longest lead time component for the shuttle. It also provides for proceeding on an orderly step by step basis with the shuttle airframe design. This may lead to continued detailed design or initiation of development of a specific design, depending on the progress of the studies now underway.

Space Shuttle

	1970	1971	1972
Vehicles.....	$8,300,000	$42,000,000	$42,000,000
Engine.....	4,200,000	38,000,000	58,000,000
Total.....	$12,500,000	$80,000,000	$100,000,000

Vehicles

The shuttle vehicle consists of a booster and orbiter. Both are fully reusable.

The orbiter and booster will each use high pressure liquid oxygen/liquid hydrogen fueled rocket engines for propulsion. In addition, the use of jet engine similar to those used by aircraft will provide the power during the cruise return to the landing area.

The shuttle's payload capability will range from 25,000 to 65,000 pounds depending on altitude, inclination and orbiter configuration.

The payload will be carried in a compartment 15 feet in diameter and 60 feet long. The compartment will be designed to accommodate a payload mix of satellites, passengers and cargo.

Extensive studies have been conducted by NASA, the Department of Defense and industry in the process of confirming the feasibility of the shuttle and defining and qualifying technology needs. These efforts were planned to insure that the critical studies would be completed in sufficient time to permit ready incorporation into the design and development effort.

The most demanding problem is the design and development of an airframe structure, particularly with the thermal protection requirements of re-entry. The materials must be lightweight and extensively reusable. Several very promising candidate materials are available and work has been focused on the applications of these materials to practical structures. Technology for the integrated avionics and control system is in hand, but the application of this technology to advanced new systems concepts will require innovation and proof of concept demonstration.

During 1969, detailed studies were contracted to prepare and analyze conceptual design for a reusable space logistics system. From the results of these efforts and other NASA and Department of Defense studies, a preliminary space shuttle configuration was established with the desired payload and performance characteristics, and preliminary evaluation of various systems and technology requirements was started.

In June, 1970, two concurrent design studies were initiated for the vehicle. These studies were awarded to the McDonnell-Douglas Corporation and North American Rockwell.

The basic objectives of the studies are:

1. To define the shuttle and the requirements for the main engine.

2. To accomplish a preliminary design of the orbiter and booster.

3. To demonstrate the feasibility of the design to meet the technical requirements.

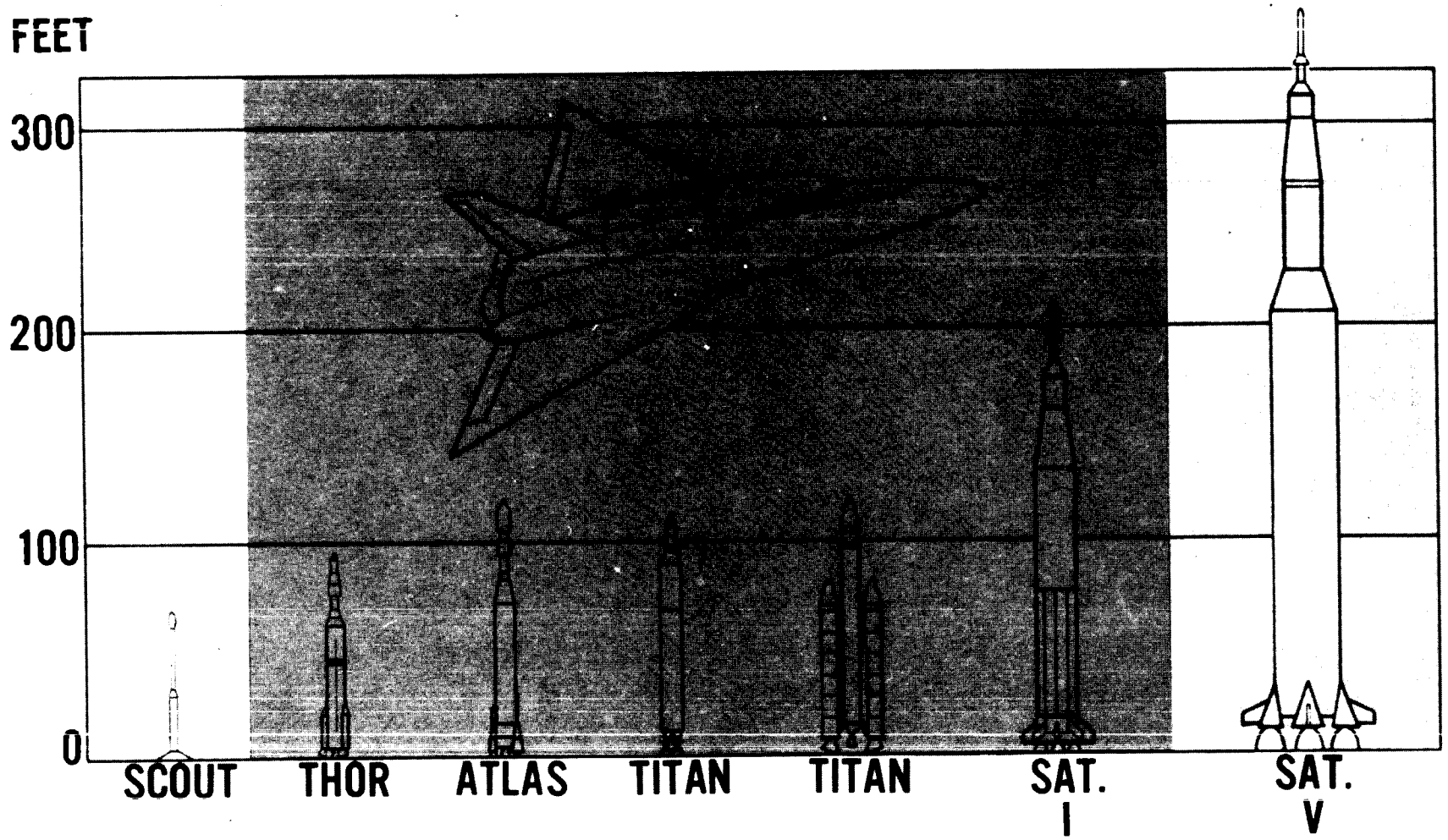
4. To refine current estimates of the scope, timing and costs involved.

5. To provide information and data for use by NASA in selecting configurations to be carried forward in later phases.

Supplemental feasibility studies of alternate vehicle concepts are being conducted by Lockheed, Grumman and Chrysler.

In parallel with the design studies, payload effect and mission traffic studies are being made. These studies are investigating the variables of projected national traffic models, and the effects of weight, volume, and reuse on payload design that result from use of the shuttle. In addition, there are several important technology areas where additional work is being

LAUNCH VEHICLE REPLACEMENT



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undertaken by NASA's Office of Advanced Research and Technology. The results of this effort and of the information developed from the design studies will be coordinated among the various contractors.

The vehicle definition and configuration studies are planned for completion in 1971. Design verification of technology data and study results will be continued through 1971. This will include wind tunnel tests, structural heat load tests, and full scale thermal protection system installation testing in preparation for possible start of vehicle design in FY 1972, subject to the results of our on-going definition studies. This activity will provide assurance that the ensuing shuttle development will be successful.

Existing information and continued progress in basic technical areas have provided the keystone for the successful current definition studies and future design of the shuttle. High pressure hydrogen-oxygen propulsion experience will make possible the compact and lightweight engines with high thrust and high efficiency required. Spacecraft technology, advanced so far during the past decade, provides us with the assurance that the necessary airplane flight characteristics can be built into the shuttle vehicle. Previous knowledge in electronics, guidance and control, aircraft structures, and heat shields has been extended and focused on application to shuttle definition and design requirements.

In Fiscal Year 1972, vehicle definition will be advanced by wind tunnel testing to define the precise aerodynamic heating, launch aerodynamics, staging separation forces, re-entry stability and control characteristics, and atmospheric propulsion effects. Dynamics testing will proceed to determine wind loads, vehicle flutter effects, and the acoustic environment which will exist. Design of long lead time hardware and subsystems, test devices and tooling fixtures will be performed.

Test demonstrations to verify design concepts constitute an important part of the shuttle study program. NASA will test the static and dynamic performance of structures proposed for fuselage, wings, tanks, and attachment mechanisms. Mission simulations will be performed in combination with thermal protection systems. Analysis and test of many new alloys and promising materials are planned. A flight research program will investigate attitude maneuvers for the defined configurations, determine control system requirements, and provide the necessary flying test bed for flight system components.

Initiation of detailed design and system development effort may be undertaken in FY 1972 depending on the results of the studies and tests described above.

Engines

A significant factor in development of the vehicle propulsion system is the

long lead time required for engine development. An early initiation of design effort is required to have the engines properly integrated into the vehicle system. This engine will have increased performance by virtue of developing higher specific impulse at much lower weight. A considerable base of technological experience with advanced hydrogen-oxygen engines has been developed over the last several years which provides a high level of confidence that the required shuttle rocket engine will be successfully developed.

Drawing upon data developed from feasibility studies that have been completed, the main engine characteristics being used as baseline in the definition studies now underway include a throttlable, high pressure, hydrogen-oxygen engine that will be clustered for use on both the orbiter and the booster. Three concurrent definition contracts are underway with the Rocketdyne Division of North American Rockwell, Pratt and Whitney and Aerojet General.

The main engine design and development is scheduled to begin in 1971. In Fiscal Year 1972 main engine efforts will include development testing of the thrust chamber and engine controls, and design of a prototype engine. Propulsion subsystem test facilities will be modified and development hardware tested. Also, NASA will initiate fabrication of a prototype engine during fiscal year 1972.

Orbital Systems and Experiments

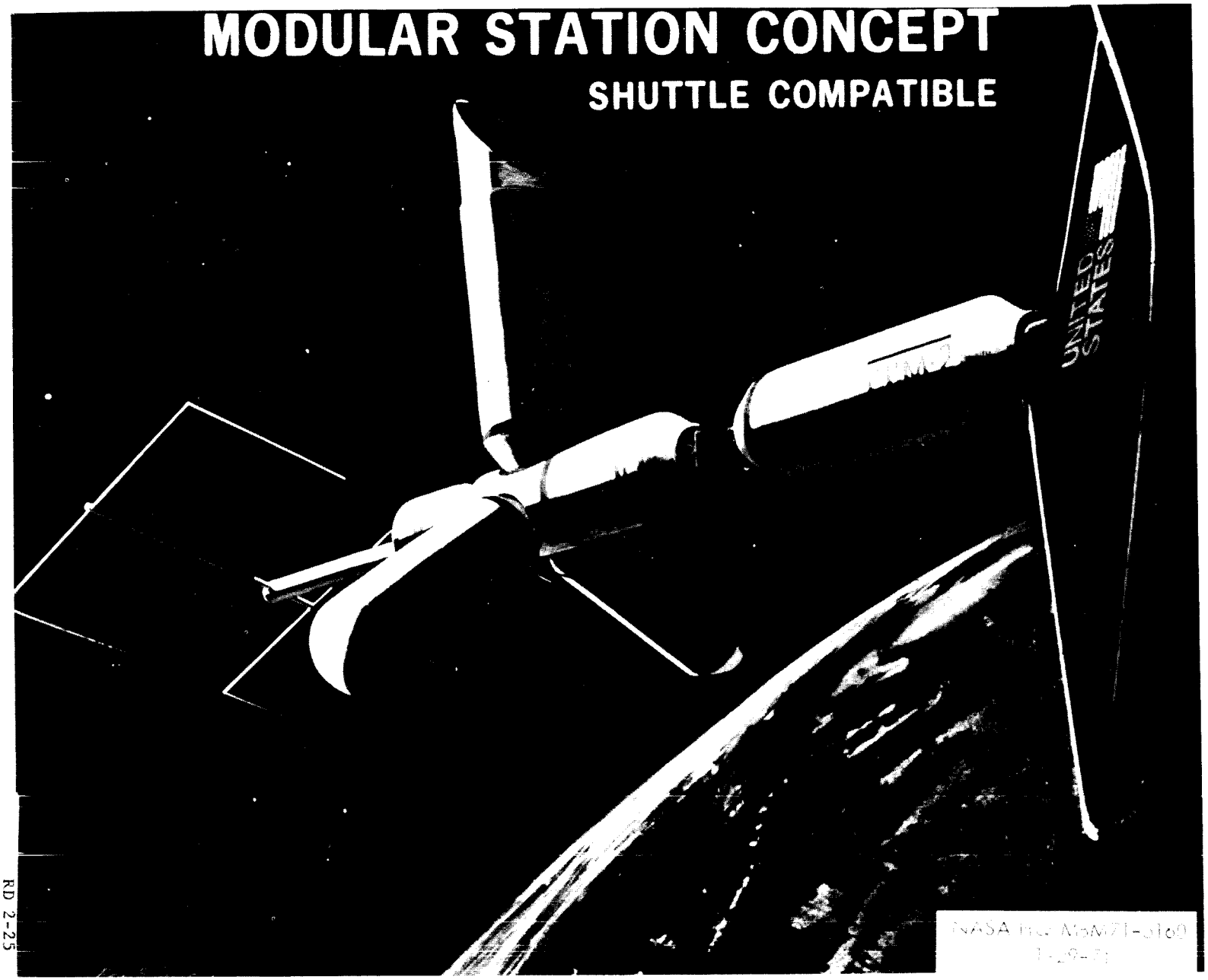
Orbital Systems and Experiments encompasses work relating to manned earth orbital flight after the Skylab missions. The work focuses on the major systems of a space station core and modules, on the experiments to be conducted in earth orbit in the space station or on shuttle missions, and on the life sciences aspects of space flight.

Space Station Modules:

A long duration space station provides a facility for many diverse scientific and applications activities in low earth orbit. The station will be an evolutionary progression from Skylab, and its final design will incorporate flight data obtained from that program. Logistically supported by the space shuttle, the station will have extended in-orbit lifetime with maintenance and replacement of systems. The station will feature modularity so that elements can be replaced, updated, and added for greater capability. Two contractors, the McDonnell-Douglas Corporation and the North American Rockwell Corporation, are in the process of completing program definition studies on their conceptions of a 33-foot diameter space station with self-contained living quarters, subsystems, and general purpose laboratories. The core modules of these space stations are designed to be placed in-orbit by a launch vehicle with a heavy payload capability, such as the Saturn V. Docking and support facilities are provided for later internal addition of small size experiment packages and for intermittently and permanently attached laboratory and observatory modules.

MODULAR STATION CONCEPT

SHUTTLE COMPATIBLE



Under study are other potential configurations, which can provide a similar capability but which feature a more evolutionary program approach. These alternate concepts are functionally modularized to a much greater degree than those defined in the large diameter station studies. Most of these modular concepts require a cluster of modules to be assembled in orbit before operations could begin. Nearly all of the cluster modules would be carried to orbit in the cargo bay of the shuttle and would be limited by the volume and weight payload capabilities of the shuttle. The modular space station concepts all have less initial capability, but can grow in time through replacement, uprating, and attachment of additional modules to provide the expanded capability that is available with the large diameter station.

Two modular station concepts are currently being considered. One uses only shuttle compatible modules, the other would evolve from a basic Skylab system using a similar core module launched by a two-stage Saturn V. After the initial launch, this core module would be supplemented by attaching smaller modules. This approach could combine the best features of an all-up approach, ground assembly and checkout, and operational capability following first launch, while providing for a subsequent growth capability of the station employing shuttle compatible modules.

Studies are underway, both in-house and with several contractors, on developing and comparing the candidate concepts in some detail, especially in the area of specific design characteristics, operational sequences, shuttle interface, experiment support capability, initial and growth phasing and capability, and funding requirements.

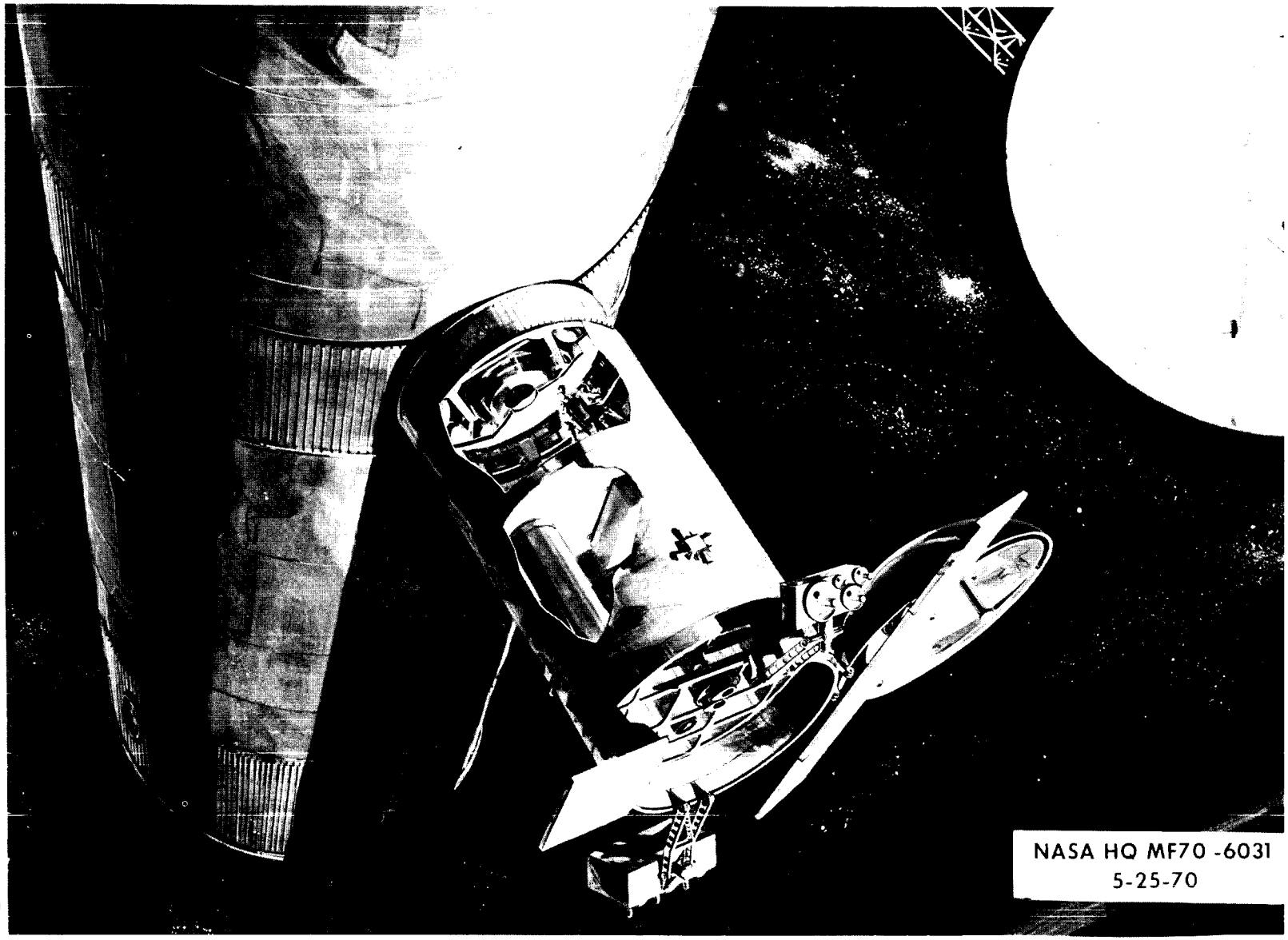
To augment the capability of both the space station and shuttle, NASA has undertaken the definition of research and applications modules. These modules can be operated in conjunction with a space station as attached modules where the scientific apparatus would be too large to be included within the space station itself, or in a free-flying mode where experiments will require operations at some distance from the environment of the station.

The modules, which are expected to feature common subsystems, will be specifically configured to support investigations in the field of solar and stellar astronomy, space physics, bioscience, biomedicine, earth surveys, and materials sciences and processing. The modules will be designed for long life through in-orbit maintenance, resupply and retrieval, and after return to earth using the shuttle, future updating and modifications on the ground.

Experiments:

Paralleling the space station studies are efforts underway to develop a balanced program of payloads and experiments to utilize the initial shuttle capability and the space station when it becomes available. Definition activities are essential to the orderly evolution and development of payloads

EARTH RESOURCES MODULE CONCEPT



and experiments compatible with the future space flight transportation systems.

The candidate experiment areas to be operated in association with the space station and space shuttle include earth surveys, space physics, astronomy, chemistry, materials sciences and manufacturing, bioscience and biomedicine, and communications and navigation.

Studies of the candidate experiment groupings will be continued in FY 1972. In many of the disciplines, the experiments presently represent the major focus of activity within this country's proposed flight program for the latter half of this decade and beyond. As these experiments form a major segment of the near earth scientific and applications activity in future decades, associated studies and supporting technology tasks related toward a greater understanding of their requirements are being undertaken by many elements of NASA, including the Office of Space Science and Applications and the Office of Advanced Research and Technology.

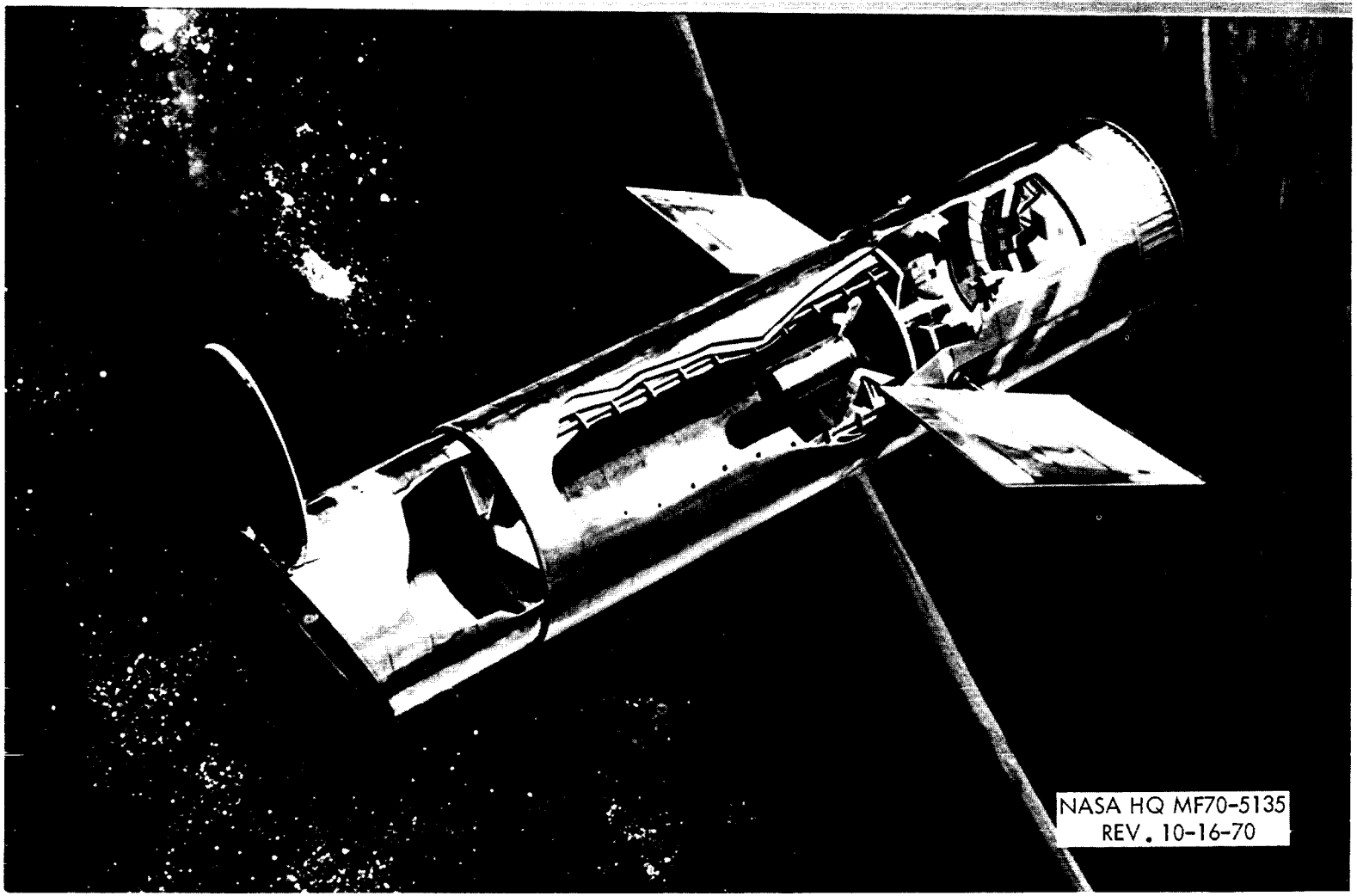
The principal experiments and experiment areas that are described represent facilities and laboratories that require in varying degrees man's participation, some only infrequently, such as for maintenance or data retrieval; while others require his nearly continuous attention. It is expected that the experiments would be flown at different times during the next several decades and reviews will be conducted, principally at the conclusion of the definition studies, on the proper flight sequencing and the appropriate initiation dates for detailed design and development.

The earth survey experiments would be used to better define the earth's geometry, surface characteristics, and dynamic processes; to improve the understanding of atmospheric physics, improving weather forecasting, and establishing the basis for possible weather modification and climate control; and finally, and most importantly, providing information for the responsible management of the earth's resources and environment. Initial studies indicate that as many as twenty sensors would be incorporated into the earth observations module. These sensors include cameras, radiometers, scanners, spectrometers, radars, and receivers and cover the spectrum from the ultraviolet through the visible and infrared of the optical range into the microwave range.

The information from these sensors will be applied toward the following general areas: (1) world land use mapping; (2) weather and the atmosphere; (3) air and water pollution; (4) resources identification and conservation; (5) natural disaster assessment; and (6) ocean resources.

This effort fosters the development of observational systems in space to assist in the monitoring and development of our natural resources. The unique perspective provided by observations from space will enable us to manage efficiently our agricultural, forest, mineral, marine, and water resources.

RESEARCH AND APPLICATIONS
3-METER STELLAR ASTRONOMY MODULE



Within the astronomy and physics experiment areas, instruments will be developed to greatly expand man's knowledge of the sun and solar system, other stars, galaxies, and the nature and dimensions of the universe itself.

An X-ray stellar astronomy module using several telescopes of different capacities could identify and locate X-ray sources, provide information on emission mechanisms, and the amount and distribution of energy in each source.

An advanced stellar astronomy module would greatly improve man's observation of stellar objects and would feature a telescope as large as two or three meters in diameter. The telescope would be designed to accommodate different instruments at the foci so that instrument substitutions could be made to provide for the investigator's needs.

An advanced solar astronomy module would consist of two groups of telescopes with their associated experiments. The first group, consisting of high resolution telescopes, would examine phenomena in the solar structure emphasizing areas of high activity. The second group, using two coronagraphs, would measure phenomena in the region of the solar corona.

The ultraviolet stellar survey would map and indicate the relative brightness of ultraviolet sources in the celestial sphere; and then use narrow field telescopes to make detailed studies of galactic emissions, star clusters, nearby galaxies, and planetary nebulae.

The high energy stellar astronomy facility would consist of X-ray telescopes, counter and detector arrays, a spectrometer, and spark chamber. This equipment would be used to correlate measurements of flux, spectral distribution, location, and polarization of radiation from selected sources, and would measure the dimensions, intensity, and location of selected X-ray and gamma ray sources.

The infrared stellar survey would employ a one meter infrared telescope for use in determining the distribution, location and brightness of infrared sources and correlating infrared and X-ray spectra.

The cosmic ray physics laboratory would advance the understanding of astrophysical phenomena by studying the change and energy spectra of cosmic ray nuclei; the energy spectra of high energy electrons and positions; the isotropic composition of light elements; and to search for nucleonic antimatter and extremely heavy nuclei.

The plasma physics laboratory would examine the plasma wake around orbital bodies; plasma resonances and their harmonics; wake particle interactions with very low frequency electromagnetic waves; and would, through the use of electron and ion beams, study the magnetosphere.

The space physics research laboratory would be comprised of between 20 and 25 instruments that can be applied to study atmospheric and magnetospheric science including aurorae; cometary cloud physics; meteoroids including an analysis of trajectory, mass, velocity, and composition; and selected astronomical observations using small telescopes.

The research areas in life sciences are: medical; biology, including small vertebrates and primates, invertebrates, microbiology, and plants; man-systems integration, including the behavior of man; and life support and protective systems. The laboratories and facilities would be used to determine the impact of space on the physiological, biochemical, microbiological and behavioral functions of man, and to develop data for detecting symptoms or precursor indicators; and the fundamental role of gravity in the physiology, biochemistry, and behavior of biological specimens.

A physics and chemistry laboratory would support a wide range of experiments utilizing the unique environment of space - zero gravity, vacuum, solar and cosmic radiation - and hypervelocity atomic, molecular, and ionbeams. Among the experiments that would be conducted are the critical point phenomena of fluids, gas-surface interactions, molecular beam scattering, heat transfer in a convectionless medium, operational characteristics of chemical lasers, flame chemistry and reaction kinetics at zero G, quantum effects at low temperature and zero G, and gaseous reaction kinetics in a space vacuum.

The communications and navigations research facility would develop space technology for communications, navigation, and traffic control, and optimize the use of the electromagnetic spectrum for communication and navigation satellite systems.

The materials science and manufacturing experiments would consist of a series of experiments in five principal areas: metallurgical processing; crystal growth; glass processing; biological processing; and the physical processes of fluids. It is expected that utilization of the space environment can produce materials for use on earth with properties superior to or not attainable in terrestrial production. The ultimate goal is the establishment of facilities for commercial research and manufacturing in space.

Finally, space technology experiments will advance fundamental knowledge pertinent to space flight to provide the technical capability of undertaking future missions, and expand the usefulness and reduce the cost of space operations.

Experiment definition studies also evaluate the use of the various manned space flight transportation systems to reduce the cost of payload and experiment design, and help establish requirements for flight transportation system hardware development. In addition, the reuse capability of the space shuttle will be evaluated from the standpoint of its influence on the design

of payload and experiment hardware systems for ease of maintenance, repair, and refurbishment at low cost.

Life Sciences:

Life sciences integrates the space medical, biotechnology, and terrestrial biology activities of the National Aeronautics and Space Administration. Formerly the funding and direction of these activities was dispersed throughout the three major program offices. With the creation of the position of NASA Director of Life Sciences in December 1970, these efforts are being managed in one office reporting to the Associate Administrator for Manned Space Flight.

The program includes the following functional areas:

1. Bioresearch provides for study and investigation in medical, biological, and behavioral areas to develop an understanding of man and other selected biological species and their adaptation and tolerance to space operations, as well as the use of the unique features of the space environment in studying fundamental biologic processes.

2. Bioengineering provides for the study and advancement of biological technology; the experimental test of bioinstrumentation and bioassay concepts to measure or detect parameters of interest in man and other living systems; and the design of space vehicles for habitability. It also supports research and technology efforts necessary for the integration of man and machine in space operations through the investigation of workload criteria, maintainability concepts, techniques for ground simulation of space flight environments, and the advanced development of human augmentation devices to enhance man's capabilities for space operations.

3. Bioenvironmental Systems include studies to advance technology through the testing of experimental life support and protective devices as well as systems for providing breathing atmospheres, thermal control, crew equipment, and food, water, and waste management necessary to provide safe and habitable conditions in space flight; and to protect man from the hazardous environments often associated with the test, launch, and recovery of space vehicles.

Orbital Systems and Experiments

	1970	1971	1972
Space station modules.....	$2,490,000	$17,000,000	$7,100,000
Experiments.....	3,510,000	13,000,000	10,500,000
Space life sciences.....	---	---	19,775,000
Total.....	$6,000,000	$30,000,000	$37,375,000

The space station definition contractors, McDonnell-Douglas Corporation and North American Rockwell, are completing comprehensive program studies on the large diameter (33') core module space stations which could be launched on a Saturn V class vehicle. Upon completion of these studies, operational, technical, and programmatic information on the station, its facilities, experiments, and research and applications modules will be available for comparison with other station designs now under consideration. FY 1971 funding provides for the completion of the two program definition studies with North American Rockwell and McDonnell-Douglas of the large diameter space station, and for definition studies of alternative modular space station concepts.

In addition, as a follow-on to a feasibility study effort conducted in FY 1970, a single competitive contract for the definition of research and applications modules will be initiated. FY 1971 funding will also provide for other related space station study efforts during the year.

Prime contractor support in FY 1972 will incrementally fund extension of definition efforts. Activities to be supported include technical, programmatic, and cost trade off comparisons of space station concepts compatible with launch and return by the space shuttle, and indepth studies of specific technical problems. Funding will also support design verification activity including additional trade off analyses to verify the contractor's systems selection; initiation of preliminary engineering designs of selected long-lead systems; and technology verification and proof of concept through early initiation of breadboard testing of critical systems. Efforts will be continued on a solar array battery power system, environmental control and life support system, and high volume data processing system. Planning and design will be started to integrate these systems into a functional space station subsystem test bed. Supporting studies relative to information management systems, habitability, and experiment management will also be continued. Fiscal Year 1972 funds will also support continuation of the research and applications module definition efforts undertaken in FY 1971.

The experiment effort involves the study and definition of potential experiments for the space station and shuttle. All disciplinary areas will be represented with emphasis and priority being given to the start of work on long-lead time items such as the stellar telescope, cosmic ray laboratory instrumentation, space manufacturing test beds, and life science experiments.

Experiment definition efforts directly relate to the design configurations underway on the research and applications module and on the station, and consequently these interfaces must be considered in the design of the shuttle. It is important, before proceeding with the detailed design and development of these space vehicles, that a full understanding of experiment requirements be in hand. The experiments and the information they provide represent much of the basis for continuing a program of space exploration.

The FY 1971 effort consists of numerous small contracts to principal investigator groups for definition of experiments that are planned to be flown on manned missions.

The FY 1972 request provides funding for general studies to evaluate experiment design concepts that reflect the space shuttle and space station capabilities to reduce cost, and to define the role of man in support of the performance of experiments.

Specific experiment definition activities include: detailed studies, analyses, and reviews to identify the objectives and content of a properly balanced payload and experiment program for manned space flight; definition studies to evaluate the use of the various manned transportation systems to reduce the cost of payload and experiment design; initiation of long-lead time studies leading to proof of principle and "breadboard" type hardware prior to commitment of funds for the development of flight hardware; and the evaluation of manned flight systems and the role of man in the actual performance of experiments in flight.

The early and accurate definition of experiments and payloads is vital to eventual mission success and the achievement of program objectives and national goals. Experiment definition funding provides the early impetus for acquiring the technical and scientific effort needed in identifying and verifying, through ground experimentation and analysis, those worthwhile experiments conducted by man in space, to assure effective use of future manned space flight systems for the benefit of the nation.

Fiscal Year 1972 effort in the three main areas of life sciences, bioresearch, bioengineering, and bioenvironmental systems, is outlined below.

Bioresearch - In FY 1972 bioresearch will provide funding for a broad based research program to investigate the effects of the unique environmental factors of space flight on living systems in support of man in space, and to gain fundamental knowledge of biological significance. The medical component will emphasize studies to evaluate physiological changes already found as a result of space flight and those which might be anticipated. Studies of specific organ systems and of specific environmental factors are oriented toward the determination of effects, their mechanisms, and predictive means and countermeasures to prevent or treat them inflight. Microbiological and toxicological hazard potential will be evaluated and health and safety standards will be established and/or revised in accordance with research findings. Further research data related to the medical operational support of man in space will be provided by investigations of onboard clinical medical techniques, preflight astronaut and ground crew preventive medical measures, crew and passenger selection criteria, and the medical significance of spacecraft rotation for artificial "G".

A behavioral element will include research of space environmental factors on human performance, behavioral physiology and on neurobehavioral function. It will include investigations of improved measurement techniques, behavioral selection and learning processes, small group dynamics, circadian rhythms, factors influencing sleep and alertness, and related neurobehavioral functions.

In biology, efforts will be devoted toward the development of conceptual and methodological knowledge directed toward the support of space flight, and the establishment of basic biological principles, through research into the influences of the unique environmental factors of space on living systems. The scientific investigations deal with the effect of simulated space environments on living terrestrial organisms, and identification of organisms for the best biologic return in space flight. This involves study in all the classic disciplines with emphasis on regulatory biology, developmental biology, genetic biology, and radiobiology. An important segment of the program is the group of research efforts in radiobiology which is oriented primarily to the information requirements of space flight. This segment emphasizes investigations into the human effects of the dose ranges, rates and quality factors of the radiation which may be anticipated in space.

Selected flight experiments will be identified for further design definition as candidates for inclusion in the scientific payloads of future space flight vehicles.

Bioengineering - The bioengineering effort in FY 1972 will include the investigation of the optimum roles of man in space systems as a manager, operator, technician, and scientist. The program will include the development of human augmentation technology, such as teleoperators, to extend man's physical and sensory capabilities by remotely controlled devices in space, and instrumentation to detect and measure the status of physiological and psychological parameters which may be used to predict changes caused by the influence of the space flight environment.

Work aids such as tools, restraint systems, and maintenance procedures will be developed to permit man to work effectively in zero "G" and in reduced gravity. Design criteria for work areas, living quarters, and off-duty facilities for long duration habitability by various size crews in space will be developed and evaluated.

Advanced bioinstrumentation and bioassay concepts will be developed and tested to assess the status of selected physiologic and psychologic parameters which may be used to predict changes in man caused by the influence of the space flight environment. The resultant bioinstrumentation, in conjunction with current technology and appropriate data management techniques, will provide an integrated biomedical measurement system that will be flexible enough to meet the needs of future space flights.

Bioenvironmental Systems - The bioenvironmental systems element will study, advance the technology, and test the feasibility of life support and protective subsystems and systems for providing a habitable cabin atmosphere through the following functions: atmospheric supply, pressure control, carbon dioxide removal and reductions, oxygen reclamation, contaminant control, thermal control, water and waste management, and food systems. Protective systems include space suits, portable life support systems, and emergency support equipment. Efforts will focus on regenerative life support and protective subsystems emphasizing the ground testing of integrated life support systems. As an example, the weight and volume penalties associated with supplying water for body metabolism are among the most significant factors in designing the life support system. Recent tests have proven that the reclamation of potable water from urine, wash water and humidity condensate is technically feasible, and interaction of the man with these subsystems has been proven acceptable.

A space suit system technology development area encompasses the design, development, and design verification testing of intravehicular and extravehicular space suits. Constant volume joint technology is being integrated into space suit main frame structures and glove assemblies. Astronaut cooling subsystems incorporate evaporative, indirect liquid cooled, and automated control techniques.

The portable life support system (PLSS) technology area includes intravehicular, extravehicular, and PLSS service equipment development. Primary efforts consist of integrated regenerative/regenerable subsystems and non-regenerative portable environmental control systems for duty and contingency use conditions.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1972 ESTIMATES

OFFICE OF MANNED SPACE FLIGHT — ADVANCED MISSIONS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objectives of the Advanced Missions activities include examining the enhancement of current and advanced manned space flight program concepts and developing the requirements for future systems. The studies conducted provide both guidance for the research and technology effort required to support these systems and technical information upon which to base future program decisions.

SUMMARY OF RESOURCES REQUIREMENTS:

	1970	1971	1972
Advanced mission studies.....	$2,500,000	$1,500,000	$1,500,000
Total.....	$2,500,000	$1,500,000	$1,500,000

Distribution of Program Amount by Installation:

John F. Kennedy Space Center, NASA	---	$100,000	$100,000
Manned Spacecraft Center.....	$1,390,000	500,000	600,000
Marshall Space Flight Center.....	760,000	700,000	600,000
NASA Headquarters.....	350,000	200,000	200,000

BASIS OF FUND REQUIREMENTS:

Advanced Mission Studies

	1970	1971	1972
Advanced mission studies.....	$2,500,000	$1,500,000	$1,500,000
Total.....	$2,500,000	$1,500,000	$1,500,000

Advanced studies are conducted to provide the necessary knowledge to assess and to direct the future course of this country's manned space flight program. The studies utilize the capability of industry to perform conceptual designs and provide comparative technical data to supplement in-house activities. During FY 1972, the studies will investigate new requirements for near and long-range flight missions, and conduct comparative studies of the possible long-range utilization of systems presently being defined or under development, such as the space station, Skylab, and shuttle.

Lunar exploration studies for activities beyond the present Apollo program will be directed toward aggregating and assimilating the knowledge gained from previous missions, and applying this information toward the extent and nature of future exploration, both on the lunar surface and in lunar orbit.

An assessment of program directions will continually be compared with national objectives to assure that advanced planning is kept current and responsive.

Cost and performance improvements are to be studied in relationship to existing or prospective programs such as the shuttle and space station. The impact of new missions and systems on flight and ground operations and, conversely, the impact of advanced operations concepts on future missions and systems will be studied to assure that the entire program benefits from advances in each area.

As operational safety is of the utmost importance, studies will be directed towards promoting new safety criteria for advanced concepts during the early phases of mission development.

Areas of study that will receive attention during Fiscal Year 1972 are:

(a) Earth orbital mission analysis to determine the most advantageous combination of flight systems for projected mission objectives. In addition these studies can identify a requirement for alternative mission and flight hardware concepts when it is indicated that these alternatives show advantages over the concepts that had been planned for use.

(b) New missions requirements investigations to focus attention and NASA resources on potential applications of space that will improve the quality of life on earth.

(c) Lunar exploration, beyond the present Apollo program and in the next decade, for extended exploration of the moon and its near environment both from lunar orbit and on the lunar surface.

(d) Ground and flight operations analyses to determine how advanced concepts would affect projected operations using current systems, and how proposed new systems would affect future operations.

(e) An integrated space program safety study to produce guidance for future missions, by establishing a focal point within Manned Space Flight for new safety concepts as they relate to the development of advanced missions. This study will continue the safety study work conducted during FY 1971 to a greater level of detail and refinement.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1972 ESTIMATES

RESEARCH AND DEVELOPMENT BUDGET PLAN FOR

SPACE SCIENCE AND APPLICATIONS PROGRAMS

Program	1970	1971	1972
Physics and astronomy.....	$112,851,000	$116,000,000	$110,300,000
Lunar and planetary exploration.....	150,900,000	144,900,000	311,500,000
Bioscience.....	19,655,000	12,900,000	---
Space applications.....	128,304,000	167,000,000	182,500,000
Launch vehicle procurement....	107,819,000	124,900,000	146,100,000
Total.....	$519,529,000	$565,700,000	$750,400,000

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1972 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS — PHYSICS AND ASTRONOMY PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objectives of the Physics and Astronomy program include investigations of the earth, sun and solar system, galactic and extragalactic phenomena and the interrelationships among them. We are exploring our space environment in order to understand its nature and the physical processes that shape it. In doing so, we are increasing our knowledge of the fundamental laws and principles of nature.

In carrying out these investigations, a variety of techniques are used to gather information. These include large orbiting observatories, smaller explorer satellites, sounding rocket flights, aircraft and balloon flights as well as theoretical and ground based laboratory research. Research groups participating in this effort are distributed all over the US and the free world. Groups are located at most of the NASA centers, at several other Government laboratories, and at many universities and industrial laboratories. Foreign participation is arranged through the science ministry of each of the participating countries, which undertakes responsibility for its own share of the costs without a transfer of funds from the U.S.

The technology developed and data gathered in this program are made available to the scientific and technical community in order to contribute to future scientific research, education, and the advancement of the technology of our country.

SUMMARY OF RESOURCES REQUIREMENTS:

	1970	1971	1972
Large observatories.....	$47,798,000	$42,831,000	$43,400,000
Orbiting explorers.....	18,295,000	26,200,000	24,500,000
Sub-orbital programs.....	21,100,000	23,000,000	21,500,000
Supporting activities.....	25,658,000	23,969,000	20,900,000
Total.....	$112,851,000	$116,000,000	$110,300,000

Distribution of Program Amount by Installation:

	1970	1971	1972
Manned Spacecraft Center.....	$400,000	$220,000	$200,000
Marshall Space Flight Center.....	1,534,000	2,940,000	14,050,000
Goddard Space Flight Center.....	84,906,000	85,659,000	68,290,000
Jet Propulsion Laboratory.....	875,000	335,000	350,000
Wallops Station.....	650,000	1,674,000	2,000,000
Ames Research Center.....	2,773,000	3,820,000	4,860,000
Electronics Research Center.....	25,000	---	---
Langley Research Center.....	523,000	1,080,000	1,055,000
NASA Headquarters.....	21,165,000	20,272,000	19,495,000

BASIS OF FUND REQUIREMENTS:

Large Observatories

	1970	1971	1972
Orbiting Solar Observatories (OSO)	$14,515,000	$16,431,000	$19,000,000
Orbiting Astronomical Observatories (OAO).....	33,283,000	26,400,000	11,000,000
High Energy Astronomy Observatories (HEAO).....	---	---	13,400,000
Subtotal Large Observatories.....	47,798,000	42,831,000	43,400,000
(Launch Vehicle Procurement program):			
Delta (OSO).....	($2,200,000)	($200,000)	($2,400,000)
Centaur (OAO).....	($5,600,000)	($1,500,000)	(---)
Titan III D (HEAO).....	(---)	(---)	($2,300,000)
Total (including Launch Vehicles).....	($55,598,000)	($44,531,000)	($48,100,000)

Orbiting Solar Observatories (OSO)

The objective of the OSO program is to obtain new knowledge of the sun, the earth's atmosphere, and sun-activated terrestrial phenomena over a broad range of the electromagnetic spectrum not detectable by ground-based observatories. The OSO's obtain scientific information on the sun, its internal energy mechanisms and influences on the solar system over long durations including changes with periods of the order of 11 and 22 years, the known periods of the solar activity cycle. Detailed observations are also conducted on the rapid variations in solar structure in a few seconds as in the case of solar flares which are explosive events with profound effects on the earth's environment and radio communications.

The OSO's have provided significant discoveries about the sun and the earth, and have expanded man's understanding of the nearest star and its interactions with the earth. The OSO-5 and OSO-6 spacecraft are still

actively providing valuable observations. Daily X-ray maps of the sun are supplied to ESSA (Solar Geophysical Data Reports). Sufficient data are now in hand to complete the discovery phase of the study of short-lived large scale phenomena on the sun, and the ground work has been laid for the study of a complete solar activity cycle. The temperature in flares was found to be more than 10,000 times higher than expected; the average temperature structure in the solar atmosphere has been inferred, heat flow in active regions studied, and the physical scale and observational models of solar phenomena identified.

Four OSO missions are scheduled for launch through the mid-1970's. Each OSO mission will contain a unique problem-oriented payload to complement and extend knowledge obtained from previous OSO's and other techniques. OSO-H, presently being assembled in preparation for a 1971 launch, is designed to concentrate on studies of the solar corona and flares. The three remaining OSO's (I,J,K) provide the means for exploiting previous discoveries with increased spectral, angular, and time resolution necessary for the solution of fundamental problems in solar physics.

OSO-I is scheduled for launch in 1973. A major French experiment and a comparable U.S. experiment on the pointing section will permit study of the energy transfer from the photosphere to the higher levels of the solar atmosphere under quiet sun conditions. For the first time, data acquisition and analysis will be handled by an international team made up of astronomers from many states and foreign countries.

Experiment proposals for OSO-J have been received from a number of U.S. investigators and three foreign countries. A problem-oriented payload with special emphasis on solar terrestrial relations will be chosen in early 1971. It is expected that the study of heat and particle radiation flow, which is the objective of OSO-I, will be traced further outward from the sun and its effects on the earth studied. OSO-K will be used to obtain high resolution data for studying solar activity and flares and the effects of transient solar events on the earth.

Fiscal Year 1971 funds provide for the assembly, test, and launch support of OSO-H, scheduled in late FY 1971. In addition, FY 1971 funds provide for the design and manufacture of the OSO-I experiments and for initiating the contract for the OSO-I, J, K spacecraft, the continued in-orbit operations of active observatories, and data reduction and analyses of scientific measurements.

Fiscal Year 1972 funds will support the development, assembly, and testing of OSO-I spacecraft and OSO-I experiments. Along with the development of the OSO-J spacecraft, design and fabrication of OSO-J experiments will be initiated. Funds will also continue the important coordinated in-orbit operations, reduction, and analyses of OSO experiment data.

Orbiting Astronomical Observatories (OAO)

The OAO program provides to astronomers an accurately stabilized, automated space observatory for telescopic observations of celestial objects in the spectral range from the X-ray through the ultraviolet into the visible region.

The OAO-2, launched December 7, 1968, continues to make major contributions to our understanding of the universe by providing critical information in the ultraviolet region of the electromagnetic spectrum. This observatory has sucessfully conducted scientific observations for over two years.

Some of the major OAO-2 scientific accomplishments include:

1. Ultraviolet excess in M31 galaxy which is interpreted as due to a large number of hot stars. This may contribute to the solution of the "missing mass" problem of the closed Universe theory.

2. Ultraviolet observations of Beta Aurigae, an eclipsing binary which has long been used as a calibration source have shown it to be cooler, larger, and therefore, closer than suspected.

3. Observations of a nova outburst (Stellar explosion), Nova Serpentis, from immediately after maximum intensity through the next two months.

4. The discovery of extensive hydrogen clouds around two bright comets and the accurate measurement of the temperature of the clouds.

5. Discovery of ozone on the planet Mars, which is very important to the understanding of the entire oxygen and carbon dioxide chemistry of the planets.

Measurement of these phenomena and others will be studied in greater detail with subsequent missions. Each measurement made by these observatories adds new and unique fundamental knowledge to the field of astronomy and astrophysics.

A guest observer program was initiated with OAO-2 to provide an opportunity for astronomers, both national and international, to participate in the investigation of celestial objects in spectral regions not observable from the ground. This program, which has developed considerable interest, is similar to the one that has made unique ground-based facilities available to the astronomical community. The program will be continued on OAO-C not only to provide scientific data, but to also collaterally demonstrate the peaceful use of space.

OAO-B was launched on November 30, 1970. It carried a 38-inch reflecting telescope system capable of spectrophotometry in the ultraviolet wavelength regions. This observatory failed to achieve orbit due to a launch vehicle failure which did not allow the shroud to jettison. OAO-B was designed to extend the OAO-2 sky survey of ultraviolet sources and the investigation of the gross characteristics of celestial objects in the ultraviolet spectral region by exploring fainter objects and studying brighter objects in somewhat greater detail.

OAO-C, which will be launched in 1972, is designed primarily to explore the important problems of the abundance and temperature distribution of the interstellar gas from which stars form. In addition, the high resolution will be extremely valuable for the study of the structure of stellar atmospheres through the detailed analyses of the shapes of a limited number of both strong and weak lines in relatively bright stars. However, since the very high resolution allows only a few photons per second to be recorded, the observations will be made primarily of spectral lines within the brighter stars.

Fiscal Year 1971 funds supported the preparation of OAO-B for launch, the in-flight operations and data analyses of the highly successful OAO-2, and the assembly and testing of OAO-C. FY 1972 funds will provide for launch and support of the in-orbit operations of OAO-C, and the reduction and analyses of data obtained by the scientific experiments.

High Energy Astronomy Observatories (HEAO)

The primary objective of the HEAO project is to observe our galaxy and the universe in the X-ray and gamma-ray regions of the electromagnetic spectrum and to measure the energy spectrum and chemical composition of the corpuscular cosmic radiation. The HEAO project is expected to:

Provide sky surveys necessary to describe the universe

Contribute to understanding of observed phenomena (Quasars, Pulsars, etc.)

Provide potential for major impact on the understanding and development of new energy processes

Provide direct opportunity to study matter and seek anti-matter from outside our solar system

Provide potential opportunity to probe deeper into the nature of elementary matter by observations of higher energy interactions than now achievable otherwise

Provide high potential for surprises

This program of investigations has been given the highest priority for new starts by the National Academy of Sciences (Woods Hole Summer Study) and the Astronomy Missions Board (AMB) of NASA.

A series of missions have been planned commencing with a total sky survey for obtaining a broad description of the universe as viewed in this region of the electromagnetic spectrum and evolving to more comprehensive detailed investigations in the later missions.

HEAO-A will perform a total sky survey in cosmic ray, X-ray and gamma-ray emissions. This first mission will operate in an automated mode using subsystems which are currently available and experiments which are either fully developed or under advanced development; e.g., balloon payloads. The first mission will be launched in 1975. The second mission will provide pointing capability for improved observations. The third and fourth missions will utilize a finer pointing capability in order to conduct high resolution investigations.

The HEAO spacecraft must have the capability for carrying the large experiment instrumentation required for the surveys. The approximate dimensions will be a nine foot cylinder, thirty feet long. It is expected to weigh 20-25,000 pounds, carry 10-15,000 pounds of experiment instrumentation and require approximately one kilowatt of power generated by solar cells. The spacecraft will be designed to insure an acceptable lifetime in an 180-200 nautical mile orbit.

The Titan class of launch vehicles has been tentatively identified for the initial missions and studies will be conducted to find ways for taking advantage of Space Shuttle capability for later missions - i.e., launch, repairs and updating.

Thus far, payloads for use in the current definition study have been selected for HEAO-A and HEAO-B and a partial payload for HEAO-C. These payload selections represent 15 American universities, 4 Government laboratories, 4 industrial companies and 3 foreign institutions. Confirmation of flight assignment for these payloads will be given after program approval and review following completion of definition studies.

The Marshall Space Flight Center (MSFC) is directing the technical definition of HEAO. An in-house feasibility phase was completed and the definition phase is progressing with two study contracts. It is planned to issue a Request for Proposals (RFP) in open competition next summer for the design and hardware phases. A single contractor for systems and integration is anticipated.

Fiscal Year 1972 funding will allow experimenters on missions A and B to complete instrument design and procure long-lead items such as large crystals. FY 1972 funding will also permit selection and contract award to the spacecraft contractor; contractor effort will include detailed designs and procurement of long-lead items prior to spacecraft fabrication.

In addition, MSFC will conduct feasibility studies aimed at utilization of the space shuttle for activities associated with later missions.

Orbiting Explorers

	1970	1971	1972
Explorers.....	$18,295,000	$26,200,000	$24,500,000
Delta (Launch Vehicle Procurement Program).....	($5,200,000)	($2,900,000)	($7,300,000)
Scout (Launch Vehicle Procurement Program).....	($3,800,000)	($500,000)	($4,100,000)
Total (including Launch Vehicles)	($27,295,000)	($29,600,000)	($35,900,000)

The Explorer program makes use of relatively small spacecraft, each dedicated to specific, problem-oriented objectives, thus enabling the design of the spacecraft and the parameters of the orbit to be optimized to meet each objective. Problems in X-ray and radio astronomy, atmospheric and ionospheric physics, radiation belts, magnetospheric boundaries and interplanetary space are being investigated in this way. This program also provides a major means for cooperative missions with other Government agencies and other countries, where mutual program objectives can be met with the cooperating party paying its own costs.

Explorer spacecraft average about 2 or 3 launches per year. Conceptual and systems studies to support this launch rate are carried out on a continuing basis. In addition, NASA engages in cooperative missions with other Government agencies and other countries whenever these missions will assist in achieving NASA objectives. These cooperative missions also average about 2 or 3 launches per year, usually on Scout vehicles, with the cooperating partner providing the spacecraft.

In December 1970, the first mission in the Small Astronomy Satellite (SAS) series was successfully launched. SAS-A, or Explorer 42, also called Uhuru (Freedom) was launched by an Italian crew from the San Marco launch platform off the coast of Kenya. This is the first NASA satellite to be launched outside the United States, and the first to be launched by a foreign crew. A launch from the United States into the same orbit would have required a larger vehicle. The mission of Explorer 42 is to search systematically for X-ray sources in space and to map the brightness of the celestial sphere in the 2-20 keV energy range.

Fiscal Year 1972 funds will be used to support missions that will be launched over the next several years. These Explorer spacecraft will be used to obtain data for investigations in X-ray and radio astronomy, atmospheric and ionospheric physics, the radiation belts and magnetospheric

boundary, and interplanetary space. Activities to be funded will include the development of the spacecraft and instruments, the pre-flight testing, launch, and the analysis of data from operating satellites.

The first Radio Astronomy Explorer (RAE-A) launched in 1968 is observing extraterrestrial and solar radio sources. RAE-B is being prepared to operate in lunar orbit to use lunar occultation for more precise location of the sources, and to reduce terrestrial noise interference.

Small Astronomy Satellites (SAS-B and C) are being prepared to continue SAS-A studies in other wavelength ranges, and a fourth mission (SAS-D) is under definition as a possible cooperative effort with participation by the United Kingdom and ESRO. In addition, cooperative astronomy missions are underway with the United Kingdom (UK-5) and the Netherlands (ANS-A).

The major absorption of solar energy takes place at altitudes in the 100-200 mile range. To investigate the absorption and transformation of energy in this region, which controls many ionospheric features, Atmosphere Explorers (AE-C,D,E) are being developed with new variable orbit and rapid data handling capabilities.

The Small Scientific Satellite (SSS-A) is being prepared to explore the ring-current particles which are believed to be responsible for the magnetic fluctuations observed during geomagnetic storms. A cooperative barium release project with Germany is scheduled to investigate electric and magnetic fields in the outer radiation belts. Other cooperative space physics missions include those with the United Kingdom (UK-4), Italy (San Marco C) and Germany (GRS-A2). A possible cooperative program with Spain is also under consideration.

Interplanetary Monitoring Platforms (IMP-H,I,J) missions will continue to study the boundaries in front of and behind the earth which define regions of interaction between solar particle streams and the earth's environment.

Future space physics missions under study include Dual Air Density, Injun F, and IMP KK'.

Sub-Orbital Programs

	1970	1971	1972
Sounding rockets.....	$18,500,000	$19,000,000	$18,000,000
Airborne research.....	1,600,000	3,000,000	2,500,000
Balloon support.....	1,000,000	1,000,000	1,000,000
Total.....	$21,100,000	$23,000,000	$21,500,000

Sounding Rockets

Sounding rockets are the only means of obtaining data below 150 kilometers, where satellites cannot survive, and of providing vertical profiles of geophysical parameters which are complementary to satellite observations. Sounding rockets are a flexible, timely, and cost-effective means of providing space flight opportunities and, as such, constitute an invaluable component of a balanced program in space research.

A flexible stable of relatively inexpensive vehicles is utilized to carry a wide variety of scientific instruments developed for studies in the disciplines of aeronomy, energetic particles and fields, ionospheres and radio physics, galactic and radio astronomy, and solar physics.

Sounding rockets provide timely opportunities for: (1) conducting test flights of instrumentation being developed for spacecraft; (2) studying scientific phenomena in the exploratory phase and (3) taking advantage of unique opportunities (eclipses, novae, flares etc.).

During the solar eclipse operation of March 7, 1970, thirty-one sounding rockets were successfully launched from Wallops Island. Seventeen of these vehicles were launched during a one hour period. The payloads developed for these flights were designed to conduct coordinated complementary experiments in solar physics, ionospheric physics, aeronomy and upper atmosphere meteorology.

Recoverable sounding rocket payloads continue to be a unique means for collecting samples of micrometeorites, interplanetary dust, noctilucent cloud particles, and upper atomsphere trace gases. The study of cosmic radiation and energetic particle influx and their relationship to such phenomena as aurora and airglow have passed the exploratory phase and are being continued at a reduced level in order to permit increased emphasis on exploratory stellar and solar investigations. Our knowledge and understanding of the nature, characteristics, and dynamics of heterogeneous layers of the ionosphere continues to be enhanced with rocket borne measurements of electron and ion concentrations, altitude distributions, and mass spectra from a variety of launch sites around the world. Studies of the atmospheres, emissions and dynamics of the planets, Sun, and stars continue to be made over a complete range of wavelengths of the energy spectrum. Particular effort has concentrated on the study of stellar X-ray and ultraviolet sources, flares and active areas of the sun and its corona, and the atmospheres of the inner planets. Major advances in our ability to conduct these studies have resulted from increased utilization of our recently developed stellar and solar pointing controls that are able to hold scientific instruments pointing at their celestial target within approximately $\pm$ 1.0 arc second, allowing discrimination of very localized regions of interest for study.

The FY 1972 fund request provides for a flight program at an approximate level of 80 flights per year. Some slight reduction in total flights may be anticipated as a result of increasing emphasis on the more complex stellar and solar investigations as recommended by the Woods Hole Study effort. Forty to fifty scientific teams will be supported by this effort.

Airborne Research

Airborne research with instrumented jet aircraft bridges the gap between ground-based experiments and those requiring balloons, rockets and space vehicle systems. The flexibility involving the direct participation of scientists and the large payload capacity with the ability for extended observations over any geophysical area has yielded excellent scientific results and correlations with NASA's satellite systems. The airborne research program is demonstrating an approach which may be applicable to space shuttle and space station operations in the future.

The physics and astronomy airborne research program emphasizes the support of infrared astronomy, and investigations of the physics of the aurora and airglow. Infrared astronomy of the sun, planets and galaxies with small (12-inch) telescopes has been undertaken from the CV-990 and Lear jet aircraft. A 36-inch aperture f/13.5 Cassegrain telescope is now being built for observations from a C-141A jet aircraft.

The FY 1971 airborne research funding is almost entirely allocated for the IR telescope and the C-141A purchase.

The FY 1972 airborne research budget is also programmed primarily for the IR airborne observatory and will be utilized for the completion of the 36-inch telescope and to its integration into the C-141A aircraft.

Balloon Support

Balloons play an important role in the Physics and Astronomy program by providing timely and relatively low cost flight opportunities for (1) testing proposed satellite instrumentation in the space environment, (2) obtaining observations at altitudes which are not accessible to satellites, (3) lifting instruments which are too heavy and voluminous for flight in present automated satellites, (4) utilizing instruments which can be safely recovered and reused, and (5) obtaining observations for relatively extended periods of time (in contrast to short duration rocket flights). Approximately one million dollars are expended annually to support about 60 balloon flights a year. This estimate includes balloons, launch services, tracking and recovery. Funding for the experiments is provided from Supporting Research and Technology (SR&T).

Supporting Activities

	1970	1971	1972
Supporting research and technology (SRT)	$16,718,000	$16,569,000	$15,400,000
Large space telescope studies (SRT).....	---	---	500,000
Data analysis.....	8,940,000	7,400,000	5,000,000
Total.....	$25,658,000	$23,969,000	$20,900,000

Supporting Research and Technology/Advanced Studies

This effort enhances the overall scientific and technological return from NASA flight projects and helps assure continued excellence and viability of the future research program in space science. The objectives can be stated in the following three broad categories: (1) enhancement of the value of current space missions by supplementary simultaneous ground-based observations; (2) development of theories to explain observed phenomena and predict new ones; and (3) optimization of the return expected from future missions by problem definition, development of advanced experiments and concepts, and the careful definition of proposed new missions.

The work in space physics is largely devoted to support of research related to the physics of the earth's environment. It includes study of the sun-earth environmental factors as well as extra-solar factors such as cosmic rays. Advanced development work on experimental tests of the validity of Einstein's Theory of Relativity is also supported in this area. In general, these tasks may be categorized in the traditional disciplines of particles and fields, ionospheres, and interplanetary dust.

Research supported in the field of astronomy involves the study of the sun, and objects outside the solar system. Research tasks include studies of the solar spectrum, influence of the sun on interplanetary and planetary environments, instrument development, and laboratory and theoretical studies of basic physical processes peculiar to the sun. Research tasks related to objects outside of the solar system include observation by ground-based and balloon-borne telescopes, and instrument development. Theoretical studies of stars, galaxies, interstellar and intergalactic matter are also supported in this area.

During FY 1971, tasks are being supported at universities, nonprofit and industrial research institutions, NASA centers and other Government agencies in two thirds of the states and the District of Columbia.

During FY 1972, we plan to support the continuation of those tasks which are critical to maintaining a firm base for a viable Physics and Astronomy program. Of special significance is the initiation of Phase B studies for the Large Space Telescope (LST). The LST will be a generally useful, multiple observing instrument, optical telescope system. The precursor

telescope planned for the 1977-78 time period will lead to a 3-meter class diffraction limited telescope by the 1980's. As now envisioned, the LST will be in earth orbit and will be operated as a national facility. By appropriately combining redundancy and manned maintenance in conjunction with a shuttle/space station such a system will be kept in operation nearly continuously for a minimum of a decade.

In Fiscal Year 1972 it is planned to analyze the performance of various instruments making up the complement for the LST and to resolve the instrument interfaces. Trade-off analysis of the errors associated with the instruments will be performed. In addition, alternate optical systems will be evaluated, fine pointing systems developed, facilities identified, data handling techniques evaluated, project plans and costs prepared, operating orbits selected, and manned maintenance techniques developed.

Data Analysis

The purpose of this effort is to make maximum use of the investment represented by the data gathered in the space science program, and by the continued operability of a number of spacecraft well beyond their planned lifetimes.

Limited operation of spacecraft, beyond the times originally planned, has resulted in additional data being made available for specific investigations, with preference given to correlative work designed to illuminate physical problems, and the exploitation of unusual opportunities such as unexpected observations of comets, or solar occultation of deep space probes.

With the successful completion of the launch of the last Orbiting Geophysical Observatory (OGO) mission, the OGO project has been organizationally located in the National Space Science Data Center (NSSDC) at Goddard Space Flight Center for the continuation and extension of the data processing, and analysis phase of the program. In keeping with this arrangement, OGO funding requirements have been included under the Data Analysis project.

Further work using existing data is also supported, with emphasis on correlative studies. Under this project, investigators are expected to prepare data, complete with calibrations, in a form suitable for deposit in the NSSDC.

The operation of the NSSDC is also supported under this project. The NSSDC was established to serve as a central respository and clearinghouse of reduced scientific data resulting from space investigations. The amount of data to be handled has increased steadily each year. Although the proposed budget will not permit the originally planned buildup in NSSDC capabilities, it is considered adequate for supporting the most essential activities.

OFFICE OF SPACE SCIENCE AND APPLICATIONS

LUNAR AND PLANETARY EXPLORATION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Lunar and Planetary Exploration program is directed toward investigation of the moon, the planets and their satellites, asteroids, comets and the particles and fields of interplanetary space. Its goal is the acquisition of new and more detailed data and knowledge of the origin, history and dynamics of our solar system with particular emphasis on understanding the evolution of our earth and the processes that control its environment. The current program of lunar investigation includes ground based and in situ measurements of lunar materials and phenomena and planning for further investigations utilizing the remaining lunar missions in the Apollo series. The current program for planetary investigations rely on both ground based observation and research, and on spacecraft flybys, orbiters, and landers.

Earlier unmanned programs have already greatly advanced our knowledge of the moon and provided a wealth of data. The Ranger project provided the first closeup detail of the moon's surface through vidicon pictures transmitted to earth. The subsequent Lunar Orbiter project provided large scale, detailed photographs of the moon that were required for the selection and certification of sites for the Apollo manned lunar landing missions. The Lunar Orbiter project also improved coverage of the moon by exposing new areas of the moon's near and far side surface to view. The Surveyor project, by demonstrating the soft landing capability of a complex spacecraft, increased confidence in the ability of Apollo to land on the lunar surface. In addition, Surveyor cameras took hundreds of high resolution photographs of the lunar terrain, Surveyor instruments measured the lunar surface bearing strength, and rudimentary chemical analysis was performed on lunar surface materials. Funds provided under this program finance the basic scientific research and planning essential to the design of experiments and missions of the Apollo Manned Space Flight program. It also supports the subsequent data analysis efforts to obtain the maximum scientific payoff from each mission.

The planetary and interplanetary programs have experienced a high degree of success beginning with the Mariner 2 flyby of Venus in 1962 and continuing with the most recent successful launchings of Mariner 6 and 7 in 1969. Plans call for the launch of two Mariner spacecraft in 1971 to orbit Mars for a minimum of 90 days each. Martian exploration will then be extended by the Viking mission, which will provide two missions, each containing separate

spacecraft to orbit and land on the Martian surface in 1976. In 1973 another Mariner is planned to flyby Venus and utilize the gravity assist available to make the first flyby of Mercury. Launches of Pioneer F and G spacecraft are planned in 1972 and 1973, and will provide the first measurements of interplanetary medium in the region beyond Mars, in the asteroid belt, and in the vicinity of Jupiter. In each of 1974 and 1975, two cooperative U.S./German spacecraft (Helios) will be launched to investigate the particles and fields of the interplanetary medium in as close as approximately 0.3 AU from the sun. An Astronomical Unit (AU) is the distance between the earth and the sun or 93,000,000 miles. The FY 1972 budget provides for initial development on a long duration spacecraft suitable for a variety of missions to the outer planets, including both flybys and orbiter missions. Initiation of this spacecraft development effort in FY 1972 is designed to take advantage of the unique alignment of the outer planets which will occur in the latter half of the 1970's and will make possible gravity assisted flybys of three planets with a single spacecraft. The mission set receiving primary attention includes 1976 and 1977 launches to Jupiter, Saturn, and Pluto and two 1979 launches to Jupiter, Uranus, and Neptune. A mission to orbit Jupiter will be studied as a possible alternative to the first of these missions.

SUMMARY OF RESOURCES REQUIREMENTS:

	1970	1971	1972
Mariner	$63,871,000	$46,400,000	$52,800,000
Viking	40,000,000	35,000,000	180,400,000
Outer planets missions	---	---	30,000,000
Pioneer/Helios	22,570,000	37,400,000	20,100,000
Supporting research and technology/advanced studies*	18,080,000	17,800,000	18,800,000
Planetary astronomy	3,800,000	4,800,000	4,800,000
Data analysis	2,579,000	3,500,000	2,400,000
Planetary quarantine*	---	---	2,200,000
Total	$150,900,000	$144,900,000	$311,500,000

* Planetary Quarantine and the exobiology part of SR&T were, in prior years, part of the Bioscience programs.

Distribution of Program Amount by Installation:

	1970	1971	1972
Kennedy Space Center.....	---	$42,000	---
Manned Spacecraft Center.....	$643,000	685,000	$100,000
Marshall Space Flight Center....	88,000	400,000	800,000
Goddard Space Flight Center.....	4,841,000	4,438,000	6,800,000
Jet Propulsion Laboratory.....	81,618,000	64,659,000	131,500,000
Ames Research Center.....	21,636,000	34,471,000	17,900,000
Electronics Resarch Center.....	2,000	---	---
Langley Research Center.....	28,904,000	23,166,000	133,500,000
NASA Headquarters.....	13,168,000	17,039,000	20,900,000

BASIS OF FUND REQUIREMENTS:

Mariner

Mariner Mars 1969.....	$3,715,000	$500,000	$100,000
Mariner Mars 1971.....	59,256,000	31,200,000	13,900,000
Mariner Mars 1971 extended mission operation....	---	---	500,000
Mariner Venus/Mercury 1973.....	900,000	14,700,000	38,300,000
Total Spacecraft and Support..	$63,871,000	$46,400,000	$52,800,000
Atlas Centaur (Launch Vehicle Procurement program).....	($9,200,000)	($7,500,000)	($6,100,000)
Total (including launch vehicles).....	($73,071,000)	($53,900,000)	($58,900,000)

The Mariner series of spacecraft have been the major tool in the planetary program for flyby observations of the other planets in the solar system. These spacecraft have evolved from the 450 pound Mariner 2 used for man's first successful mission to another planet to the 2,200 pound Mariner 1971 to be used for our first orbiting mission of another planet.

The Mariner 2 flyby of Venus in 1962 was followed by the Mariner 4 flight past Mars in 1965, which revealed a cratered Martian surface similar to that of the moon and yielded data on the planet's atmosphere and ionosphere. Mariner 5 flew past Venus in 1967 at a distance of 2,600 miles and made measurements including the properties of the Venusian atmosphere. According to Mariner 5, Venus is a hot planet with a thick lower atmosphere--mostly carbon dioxide.

On July 31 and August 5, 1969, Mariner 6 and 7 passed within 2,000 miles of the Martian surface completing the most ambitious and successful planetary reconnaissance ever attempted. The scientific data return greatly exceeded the minimum requirements of the mission including more than 200 pictures of the planet taken by the spacecraft on their approach trajectories. Mariner 7, which flew over the south polar cap region, found the polar cap to be composed of carbon dioxide and heavily cratered in the same fashion as the land surfaces. The possibility of life on Mars remains one of the major unanswered scientific questions, and the combined spectroscopic and imaging data from Mariner 7 provided interesting and likely regions for future missions to concentrate their efforts in pursuit of this question.

In the continuing study of Mars, the Mariner Mars 1971 missions will provide a significant increase in our knowledge of that planet. Utilizing instruments which are improved types of those previously flown, two spacecraft will be launched on Atlas Centaur launch vehicles from the Eastern Test Range during May 1971. These spacecraft will arrive at Mars during November 1971 and will be placed in orbit about the planet. Continuous observation of the planet during the basic 90 day missions will provide greater planetary coverage than has been obtained before, and will allow detection of any dynamic, seasonal or other changes on the planet's surface and in its atmosphere which may occur during that period.

The two identical Mariner Mars 1971 spacecraft will perform separate but complementary missions. One spacecraft will be primarily devoted to mapping about 70 percent of the Martian surface during the basic 90 day mission. This spacecraft will have an orbital period of 12 hours. The closest approach during orbit will be about 1,250 km (775 miles) as compared to the 3,400 km (2,100 miles) closest approach of previous Mariner spacecraft. The second spacecraft will be primarily devoted to observation of any time variable features. This second spacecraft will have an orbital period that will provide repetitive coverage of selected areas of Mars. The low point of this orbit will be 850 km (530 miles).

The basic missions are expected to satisfy their objectives within the 90 day operational period. However, a hoped for bonus will accrue if the spacecraft lifetime is extended beyond 90 days (or beyond February 1972). It is then planned to operate the two spacecraft in extended mission operation modes through November 1972. The data collected during the extended mission modes will be variable due to changing operational constraints, and will be generally less than that obtained during the basic missions. However, this data will include observations of Mars throughout a season which is similar to the season during which the Viking landers will later land on Mars.

A single modified Mariner spacecraft will be used to study both Venus and Mercury in 1973. Although the similarities of Mars, Venus and Earth make the study of these planets important to our knowledge of earth and its

place in the solar system, the knowledge of other planetary bodies can also make a significant contribution. During the 1973 opportunity, using the same rocket thrust required to go to Venus, a spacecraft can be accelerated by Venus' gravity and orbital velocity so that it can also swing by Mercury and begin the exploration of this, the closest planet to the sun. The Mariner spacecraft, which will be launched by Atlas Centaur, will return both ultraviolet and visual television pictures, atmosphere and ionosphere data, as well as thermal maps from both Venus and Mercury. In addition, it will monitor the space environment in the unexplored regions between Venus and Mercury.

In Mid-December 1970 a request for proposal was issued for a spacecraft systems contract for this mission. These proposals will be reviewed and evaluated, and the systems contractor selected by late April 1971. This contractor will have major responsibility for the spacecraft preliminary and detail design, procurement of subsystems, integration, and conduct of test operations. In addition, the systems contractor is expected to provide project support in the launch and mission operations phases of the project.

Fiscal year 1971 funds support launch and flight operations of the Mariner Mars 1971. The FY 1972 funds requested for Mariner Mars 1971 will be used to support mission operations activities and data processing and analysis activities for both the 90 day basic missions and the extended missions. On the Mariner Venus/Mercury 1973, FY 1972 funds are being requested to support the implementation phase of the master schedule, i.e., the system design, the detail design and necessary development tests.

The Office of Space Science and Applications, NASA Headquarters, is responsible for overall management of the Mariner program. The responsibility for project management has been assigned to the Jet Propulsion Laboratory. The Lewis Research Center is responsible for the launch vehicles.

Viking

	1970	1971	1972
Orbiter.....	$7,400,000	$7,900,000	$38,900,000
Lander.....	31,000,000	24,700,000	123,600,000
Project management.....	1,600,000	2,400,000	17,900,000
Total.....	$40,000,000	$35,000,000	$180,400,000
Titan Centaur (Launch Vehicle Procurement program).....	($200,000)	($3,200,000)	($8,400,000)
Total (including launch vehicles).....	($40,200,000)	($38,200,000)	($188,800,000)

The Viking 1975 mission will extend the exploration of Mars initiated by the earlier Mariner missions. The Viking mission will be the first NASA study of Mars from direct measurements obtained within its atmosphere and on its surface. Earlier Mariner missions could only study the planet from orbital or flyby distances.

The objectives established for the Viking program are to significantly advance our knowledge of the planet Mars by means of observations from Martian orbit and direct measurements in the atmosphere and on the Mars surface during the 1975 opportunity. Particular emphasis will be placed on obtaining biological, chemical, and environmental factors relevant to the existence of life on the planet at this time, in the past, or in the future.

Two Viking spacecraft will be launched in 1975 by Titan Centaur vehicles. Each spacecraft will consist of an Orbiter and a Lander. The Mariner-type Orbiter will have the capability of placing itself and the attached Lander into an orbit about Mars. Instruments on the Orbiter will obtain planetary data for at least three months. The Lander will separate from the Orbiter about 10 days after arrival at Mars and descend through the atmosphere to the surface. The Lander, designed with the soft-landing technology of the Surveyors and Apollo lunar modules, will transmit biological, geological, meteorological, and other scientific data to earth for 90 days. The Lander can either communicate directly to earth or relay its data, at a higher bit rate, through the Orbiter.

The Office of Space Science and Applications, NASA Headquarters, is responsible for overall management of the Viking program. Langley Research Center has been assigned the responsibility for project management. The Jet Propulsion Laboratory is responsible for the Orbiter. The Martin Marietta Corporation is the prime contractor responsible for the Lander and systems integration. The Lewis Research Center is responsible for the launch vehicle. The program planning being completed during FY 1971 includes development of detailed schedules, preliminary design of the spacecraft, and design and development effort on critical long-lead subsystems and science instruments.

During FY 1972, the detailed design will be completed and much of the spacecraft and preliminary design reviews will be held. The major subsystem contracts will be awarded during the year, consistent with the master schedule. Fabrication of the first developmental Landers, to be used in testing programs, will begin in this period.

Outer Planets Missions

	1970	1971	1972
Outer planets missions.....	---	---	$30,000,000
Total.....	---	---	$30,000,000

The exploration of the inner planets is well underway. In the decade ahead we face the challenge of extending planetary exploration to the outer solar system. Here lie the four giant planets--Jupiter, Saturn, Uranus, and Neptune--29 of the 32 known planet satellites; a maverick planet, Pluto, that may be an escaped satellite; thousands of comets and asteroids; and true interstellar space beyond Jupiter where the galactic wind overcomes the solar wind. Any convincing theory on the origin and evolution of the solar system must await direct investigation of the outer solar system. Knowledge of the outer planets should also help us to understand and predict the future evolution of earth.

Our experience during the 1960's has established a successful strategy of initially sending flyby missions to each planet for reconnaissance and to lay groundwork for the most productive planning of later orbiter, probe, and lander missions. We have initiated this logical sequence of exploration missions to Jupiter with the Pioneer F and G flyby missions to be launched in 1972 and 1973. Future Jupiter orbiter and probe missions, which are now being studied, can then be based on the results from these initial flyby missions.

For the outer planets beyond Jupiter, it is again appropriate to start with flyby missions. Various alternate means have been examined to accomplish these initial flyby investigations. The most economical and productive approach has been determined to be two different three-planet flybys, the first to Jupiter, Saturn and Pluto with launch opportunities ranging from 1976 to 1978, and the second to Jupiter, Uranus and Neptune with launch opportunities centered at 1979. These missions are made possible by a unique alignment of the outer planets which occurs in the late 1970's but which will not reoccur for 179 years.

NASA currently favors taking advantage of the multiple-planet opportunities with single Jupiter-Saturn-Pluto (J-S-P) launches in 1976 and 1977 and dual Jupiter-Uranus-Neptune (J-U-N) launches in 1979. The resultant flyby data from all of the outer planets would be returned in time for knowledgeable planning of second generation missions and the establishment of relative priorities among the outer planets before the next two-planet opportunities occur in the 1990's.

Another attractive avenue of outer planets exploration would be to follow the Jupiter flybys of Pioneers F and G with an intensive and detailed study of the enormously interesting planet Jupiter. It would be desirable to proceed in parallel with this detailed second generation investigation of Jupiter featuring a planetology orbiter to be followed with probe missions, while at the same time conducting the multiple-planet flyby surveys of the remaining outer planets. It is recognized that available resources may not permit pursuit of both lines of effort during the same time period. It may then be necessary to make a choice between the multiple-planet survey and the second generation exploration of Jupiter. NASA is continuing to weigh these priorities in partnership with both the SSB and NASA's in-house scientific advisory groups.

Fortunately, the initial steps toward either the multiple flyby option or a Jupiter planetology orbiter option are essentially identical. For either approach long-lead development of the Thermoelectric Outer Planets Spacecraft (TOPS), which has been under study for some time, must be started, basic experiments defined, and mission parameters determined to optimize the experiment returns. The studies to date indicate that there would be little difference in the experiment payloads selected for either the planetology orbiter or the multiple-planet flybys. This experiment and mission planning effort will be greatly advanced during the coming year by a team of highly qualified scientists to be selected in March 1971 to assist NASA in planning outer planet missions, including both the orbiting and multiple-planet flyby missions.

Over the past four years, many types and sizes of spacecraft have been studied and evaluated for accomplishing the exploration of the outer solar system. The TOPS concept for a basic multipurpose spacecraft has been selected as the most economical approach consistent with the highest priority scientific objectives and the long-life reliability required for all outer planets missions. Its stabilized scan platform, such as used on the Mariners, permits sensitive measurements to be made on the planets and satellites; it takes advantage of recent communications developments to achieve a desirable real-time data return from Jupiter orbiter and an adequate data rate over even the three billion mile distances to Neptune and Pluto; and it incorporates adaptive control and self-test and repair features believed essential to achieving long-life reliability with a high degree of confidence. The development of this technology to flight status will benefit not only the planetary exploration program, but will advance the useful lifetimes of all future spacecraft. Broad commercial spin-offs in the electronic industry are also expected.

The TOPS design features multipurpose utility. It can be readily configured for either flyby or orbiting missions. In its flyby configuration, it should also be suitable for later deep-entry probe missions to Jupiter and the other outer planets.

During FY 1972 detailed design and development will begin on this TOPS multipurpose outer planets spacecraft compatible with both multiple-planet flyby missions and with Jupiter planetology orbiting missions. Both types of missions will be defined in further detail during FY 1972. The program is scheduled to have the TOPS spacecraft developed in time to take advantage of the J-S-P opportunity in 1976.

Relative launch priorities such as between the J-S-P missions and Jupiter planetology orbiters will continue to be assessed in light of new knowledge and changing priorities. Our current program calls for the development of basic building blocks, including the TOPS spacecraft and its experiments, to permit flexible planning of an optimum program of investigation of the outer solar system.

The effort to be conducted during FY 1972 includes the following:

1. Long-lead development and qualification of electronic parts.

2. Detailed design of the spacecraft engineering model and advanced development of special subsystem components of the basic multi-mission spacecraft.

3. Detailed mission analysis and design and the support of science planning activity (including selected instrument breadboarding).

This effort is essential to developing the basic building blocks for the next decade of exploration of the solar system. The work must be started in FY 1972 if we are to take full advantage of the rare and uniquely efficient multiple-planet flyby opportunities.

Pioneer/Helios

	1970	1971	1972
Pioneer 6 - 9.....	$1,761,000	$1,500,000	$600,000
Pioneer F and G.....	20,509,000	34,000,000	17,000,000
Helios A and B.....	300,000	1,900,000	2,500,000
Subtotal.....	$22,570,000	$37,400,000	$20,100,000
Centaur (Launch Vehicle Procurement program).....	($2,100,000)	($16,600,000)	($14,300,000)
Total (including launch vehicles).....	($24,670,000)	($54,000,000)	($34,400,000)

The Pioneer 6 through 9, launched in 1965 through 1968, have achieved the scientific objectives of observations of the interplanetary phenomena in the region of 0.75 to 1.1 AU from the sun. (One AU is the mean distance

between the earth and the sun or 93,000,000 miles.) These characteristics were and are still being measured: cosmic dust; plasma; magnetic fields; electric fields; cosmic rays. The four Pioneers now in solar orbit are all functioning, and in December 1970, Pioneer 6 had operated for 5 years. These spacecraft are at widely separated positions in space and function as deep space weather stations enabling observers to detect and estimate the paths of solar storms. This information provides advance warnings of the variations in the protective magnetic envelope of the earth which affect long range radio communications or of radiation dangers to spacecraft and astronauts.

By 1968 studies confirmed the feasibility to extend these scientific measurements in the interplanetary media to 5.0 AU.

These measurements would collect data on the asteroids and meteoroids in the asteroid belt, and fly by Jupiter in order to obtain physical characteristics and images of Jupiter and its satellites. These missions were approved in 1969, and designated as Pioneers F and G. With the Pioneers F and G, we will study the possibly hazardous region of the asteroid belt, measure the gradient of the sun's influence on interplanetary space and possibly determine the extent of the boundaries of the galactic cosmic radiation in the solar system. As the spacecraft passes within 150,000 miles of Jupiter, instruments will transmit an image of the planet, measure the magnetic fields, electromagnetic emissions and the charged particles and thermal balance associated with this largest planet in the solar system. Data from these measurements will help us determine the composition and dynamics of the atmosphere of Jupiter and its interaction with the interplanetary medium. Since Jupiter is such a great distance from the sun, radioisotope thermal electric generators will be used for electrical power generation in place of the solar panels used in earlier Pioneer spacecraft. The Pioneers F and G weigh about 550 pounds and carry about 60 pounds of scientific instruments.

In 1969 a joint mission definition group consisting of German and United States space scientists and engineers recommended that the properties and processes in interplanetary space in the direction of and close to the sun (about 0.3 AU) be investigated. This international cooperative project was subsequently approved and designated as Helios.

The Helios program is the largest international cooperative program to date. The spacecraft will weigh about 560 pounds, carry about 110 to 120 pounds of scientific instruments and be developed in West Germany utilizing consultants from U. S. aerospace companies.

Three of the ten scientific experiments will be supplied by U. S. investigators. NASA will provide the launch vehicle and the tracking

and data systems for the first phase of the mission. The West German Government will control the spacecraft during all of the operations, plus track it, and acquire the data during the later mission phases.

Fiscal year 1971 funds will be used: (1) to continue to track and analyze data from the Pioneer 6-9 orbiting spacecraft; (2) on Pioneer F and G, to complete the design and integrate scientific instruments and continue necessary testing; (3) on Helios, to continue to define spacecraft and experiment interface specifications and initiate thermal model testing.

Fiscal year 1972 funds will be used for the continued development of the Pioneer F and G spacecraft including prototype qualification testing and the acceptance testing of the flight F spacecraft. The Pioneer F spacecraft will be launched in the third quarter of fiscal year 1972

Development of the U. S. experiments for Helios will continue with the delivery of the engineering models of the scientific instruments to the spacecraft contractor for integration and test, and with the initiation of fabrication of the prototype models for these instruments.

The Office of Space Science and Applications, NASA Headquarters, is responsible for the overall management of the Pioneer project and is responsible for the technical interface between the U. S. and West Germany on the Helios project. The responsibility for project management on the Pioneer project has been assigned to the Ames Research Center. The project management responsibility for the U. S. portion of the Helios project has been assigned to the Goddard Space Flight Center. The Lewis Research Center is responsible for the launch vehicles.

Supporting Research and Technology/Advanced Studies

	1970	1971	1972
Lunar science.....	$6,580,000	$6,400,000	$3,000,000
Planetary science.....	4,425,000	4,200,000	4,700,000
Planetary advanced technical development.....	5,875,000	6,000,000	6,000,000
Planetary advanced studies.....	1,200,000	1,200,000	1,200,000
Exobiology*.....	---	---	3,900,000
Total.....	$18,080,000	$17,800,000	$18,800,000

* The Exobiology project was, in prior years, part of the Bioscience program.

Supporting Research and Technology and Advanced Studies projects are the research activities which provide support to the flight missions by providing the base for defining the scientific objectives of future missions, and establishing the scientific and engineering capabilities essential to the performance of these missions.

The activities of the Lunar Science program are devoted to increasing our scientific knowledge of the moon by continuing laboratory investigations and theoretical studies, drawing on basic data derived from ground based research and from Ranger, Surveyor, Lunar Orbiter, and Apollo missions. Apollo lunar missions have demonstrated dramatically a growing capability for useful scientific accomplishments in orbit and on the lunar surface. Initial surface exploration, in mare areas in the equatorial belt, has provided basic new data of great scientific value on the surface rock composition (rock analysis), subsurface structure (passive seismic measurements), and environmental factors such as solar radiation effects and magnetic field strength. Continuing these experiments and expanding the data base is vital if the Nation is to take full advantage of the Apollo capability to explore the moon, and exploit the discoveries made in the earlier phases of lunar exploration. With startling scientific successes to date and additional missions scheduled, we await new discoveries related to environmental factors, rocks, and history at later landing sites at high latitudes and in older highland areas that will be attainable with increased EVA time and new equipment.

The FY 1972 lunar science effort will include in addition to all the above: continued production of geologic maps of Apollo landing sites; plotting traverse routes; evaluation of succeeding Apollo landing sites; and the appraisal of automated instrument concepts for physical and chemical analysis by remote sensing from lunar orbit and surface rovers. Laser ranging from earth telescopes to corner reflectors on the lunar surface is continuing to determine the relative motions of the earth-moon system to improve determination of absolute distance between points on the earth's surface, and to provide better understanding of the structure and dynamics of the earth.

The Planetary Atmosphere program supports research in atmospheric phenomena of the planets including that of the earth, and the gaseous phenomena associated with comets. In FY 1972, research will emphasize the design, development, and modification of instruments for use in the exploration of the outer planets. Direct measurement experiments and instrumentation for the exploration of the lower atmosphere of Venus will also be stressed.

Another area financed under Planetary Supporting Research and Technology is the Planetology project which supports research in the increasingly important field of planetary geology including geochemistry, geophysics

and photogeology. As the planetary program progresses from earth based observational data to flyby and orbiter data, and in 1975 to data from Mars landers, planetology research will play a more important role in determining the nature and properties of the planets. In FY 1972 the emphasis will be on the development of instrumentation for geochemical and geophysical studies of Mars and the outer planets. In the area of engineering technology, the Advanced Technical Development (ATD) program supports the development of new and improved design of spacecraft hardware to: (1) improve lifetime and reliability of the systems for long duration missions such as those to the outer planets; (2) develop more efficient data management systems to permit the return of more data or lower power demand; (3) develop instruments and subsystems which will survive in hostile environments; (4) develop technology for high speed planetary entry. In FY 1972, research in the ATD program will continue work in these areas, with somewhat more emphasis on the critical technologies for Venus and Jupiter probes and comet rendezvous missions.

In the Planetary Advanced Studies program, surveys of potential future scientific missions are made, and an up to date catalogue of mission opportunities, their general system requirements and their value in fulfilling established goals and objectives of NASA are defined. Alternative mission approaches, including the utilization of existing systems are evaluated, resource requirements determined, and advanced technology requirements examined. In FY 1971, studies were conducted on: (1) solar electric missions; (2) surface sample return from Mars; (3) atmospheric probes of Venus; (4) Jupiter entry probes; (5) comet missions and (6) outer planet subspacecraft. In FY 1972 it is planned to continue the investigation of the atmospheric probes and orbiters of Venus, and other promising missions, and to initiate additional studies such as: (1) orbiters of Saturn and other outer planets; (2) atmospheric probes of Jupiter, Uranus and Neptune; (3) comet and asteroid rendezvous; and (4) Mars rovers for sample return.

The Exobiology research program has dual objectives of understanding the controlling factors in the origin of life, and determining the uniqueness of life on earth. The research ranges from the analysis of fossil remains and simulation of planetary atmospheres and other environmental extremes, to the development of automated life detection equipment intended to increase the reliability of the data by broadening the basis for analysis of individual samples. In addition to the biological interest in Mars, laboratory experiments now suggest that organic synthesis may be occurring on Jupiter, which has a primitive reducing atmosphere. The development of prototype instrumentation for exobiologic studies in the Martian surface is needed as a precursor to flight

instruments for future Mars landers. The life detection and organic analytical techniques developed in various laboratories must now be converted into engineering models of flight instruments for testing and potential later selection as a payload in order to achieve the scientific objectives of the exobiology program. Such work must be done to support the planetary exploration program.

Planetary Astronomy

	1970	1971	1972
Planetary astronomy.....	$3,800,000	$4,800,000	$4,800,000
Total.....	$3,800,000	$4,800,000	$4,800,000

A basic technique in the scientific exploration of the solar system is the observation of the planets and other celestial bodies from the vicinity of the earth. While the planets have been studied by astronomers for hundreds of years, observations made from the vicinity of the earth are still yielding a wealth of valuable information. The use of airplanes, balloons, rockets, and earth orbiting satellites as observing platforms with new instrumentation and observing techniques in addition to ground based observatories, have increased the capability of astronomical observations far beyond those considered feasible a few years ago.

Planetary studies by radar observation illustrates the great potential value of using new observation techniques. Within the last eight years, radar observations of the planets have resulted in the determination of accurate rotation periods for the planets Venus and Mercury, and precise distance values and information on the size of Mars and Venus. Martian topographic variations have also been obtained for limited regions of that planet. Improvements to one or more of the largest existing radar systems (e.g., Arecibo, Puerto Rico) will make possible the mapping of the entire cloud covered surface of Venus at sufficient resolutions to observe in detail features such as mountains, craters, etc.

The combination of the data obtainable from the vicinity of the earth with the scientific return from the presently planned planetary flight program, is required to achieve planetary program objectives in the most economical way. Earth based observations are extremely cost effective compared to planetary missions, and require relatively short turn around times for instrumentation changes. They are also repeatable, when necessary, over long periods of time.

Simultaneous programs in laboratory and theoretical studies to assist with the interpretation and analysis of the observations are also supported. Telescopes, radio and radar systems, spectrographs, etc., that are already available are used as much as possible. However, when new instruments

such as large telescopes or relatively smaller items such as photometers, are required to obtain data, the development and construction of such instruments are supported through this program.

In FY 1972, astronomical research tasks supporting the planetary flight program will be continued at the existing level of effort. Joint effort with the National Science Foundation will be conducted to upgrade the radar/radio astronomy facility at Arecibo, Puerto Rico.

Data Analysis

	1970	1971	1972
Lunar data analysis.....	$2,000,000	$1,600,000	$1,000,000
Planetary data analysis.....	579,000	1,900,000	1,400,000
Total.....	$2,579,000	$3,500,000	$2,400,000

The data analysis project provides for the support of scientists analyzing the results of flight experiments after the initial period of funding provided by the flight project. It also provides support for scientists not associated with the flight project to analyze data obtained from flight investigations.

The long term objective of Data Analysis is to interpret the scientific data acquired by spacecraft missions and incorporate the results in the growing body of knowledge of the characteristics and history of the moon and planets.

In the Lunar Data Analysis emphasis in analysis has shifted from Ranger, Surveyor, and Lunar Orbiter data, to Apollo data, where it is expected to continue for several years. For these studies the Orbiter data are supplemented by an increasing wealth of new high resolution Apollo photography, much of it in color, of selected parts of the lunar equatorial zone. This information will be correlated with that obtained from the lunar samples and geologic exploration of the Apollo landing sites by the astronauts. This analysis of Apollo scientific data, other than that done initially by the principal investigators, will be a significant part of the FY 1972 Lunar Data Analysis program.

The Planetary Data Analysis project will provide for reduction of data from earlier Mariner missions to Mars and Venus and in particular from the Mariner Mars orbiter 1971 missions, the Pioneer missions in interplanetary space, and earth satellite and sounding rocket missions pertinent to scientific exploration of the earth's upper atmosphere.

Planetary Quarantine

	1970	1971	1972
Planetary quarantine*.....	---	---	$2,200,000
Total.....	---	---	$2,200,000

* In prior years, the Planetary Quarantine project was a part of the Bioscience program.

Accompanying NASA's high priority goal in space exploration to search for life or its origin is the absolute requirement that all feasible measures be taken to prevent the transfer of viable terrestrial microorganisms to the planets until the search for extraterrestrial life can be completed and a confident assessment of the consequences of contamination can be made. To accomplish this, outbound unmanned spacecraft missions destined for landing, flying by or orbiting a planet of biological interest, are required to meet rigid constraints so that the probability of biological contamination of the planet is less than one chance in a thousand.

Developing the new technology required to measure, control and destroy the microbial life in spacecraft hardware and finding appropriate compatible decontamination and sterilization procedures has been the major challenge in meeting the objectives of planetary quarantine.

A transition is underway from a research oriented program to one of operations for the Mariner 1971, Viking, Pioneer and other planetary missions. A lowered level of research is continuing to provide alternate techniques of sterilization other than dry heat which will be more efficient and/or economical or more reliable if the survival of the spacecraft should be in question. This will give flexibility in the choice of methods, particularly in the sterilization of scientific instruments. Also under consideration are alternative chemical sterilants which may provide self-sterilization on or in spacecraft parts and materials to reduce the bioload prior to terminal sterilization.

Additional attention is being given to the operational requirements of the Viking bioburden prediction and sterilization models to guide and support the implementation of requirements on flight projects and allow for trade-off studies which may ease the impact of the sterilization requirement. The planetary quarantine effort to date has been focused on Mars and Venus. However, within this decade we may be concerned with additional missions to the outer and inner planets.

Spacecraft bioassay activities at the Cape Kennedy laboratory will continue to provide the inventory and surveillance data on Apollo missions and the upcoming Mariner Mars 1971 orbiting mission in accord with NASA directives.

OFFICE OF SPACE SCIENCE AND APPLICATIONS — BIOSCIENCE PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Bioscience program was established in 1961 to implement a Space Biology and a Planetary Biology program (Exobiology and Planetary Quarantine). A decision was recently made to bring together in the Office of Manned Space Flight the greater part of the NASA life sciences activities formerly distributed among the Space Medicine Division of the Office of Manned Space Flight, the Biotechnology and Human Research Division of the Office of Advanced Research and Technology, and the Bioscience Programs Division of the Office of Space Science and Applications.

The decision to consolidate Life Sciences activities was supported by a recent study of the National Academy of Sciences. The consolidation of Life Sciences excluded two general functional areas, Planetary Biology and Aeronautics. The Planetary Biology effort of Exobiology and Planetary Quarantine will be retained in the Planetary Programs Division of the Office of Space Science and Applications because of the central role that these activities play in planetary exploration. The Aeronautics portion of the former Human Factors program will be retained in the Office of Advanced Research and Technology because of its criticality to aeronautical flight and research operations.

The Life Sciences budget is included in the Office of Manned Space Flight budget in FY 1972.

SUMMARY OF RESOURCES REQUIREMENTS:

	1970	1971	1972
Planetary quarantine.....	$2,540,000	$2,000,000	---
Biosatellite.....	5,970,000	332,000	---
Supporting research and technology/ advanced studies.....	11,145,000	10,568,000	---
Total.....	$19,655,000	$12,900,000	---

Distribution of Program Amount by Installation:

Manned Spacecraft Center.....	$328,000	$197,000	---
Marshall Space Flight Center.....	364,000	85,000	---
Goddard Space Flight Center.....	50,000	100,000	---
Jet Propulsion Laboratory.....	1,614,000	1,501,000	---
Wallops Station.....	30,000	---	---
Ames Research Center.....	7,774,000	1,519,000	---
Langley Research Center.....	127,000	28,000	---
NASA Headquarters.....	9,368,000	9,470,000	---

OFFICE OF SPACE SCIENCE AND APPLICATIONS — SPACE APPLICATIONS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objectives of the Space Applications program are to: (1) expand our knowledge of geophysical, oceanographic, atmospheric, and space phenomena; (2) conduct a broad program of research and technical development oriented toward the application of space techniques for the benefit of mankind; (3) develop and test procedures, instruments, subsystems, spacecraft, and interpretive techniques for the various applications; (4) fulfill NASA's responsibilities under the Communications Satellite Act of 1962; (5) develop and implement for the National Oceanic and Atmospheric Administration (NOAA), Department of Commerce, the operational meteorological satellite system; (6) cooperate with the user Government agencies, such as the Departments of Agriculture, Commerce, Interior, and Navy through the Earth Resources Survey Program Review Committee to achieve practical benefits to mankind in earth resources; (7) cooperate with other Government agencies in space related activities in the communications, navigation, and geodesy/earth physics disciplines; and (8) cooperate to the extent possible with foreign countries in the general advancement of space applications.

Within the Space Applications program objectives, a number of current goals have been established which should be achieved in the near term. One or more goals have been established in each major disciplinary area.

In the area of Earth Resources Survey from space three goals have been established: (1) develop technology for remote sensing of the earth from aircraft and space for ecology surveys of the earth for the benefit of man; (2) develop applications of this new technology including user requirements for agriculture, forestry, oceanography, geology, hydrology, geography, and cartography; and (3) develop technology for handling large quantities of remotely sensed data and associated problems concerning data transmission, data reduction, data processing, data storage and retrieval, and data dissemination.

In communications the endeavors are to: (1) study the factors which affect efficient use of space and thus permit greater utilization of the frequency spectrum; (2) develop and test improved technology for accurate stabilization and pointing of the large space erectable antennas which will be required on spacecraft; (3) develop efficient satellite techniques for collecting data from many remote, unattended platforms; (4) study the requirements, technical approaches, and cost factors involved in the potential use of satellites for

television transmission to low cost ground terminals for community TV and direct TV to home receivers; (5) study factors influencing allocation of positions in the geosynchronous orbit so as to minimize mutual interference between terrestrial and space communications systems sharing the same frequencies; (6) cooperate with Alaska and India on their potential TV experimentation by utilizing ATS-1 and ATS-F satellites; (7) cooperate with France and Canada on joint communications and technological satellite missions; and (8) study information network requirements and systems.

In meteorology the goals are: (1) from the successful infrared sounding of the vertical structure atmosphere by the Nimbus 3 and 4 satellites improve and extend the capability to higher altitude regions, greater spatial resolution, and various infrared spectral regions and to augment the sounding techniques to include the use of the microwave spectral region; (2) to develop a first generation prototype operational Synchronous Meteorological Satellite for the continuous viewing of the atmosphere and weather conditions; and (3) to develop third generation operational meteorological satellite instrumentation with the ability to measure the vertical temperature structure and water vapor content of the atmosphere in addition to day and night cloud cover. The achievement of these will provide three-dimensional meteorological measurements and the temporal variation which can be used to obtain a fuller understanding of the meteorological processes that are a prerequisite to long-range forecasting utilizing numerical models of the atmosphere. The continuous viewing of short-term severe atmospheric disturbances such as thunderstorms and tornadoes and the monitoring of the tropic areas to detect tropical disturbances and hurricanes will assist the improvement of short-term prediction.

In geodesy/earth physics the aim is to: (1) apply geodetic satellite technology, precision satellite tracking techniques, and precision astronomical techniques to measurements of the dynamics of the solid earth and oceans; (2) establish marine geodetic control points; and (3) contribute to the objectives of the National geodetic satellite program with respect to accurate determination of the size and shape of the earth. Achievement of the first goal will contribute to the development of techniques for predicting earthquakes, volcano eruptions, and general oceanic circulation. Achievement of the second goal will facilitate the production of mapping of resources on the ocean floor.

In navigation, the goals are to understand: (1) the various needs for better navigation, communications, traffic control, aircraft and ship position determination, and collision avoidance; (2) the technical requirements necessary to achieve the various needs; and (3) the various satellite designs and cost factors which would best meet the requirements of the maritime and aviation community. NASA is cooperating with France (CNES), the Federal Aviation Administration (FAA), and the aviation industry in navigation, communications, and traffic control satellite experiments.

SUMMARY OF RESOURCES REQUIREMENTS:

	1970	1971	1972
Earth resources survey:.....	$26,000,000	$59,950,000	$48,500,000
Earth resources technology satellites.....	(15,000,000)	(48,950,000)	(37,500,000)
Aircraft program.....	(11,000,000)	(11,000,000)	(11,000,000)
Applications technology satellites.....	38,965,000	30,300,000	60,300,000
Nimbus.....	27,239,000	25,300,000	23,100,000
Synchronous meteorological satellites.....	2,700,000	10,850,000	13,000,000
Cooperative applications satellites.....	83,000	100,000	2,600,000
Global atmospheric research program.....	---	1,000,000	2,500,000
Meteorological soundings.....	3,000,000	3,100,000	2,500,000
TIROS/TOS improvements.....	3,700,000	3,200,000	1,600,000
Radio interference and propagation program.....	438,000	1,000,000	1,000,000
Geodetic satellites.....	1,700,000	1,700,000	1,300,000
Earth observatory satellite studies.....	---	---	1,000,000
Air traffic control satellite studies.....	---	3,000,000	---
Supporting research and technology/advanced studies.	24,479,000	27,500,000	25,100,000
Total.....	$128,304,000	$167,000,000	$182,500,000

Distribution of Program Amount by Installation:

Manned Spacecraft Center....	$12,795,000	$12,710,000	$11,700,000
Marshall Space Flight Center	150,000	280,000	200,000
Goddard Space Flight Center.	92,450,000	128,346,000	140,450,000
Jet Propulsion Laboratory...	2,731,000	1,087,000	1,300,000
Wallops Station.....	1,002,000	1,220,000	1,300,000
Ames Research Center.....	383,000	675,000	1,650,000
Electronics Research Center.	277,000	---	---
Langley Research Center.....	6,265,000	5,085,000	3,650,000
Lewis Research Center.....	1,320,000	1,390,000	3,700,000
NASA Headquarters.....	10,931,000	16,207,000	18,550,000

BASIS OF FUND REQUIREMENTS:

	1970	1971	1972
Earth resources technology satellites			
Spacecraft.....	$1,747,000	$19,588,000	$15,000,000
Experiments.....	12,453,000	17,327,000	13,500,000
Ground operations.....	800,000	12,035,000	9,000,000
Subtotal.....	$15,000,000	$48,950,000	$37,500,000
Delta (Launch Vehicle Procurement Program).....	(---)	($3,400,000)	($3,100,000)
Subtotal (including launch vehicles).....	($15,000,000)	($52,350,000)	($40,600,000)
Earth resources survey/aircraft			
Operations.....	$1,950,000	$3,435,000	$3,200,000
Data processing.....	1,826,000	3,610,000	3,900,000
Sensors.....	7,224,000	3,955,000	3,900,000
Subtotal.....	$11,000,000	$11,000,000	$11,000,000
Total, Earth Resources Survey (including launch vehicles)	($26,000,000)	($63,350,000)	($51,600,000)

The objectives of this project are to: (1) assess the practical value of remote sensing of earth resources from space; (2) compare the capabilities in earth resources data acquisition of a space system with and without complementary aircraft coverage; (3) determine whether or not, and in what configuration, an operational space-assisted and user-oriented earth resources survey system could be developed to meet existing requirements; (4) determine which remote sensors are most effective for earth resources surveying; (5) develop and improve data handling procedures; and (6) ensure full understanding of future operational system requirements and costs.

This project consists of a comprehensive program to design, launch, and evaluate experiments on Earth Resources Technology Satellites, and a supporting aircraft program to develop and test remote sensing techniques, sensors, and data handling systems by conducting aircraft flights at altitudes of 500 feet to 60,000 feet. The applications requirement will be coordinated with the Office of Manned Space Flight which is developing the Earth Resources Experiment Package (EREP) to be flown on Skylab.

The objective of the Earth Resources Technology Satellite project is to design, develop, launch, and test a series of spacecraft to conduct experiments which will lead to a reliable assessment of the utility of space-

borne sensors for applications to problems related to natural and man-made resources. This assessment will lead to the capability to design spacecraft and related data handling systems to support these national programs on an operational basis. It will also lead to an evaluation of the complementary roles of aircraft and spacecraft in acquiring data on the earth's resources. This effort is progressing in Fiscal Year 1971 and will continue in Fiscal Year 1972 through the detailed design and fabrication of spacecraft, payloads, and ground systems required to launch, support, and operate two Earth Resources Technology Satellites; ERTS-A in the spring of Calendar Year 1972 and ERTS-B about one year later. Both satellites are planned for sun-synchronous orbit and are expected to have useful mission durations of one year each. ERTS-B will serve both as a backup to ERTS-A and as an improved version, capable of incorporating lessons learned in the course of fabricating ERTS-A and also capable of extending the sensitivity of the instruments into the thermal infrared region. These satellites will carry instrumentation that will meet the requirements of the user community in terms of spatial and spectral resolution as well as repetitive coverage. Both framing and line scanning sensors will be flown in order to assess the advantages of each. The satellite system will also concurrently relay data from remote ground sensors such as rain gauges, stream gauges, and seismometers to assess the value of such a network for complementing the spaceborne sensors.

The data to be acquired by the instruments on ERTS-A and ERTS-B will be managed by the use of a specialized ground data handling system (GDHS) now being constructed at the Goddard Space Flight Center. The GDHS is designed to receive, process, annotate, catalog, reproduce, and disseminate the large volume of high quality data needed to support the many investigations of applications planned to be conducted in discipline areas such as forestry, agriculture, geology, hydrology, geography, and oceanography. These data-use experiments will commence in Calendar Year 1972 with the launch of ERTS-A and will continue through the useful mission duration of ERTS-B.

Fiscal Year 1972 funds are being requested for continued development of the spacecraft and sensors for ERTS-A and -B, the GDHS, and for initial support of experimenters.

The Earth Resources Survey Aircraft supporting project objective is to conduct tests and experiments with instruments analogous to those being considered for the spacecraft systems to evaluate both the instruments themselves and the potentiality of using such instruments to perform useful tasks from space. The flights also contribute to an understanding of, and solution to, the data management problems that will be a part of the total system operation, including the interfaces with the extensive and diverse user community. This project provides essential flight test support to the earth resources supporting research and technology effort.

Two substantial additions to the aircraft instrumentation capability are being made: a 24-channel line scanner covering a broad visible and infrared

spectrum will be installed in the C-130 aircraft at the Manned Spacecraft Center, and a scanning microwave radiometer will be installed in the P3A aircraft. These, together with the RB57 high altitude aircraft, assigned to NASA by the Air Force, will provide a much improved capability for experimentation. This capability will be used on a combined mission basis with the ERTS flights so that the aircraft effort in FY 1971 will be directed at providing for aircraft-spacecraft correlated experimental investigations.

Fiscal Year 1970 funds were utilized for operation of three aircraft, for sensor procurement, and data handling systems. Fiscal Year 1971 funds are being utilized to continue this effort, procure additional sensors, and continue the modification of high altitude aircraft for use in obtaining a better understanding of atmospheric effects on remote sensing capability. Fiscal Year 1972 funds are being requested to continue aircraft operations, sensor procurement, and data processing to conduct about 150 flights over 15 test sites, which represents a change in flight emphasis needed in the preparation for ERTS-A and Skylab.

The Office of Space Science and Applications is responsible for the overall management of this project. Responsibility for management of the ERTS-A and -B project is assigned to the Goddard Space Flight Center. The contractor for the spacecraft development is the General Electric Company. Responsibility for execution of the Earth Resources Survey Aircraft project is assigned to the Manned Spacecraft Center. Effort in the Earth Resources Survey area is coordinated with other user agencies through the Earth Resources Survey Program Review Committee (ERSPRC) which includes representatives from the Departments of Agriculture, Commerce, Interior, and Navy, and is chaired by NASA. Observers from other departments such as Transportation are also frequently present.

Applications Technology Satellites

	1970	1971	1972
Spacecraft.....	$18,450,000	$7,600,000	$26,300,000
Experiments.....	18,506,000	17,700,000	31,000,000
Operational support.....	2,009,000	5,000,000	3,000,000
Total.....	$38,965,000	$30,300,000	$60,300,000
Atlas Centaur and Titan IIIC (Launch Vehicle Procurement Program).....	($6,700,000)	($4,700,000)	($12,500,000)
Total (including launch vehicles).....	($45,665,000)	($35,000,000)	($72,800,000)

The objectives of the project are to design, develop, flight test, and

evaluate a variety of scientific and technological experiments within the applications disciplines by use of a series of seven spacecraft. Five spacecraft have been launched to date. ATS-1, launched December 7, 1966, and ATS-3, launched November 5, 1967, into synchronous orbits have performed successfully and continue to operate. Because of launch vehicle anomalies the desired orbits for ATS-2 and ATS-4 were not achieved. ATS-5, launched August 12, 1969, experienced problems with the active stabilization system prior to planned despinning of the satellite, however, many objectives from seven of the twelve experiments flight tested on the mission are being achieved. Two spacecraft, ATS-F and -G, are scheduled for launch in Calendar Years 1973 and 1975, respectively. Utilizing three-axis active spacecraft stabilization, these spacecraft will be launched into synchronous orbit and will flight test a space-erectable, parabolic antenna, approximately 30 feet in diameter, demonstrate the high pointing accuracy it requires, and will flight test a number of scientific and technology experiments.

Effort will be continued on development of promising advanced applications flight experiments which have been defined but have not been assigned to a specific flight mission.

The Office of Space Science and Applications is responsible for overall program management. Responsibility for project management is assigned to Goddard Space Flight Center. The spacecraft development contractor for ATS-F and -G is Fairchild-Hiller Corporation.

Fiscal Year 1970 and 1971 funds are being used for development of the ATS-F and -G spacecraft, ATS-F experiments and the project-associated ground equipment. FY 1972 funds are required to continue these efforts, to initiate procurement of ATS-G experiments, to continue development of selected advanced applications flight experiments and for extended experimentation, operations and data acquisition, reduction and analyses from the ATS-1, -3, and -5 missions.

Nimbus

	1970	1971	1972
Spacecraft	$18,291,000	$14,958,000	$12,750,000
Experiments	7,089,000	9,159,000	9,420,000
Ground operations and support	1,859,000	1,183,000	930,000
Total	$27,239,000	$25,300,000	$23,100,000
Thrust Augmented Thor Agena and Delta (Launch Vehicle Procurement Program)	($2,801,000)	($1,100,000)	($1,300,000)
Total (including launch vehicles)	($30,040,000)	($26,400,000)	($24,400,000)

The objectives of this project are to develop a significantly improved meteorological satellite to provide data on atmospheric parameters for use by the scientific community; to carry out flight tests to prove the applicability of the instrumentation; to fulfill special data requirements of the atmospheric sciences research community which can be provided uniquely by this instrumentation functioning as a space meteorological observatory; and to provide the basis for further significant technological advances in meteorological satellites for operational as well as scientific uses. These objectives will be extended in the Nimbus E and F missions to develop an applications observatory in polar orbit at low-to-medium altitude that will flight test technology and experiments for meteorology and other applications disciplines.

The project includes development, launch, and operation of a series of satellites exhibiting evolutionary advances in operating characteristics and testing in orbit of sophisticated experiments for atmospheric research and operational demonstration. The satellite serves as a flexible space observatory on which a variety of advanced concepts for measuring atmospheric parameters can be tested. The satellite consists of three major subsystems: power, stabilization, and a sensory ring which can accommodate a number of sensors.

The first two spacecraft in the planned series of seven Nimbus satellites were Nimbus 1, launched on August 28, 1964, and Nimbus 2, launched on May 15, 1966. Nimbus B, a third spacecraft, launched May 18, 1968, was lost due to a launch vehicle failure. In June 1968, NASA approved launch of a replacement spacecraft which largely used flight spares or updated prototype subsystems and experiments. This mission, identical to the Nimbus B configuration, was designated B-2 prior to launch. It was successfully launched April 14, 1969, whereupon it was designated Nimbus 3. This replacement was necessary in order not to delay the flight test of that group of selected experiments and technological advances vital to the meteorological research and development program and required for long-range weather forecasting. The successful measurement from the Nimbus 3 of temperatures in the atmosphere has been termed "as significant to the advancement of meteorology as the launching of the first satellite." Nimbus 3 continued successful operation in orbit until September 25, 1970, when failure of a horizon scanner motor seriously degraded spacecraft stability. The spacecraft is maintaining its earth orientation, but useful data are being obtained from only two experiments. These are the monitor of solar energy and the radioisotope thermoelectric generator.

Nimbus 4 was successfully launched on April 8, 1970. The new advanced stabilization system has met or exceeded the performance specifications. This spacecraft carries new and improved experiments, such as a temperature/humidity infrared radiometer, a monitor of the water content of the atmosphere, and a refined world-wide data collection system which is providing

the first meaningful spacecraft obtained wind measurements. The experiment to monitor water content of the atmosphere experienced ice accretion on the radiation-cooled detector, but obtained data from the second channel (which distinguished between ice and water clouds) until mechanical failure of the experiment on June 7, 1970. The satellite continues to operate successfully, and all other experiments are providing useful data. It is the Nimbus 4-type basic spacecraft, including the new control system, on which the ERTS-A and -B spacecraft will be based.

The additional approved missions in the Nimbus series are Nimbus E and F, planned for launch in the third quarter of CY 1972 and the second quarter of CY 1974, respectively. These missions will test new infrared radiometric and spectrometric and microwave instrumentation designed to allow determination of the vertical structure of the atmosphere in cloudy areas. Current instrumentation requires a reasonably cloud free viewing area. These and other new instruments will extend sounding of the atmosphere to new areas of the electromagnetic spectrum and to higher altitudes in the atmosphere.

The Office of Space Science and Applications is responsible for overall management of this program. Responsibility for project management is assigned to the Goddard Space Flight Center. The major contractor for spacecraft structure and integration and test of spacecraft is the General Electric Company; the Radio Corporation of America is responsible for power and data storage subsystems.

Fiscal Year 1971 funds are being used to continue the development, assembly, and test of the Nimbus E spacecraft and experiments. These funds will also permit procurement of the experiments selected for Nimbus F. The spacecraft contract includes both Nimbus E and F. The FY 1971 funds are also required for continued acquisition and analysis of data from the Nimbus 3 and 4 spacecraft in orbit. These data are providing a continuing and expanding base for significant atmospheric research.

Fiscal Year 1972 funds are required for integration of the Nimbus E spacecraft systems and experiments, and final testing prior to the launch, in August 1972. These funds will also permit continued development, assembly, and test of the Nimbus F spacecraft and experiments. It is also planned to fund for continued acquisition and analysis of data from Nimbus 3 and 4 as appropriate to their operational status.

Synchronous Meteorological Satellite

	1970	1971	1972
Spacecraft.....	$235,000	$9,338,000	$10,428,000
Experiments.....	2,305,000	662,000	1,292,000
Ground operations.....	160,000	850,000	1,280,000
Total.....	$2,700,000	$10,850,000	$13,000,000
Delta (Launch Vehicle Procurement Program).....	(---)	($2,200,000)	($3,800,000)
Total (including launch vehicles).....	($2,700,000)	($13,050,000)	($16,800,000)

The objectives of the Synchronous Meteorological Satellite (SMS) are to demonstrate a prototype operational system which will meet the requirements of the National Oceanic and Atmospheric Administration (NOAA) to: (1) permit continuous observation of major weather systems routinely, thus enhancing the ability to predict and locate severe short-lived storms; (2) derive important wind field data over large areas and in much less time than heretofore possible; and (3) provide capability for rapid dissemination of processed meteorological data to local meteorologists.

The spacecraft will be spin stabilized and will contain a visible and infrared spin scan radiometer system for both IR and high resolution visible photography, a communications system for data collection and distribution, and a space environment monitoring (SEM) system. The spacecraft will be sized to permit launch into synchronous orbit by the Delta launch vehicle.

A feasibility study and a project definition study were completed by GSFC in-house in FY 1968. In FY 1970 a Phase B system design study was completed by NASA which permitted contractual effort to be initiated for the procurement of a day/night sensor and the SMS-A and -B spacecraft.

Fiscal Year 1970 funds were used for initiating the design and development of the two SMS spacecraft and sensors. FY 1971 funds are being used to initiate procurement of SMS-A and -B spacecraft and sensors. FY 1972 funds are necessary to continue the procurement of these spacecraft, their subsystems, and sensors.

The Office of Space Science and Applications is responsible for overall management of the program with responsibility for project management assigned to the Goddard Space Flight Center. The Philco-Ford Company is responsible for the spacecraft structure and integration and test of the spacecraft. Hughes Aircraft Corporation is developing the day/night sensor.

Cooperative Applications Satellite

	1970	1971	1972
Spacecraft and support.....	$83,000	$100,000	$2,600,000
Scout (Launch vehicle procurement program).....	(---)	(---)	($1,200,000)
Total (including launch vehicles).....	($83,000)	($100,000)	($3,800,000)

Two unrelated missions are included in this program: CAS-A, a cooperative project with France; and CAS-C, a planned cooperative project with Canada.

CAS-A

The CAS-A effort consists of developing instrumental balloon techniques to be utilized in conjunction with an earth-orbiting satellite for the purpose of obtaining the characteristics of air masses, especially in situ measurements of speed and wind direction at various altitudes. The data obtained will be used by U. S. and French scientists to assist in the understanding of the structure of the atmosphere and extending weather forecasting capabilities. One spacecraft and one backup with instruments will be provided by France. The spacecraft will be launched by NASA in late 1971, using a Scout launch vehicle, from Wallops Island into a 900-km circular, 50-degree-inclination orbit to gather data from approximately 500 balloons. The instrumented balloons will be developed and launched by France in the Southern Hemisphere. Satellite tracking and data acquisition, reduction, and analysis will be by France. The U. S. will provide the Scout Vehicle, and backup if required, launch services, initial satellite tracking, and, along with France, analysis of the reduced data.

Fiscal Year 1970 and prior year funding was used by CAS-A for preparation of computer program models, for U. S. scientific investigations and analysis of balloon and spacecraft antennas, and for general project and technical support. The $100,000 funded in FY 1971 are being utilized to continue technical support. FY 1972 funds are required for continued technical support and to provide launch and post-launch support.

CAS-C

The Canadian Department of Communications and the NASA plan to launch a Canadian Technology Satellite in late 1974. This mission is a substitute for the fourth planned cooperative ISIS. The overall objective of this project is to advance the state-of-the-art in spacecraft and related ground-based technologies relevant to future communications and other satellite

applications systems. Principal objectives of this mission are to: (1) flight test super-efficiency power tubes having greater than 50 per cent efficiency at a minimum output power of 200 watts and operating at approximately 12 GHz; (2) flight test unfurlable solar power arrays of approximately 1.5 kw initial capability; (3) flight test liquid metal slip rings; (4) demonstrate electric propulsion for spacecraft station keeping; (5) demonstrate accurate stabilization of spacecraft with flexible appendages; and (6) conduct satellite communications experiments with 12 GHz terminals. The Federal Communications Commission and Office of Telecommunications Policy (OTP) have asked NASA to investigate the use of frequencies above 10 GHz for communications services. The need to do this is becoming increasingly critical since U. S. domestic satellites launched in the mid-1970's will further crowd the frequency spectrum.

It is planned that the spacecraft will be developed and fabricated in Canada and will be launched from the Eastern Test Range (ETR) by NASA using a Delta class launch vehicle. The spacecraft will be placed in geostationary orbit by the U. S. and Canada will subsequently conduct experiments on a time shared basis.

Fiscal Year 1972 funds are required for CAS-C to continue high-power tube development and initiate ground system planning and procurement. Canada will provide continuing funding support for the spacecraft and their experiments.

The Office of Space Science and Applications is responsible for the overall management within NASA. Responsibility for project management of CAS-A is assigned to Goddard Space Flight Center and CAS-C to Lewis Research Center.

Global Atmospheric Research Program

	1970	1971	1972
Studies and support.....	---	$1,000,000	$2,500,000
Total.....	---	$1,000,000	$2,500,000

The Global Atmospheric Research Program (GARP) is an international cooperative program designed to increase our understanding of the general circulation of the atmosphere and to establish the mathematical and physical basis for methods of long-range weather prediction. GARP is directed jointly by the governments of interested nations (through the World Meteorological Organization (WMO)) and by the world scientific community (through the International Council of Scientific Unions (ICSU)): National and international organizations have been established to plan and execute the program.

Two major experiments are planned: a tropical experiment in the tropical Atlantic Ocean area in the fall of 1974 and a first GARP global experiment

during the period of 1975 or 1976. Tentative requirements for atmospheric data and tentative observing systems for acquisition of this data have been defined by WMO-ICSU planning groups. Operational and experimental satellites of the United States, U.S.S.R., France, and other countries have been identified as essential to the GARP experiments.

Studies conducted by NASA in FY 1970 confirmed that meteorological satellites and sensory subsystems under development by NASA could provide significant support to the GARP global serving system, and that modeling and simulation studies being conducted by NASA are highly beneficial for the specification and design of the global observing systems. These studies and analyses of proposed operational meteorological satellite systems are being continued in FY 1971 to define the optimum global observing system responsive to GARP requirements.

During FY 1972, NASA will continue modeling and simulation studies to improve mathematical models of atmospheric behavior, incorporating quantitative atmospheric data obtained from meteorological satellites, and to further define observing system data requirements. Efforts will be continued to establish preliminary systems designs for satellite global observing systems employing operational and experimental satellites available through participation by interested nations. Detailed studies and comparative analyses will be conducted to identify facilities, logistics operations, and advanced technology, and advanced development tasks required to provide data acquisition, data transmission, and data processing support for the tropical experiment and the first GARP global experiment. Detailed planning will be initiated for the conduct of the first GARP global experiment and technological studies will be conducted toward the solution of unresolved problems in acquiring, on a global basis, essential atmospheric data.

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

Meteorological Soundings

	1970	1971	1972
Research sounding rockets...	$2,026,000	$2,095,000	$1,850,000
Sounding rocket systems.....	730,000	730,000	350,000
Field experiment support....	244,000	275,000	300,000
Total.....	$3,000,000	$3,100,000	$2,500,000

The objectives of this project are to use research and development meteorological sounding rockets to measure the structure and characteristics of the atmosphere in the 30 to 100 km region and to develop an economical meteoro-

logical sounding rocket system to meet research, range support, and routine operational requirements.

Three areas of effort are involved:

(a) Research meteorological rockets of the Nike-Apache class are used to explore the characteristics of the atmosphere between 30 and about 100 km. This region which is important to meteorological science, cannot be reached except by sounding rocket. The relations and the mechanisms operating between and within the various regions of the atmosphere, and the effects of solar energy and its variations on the structure and circulation of the atmosphere are explored.

(b) A small meteorological sounding rocket system for making economical atmospheric measurements in the region 30 to 60 km is being developed. This system will be capable of launching reliable, inexpensive operational meteorological sounding rockets amenable to the requirements for range support, atmospheric research, and network operations.

(c) The field experiment support program provides, through cooperation with other countries, for the establishment of self-sustaining capabilities for coordinated meteorological sounding rocket launches from sites that will contribute mutually valuable data.

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

The FY 1971 and prior years funds were utilized to launch large research and small developmental rockets, develop and improve sounding rocket systems, and for continuation, extension, and development of field experiment projects in cooperation with countries in South America, Europe, and Asia. Approximately 50 large research rockets and about 200 small development rockets are launched each year. FY 1972 funds are required to procure additional large research and small developmental rockets, flight test various payload experiments, improve rocket performance, and to continue field experiment projects with other cooperating countries to obtain additional atmospheric research data.

TIROS/TOS Improvements

	1970	1971	1972
TIROS-M spacecraft.....	$2,033,000	$880,000	---
TOS improvements.....	1,667,000	2,320,000	$1,600,000
Total, Spacecraft & Support	$3,700,000	$3,200,000	$1,600,000
Delta (Launch Vehicle Procurement Program).....	($200,000)	(---)	(---)
Total (including launch vehicles).....	($3,900,000)	($3,200,000)	($1,600,000)

The objectives of this project are to provide research and development toward advanced operational meteorological satellite systems, specifically in support of the TOS program and the development of operational systems for the National Operational Meteorological Satellite System (NOMSS); to provide maximum interim operational data for use in weather analyses and forecasting; to provide improved operational subsystems for the acquisition of data necessary to the improvement of weather analyses and forecasts, specifically in the areas of infrared and visual observations of earth cloud cover, radiometric observations of reflective and absorbed energy for determination of vertical temperature and water vapor profiles and the earth atmosphere heat budget, and in the area of improved data processing and handling for timely operational use.

Ten TIROS research and development spacecraft, of which nine were funded by NASA and one, TIROS-X, by the National Oceanic and Atmospheric Administration (NOAA), formerly ESSA, have been successfully launched since April 1960, providing cloud cover and other meteorological data for research and operational use. TIROS-IX, as a research and development satellite in a wheel configuration, was essentially the prototype spacecraft for the TIROS Operational Satellite (TOS) system.

The development of the TOS system has been one of the main objectives of the NASA meteorological satellite program. This system has represented a significant improvement over its predecessor, the R&D TIROS spacecraft. Nine TOS spacecraft (ESSA-I through ESSA-IX) have been successfully launched.

TIROS-M (redesignated ITOS-1 upon successful injection into orbit), which is the operational prototype of the second generation operational satellite series, the Improved TIROS Operational Satellite (ITOS), was launched from the Western Test Range on January 23, 1970. The mission of the ITOS series of spacecraft is to expand the operational capability of the basic TOS system for use in day-to-day real-time weather analyses. The mission uses three-axis stabilized, earth-oriented satellites in circular, near-polar,

sun-synchronous orbits to obtain meteorological observations of the earth's cloud cover. Complete global coverage is provided on a daily basis.

Daytime coverage is furnished by a system of television cameras comprised of two automatic picture transmission (APT) cameras and two advanced vidicon camera subsystems (AVCS). The APT cameras provide the direct readout capability by which more than 500 world-wide receiving stations are able to obtain local cloud cover information. The AVCS sensors provide the stored data capability whereby the NOAA Command and Data Acquisition (CDA) stations at Goose Creek, Alaska, and Wallops Island, Virginia, acquire global cloud cover data for central analysis at the National Environmental Satellite Service, Suitland, Maryland. Also carried by the ITOS-series spacecraft as part of the primary sensor complement are two infrared scanning radiometer subsystems, which obtain nighttime cloud cover pictures for both direct readout to the APT stations and stored data playback to the CDA stations.

The secondary sensor subsystem is designed to gather earth heat-balance data and to identify proton flux levels at spacecraft altitude. The subsystem consists of a solar proton monitor and a flat plate radiometer.

The first operational member of the ITOS series, ITOS-A (redesignated NOAA-1 upon successful injection into orbit) was launched from the Western Test Range on December 11, 1970. Its primary and secondary sensor packages were identical to those flown on TIROS-M (ITOS-1).

Under the TIROS/TOS Improvements program initiated in FY 1965, effort will be continued in the development of advanced sensors and subsystems such as high resolution radiometers and attitude determination systems which will be incorporated into future operational spacecraft. In FY 1971 the effort initiated in FY 1970 to define a third generation, polar-orbiting operational satellite system is being continued. Continuation of this work is necessary in FY 1972 in order to permit the proper time phasing of system developments forming the technology base for global coverage in the post-ITOS time frame.

The Office of Space Science and Applications is responsible for the overall management of this effort, and project management responsibilities are fulfilled by the Goddard Space Flight Center. The major spacecraft contractor is the Astro Electronics Division of Radio Corporation of America.

Fiscal Year 1970 funds were utilized to complete the TIROS-M spacecraft and sensors, spacecraft integration, test and launch work, initial data acquisition, and for continued development of sensors under TOS Improvements. FY 1971 funds are being used for TIROS-M (ITOS-1) post-launch support and data acquisition and handling efforts, for continued sensor and subsystems development for TOS Improvements, and for in-depth studies for operational satellite systems for the post-ITOS time frame. FY 1972 funds are required to initiate design and development of the advanced sensors for the next generation of operational meteorological satellites.

Radio Interference and Propagation Program

	1970	1971	1972
Studies and experiments.....	$438,000	$1,000,000	$1,000,000
Total.....	$438,000	$1,000,000	$1,000,000

Effort on the Radio Interference and Propagation program (RIPP) commenced in Fiscal Year 1970 under Communications SR&T. Due to the growth in the program and the required interfaces with other agencies, it was desirable to place this program under a separate line item in the Space Applications program. The objectives of RIPP are to: (1) Determine whether communications satellite systems and terrestrial systems can continue to share the same frequency bands as the numbers of both systems increase; (2) Determine the conditions for sharing the same frequency band, such as minimum geographical separation of stations and system parameters; (3) Determine the influence of weather phenomena on satellite and ground communications systems; and (4) Determine the utility of frequencies above 10 GHz for communications satellite services. The work effort will consist of the following: (1) Measurement and modeling of atmospherically-induced interference between satellite earth stations and terrestrial microwave links sharing the same frequencies. This effort will consist of two phases: Phase 1 - to develop sharing criteria for 4 to 10 GHz, and Phase 2 - to develop sharing criteria above 10 GHz; (2) Uplink and downlink propagation experiments and studies to help establish usefulness of frequencies above 10 GHz, ground station configurations, and technical parameters of satellite and ground systems; (3) Uplink and downlink interference experiments and studies to help determine technical parameters of satellite and ground systems and ground station configurations; (4) Determine maximum allowable interference levels and satellite spacing requirements for mixed and homogenous satellite services.

Equipment has been designed and assembled for measurement of ground-to-ground interference below 10 GHz. This installation, which is jointly supported by the Office of Telecommunication Policy (OTP), the Department of Commerce (DoC) and the Department of Defense (DoD), is the only one of its kind in the nation. Initial experimental data were obtained in September 1970. Data are being reduced and reports to be used in support of U. S. positions to the World Administrative Radio Conference (WARC) are in the process of being prepared and coordinated in the U. S. and abroad. Many participants in the RIPP are involved in national and international meetings concerned with establishing international agreements on space communications. Results should also be extremely useful to the FCC and OTP in their deliberations on domestic satellite systems. Experiments and studies on uplink and downlink propagation and interference are a vital part of the program, especially with respect to opening up higher frequencies. Initially, experiments will be performed to complement the ATS-5 millimeter wave measurements. Satellite-to-satellite

interference in geostationary and nonsynchronous orbits will also be studied.

Fiscal Year 1972 funds are required to continue the present ground-to-ground interference experiments below 10 GHz and to initiate efforts to explore frequency bands above 10 GHz for satellite services by conducting satellite-to-ground and ground-to-satellite propagation and interference studies and experiments.

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

Geodetic Satellites

	1970	1971	1972
Spacecraft and support.....	$1,700,000	$1,700,000	$1,300,000
Total.....	$1,700,000	$1,700,000	$1,300,000

The purpose of the Geodetic Satellite project is to support the National Geodetic Satellite Program (joint NASA/DoD/DoC program) and to develop the technology of geodetic satellites for solid-earth geophysics and oceanography.

Three geodetic satellites have been launched: Pageos-1 in June 1966; GEOS-1 on November 6, 1965; and GEOS-2 on January 11, 1968. Data are still being obtained from GEOS-2.

Fiscal Year 1970 funds were used for continued analysis of GEOS data. FY 1971 and FY 1972 funds are required to continue analyses of data.

The Office of Space Science and Applications is responsible for the overall program. The major spacecraft contractor for GEOS is the Applied Physics Laboratory of the Johns Hopkins University.

Earth Observatory Satellites (EOS) Studies

	1970	1971	1972
Phase B study.....	---	---	$1,000,000
Total.....	---	---	$1,000,000

Studies will be conducted on the Earth Observatory Satellites (EOS) which will serve as the initial members of a family of advanced earth observations platforms for the efficient conduct of experimental research and development in earth resources surveying and meteorology. This will combine, in one

multipurpose spacecraft, the functions provided by the ERTS and the Nimbus series of meteorological technology satellites. Primary emphasis for EOS is to be placed on observations of oceanographic phenomena and interactions of the ocean surface with the atmosphere in order to meet urgent needs for research data and the development of advanced operational sensors for oceanographic and meteorological disciplines. Consideration shall also be given to other needs in atmospheric sciences, and in earth resources surveying. In this capacity, the EOS will provide a space platform for the orbital test of experimental sensors and spacecraft subsystems, for the acquisition of environmental data for research and for the development of applications of these data and techniques to problem areas in resources/environmental management and meteorology.

Remote sensing development, data acquisition, and techniques development will address advanced research requirements for data in the disciplines of oceanography, meteorology, and terrain observations, as follows:

(a) Ocean color, temperature, composition, motion, and surface roughness

(b) Interactions between the sea surface and the atmosphere

(c) Ocean currents and coastal processes

(d) Formation, transfer, and dissipation of sea ice

(e) Cloud structure and composition

(f) Atmospheric and oceanographic turbidity and pollution

(g) Interactions between different levels of the earth-atmosphere system

(h) Spectral, spatial, and temporal characteristics of significant earth terrain features.

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

Fiscal Year 1972 funds are required to initiate preliminary system design studies.

Air Traffic Control Satellite Studies

	1970	1971	1972
Support studies and long lead time technology studies.....	---	$3,000,000	---
Total.....	---	$3,000,000	---

Studies will be conducted in response to DOT requirements to establish the basis for assessing the technical approaches and cost efficiencies of commercial proposals for air traffic control and communication satellite services. Studies will also be conducted in coordination with DOT and ESRO to determine the needs for advanced satellite systems and technology and the approach to the most effective operational system for the late 1970's and early 1980's. NASA's effort includes studies of future systems and related technology developments. Some areas of technology to be pursued are medium power, high efficiency, solid state L-band amplifiers for communications/navigation transponders, flexible solar arrays and adaptive multiple beam antennas. These efforts will utilize FY 1971 funds. No FY 1972 funds are being requested by NASA for this project.

The overall management is by the Office of Space Science and Applications with project management by the Goddard Space Flight Center.

Supporting Research and Technology/Advanced Studies

	1970	1971	1972
Applications technology.....	$3,744,000	$3,560,000	$2,810,000
Communications.....	3,544,000	5,790,000	3,790,000
Earth resources.....	10,009,000	11,575,000	13,825,000
Geodesy/earth physics.....	1,687,000	1,209,000	1,075,000
Meteorology.....	2,667,000	2,500,000	2,350,000
Navigation.....	810,000	700,000	700,000
Interdisciplinary applications	2,018,000	2,166,000	550,000
Total.....	$24,479,000	$27,500,000	$25,100,000

Nearly every technique and space system in Space Applications must be preceded by Supporting Research and Technology (SR&T)/Advanced Studies. This effort includes supporting activities in all disciplines (Applications Technology, Communications, Earth Resources, Geodesy/Earth Physics, Meteorology, Navigation/Traffic Control) and a number of interdisciplinary activities.

Applications Technology efforts will include studies of the feasibility and characteristics of stabilized spacecraft; sensor and instrumentation development; and spacecraft technology activities. Research in synchronous orbit thruster motor technology will be continued along with providing a basis for optimum attitude/period control thruster selection. Also, the

establishment of feasibility and characteristics of both automated and manned rendezvous techniques with applications spacecraft will continue.

The sensor and instrumentation development includes sensors across the complete electromagnetic spectrum. Models of both mechanical and electronic multispectral line scanners will be developed.

Work is under way in advanced tape recorders and general data storage media, and central spaceborne cryogenic units. In the data management area special attention is given to multispectral correlation schemes and to the removal of redundancies in multispectral data.

In communications we plan under advanced systems to identify and develop advanced signal processing techniques for future information networking systems by undertaking technique studies and research in such areas as communications systems analysis, demand assignment communications systems, signal processing techniques, communications satellite repeater studies, digital implementation of analog demodulators, and millimeter wave communications. In addition, under advanced systems we plan to determine the applicability of satellites to provide telecommunications needs of the biomedical community. Such needs include interchange of data from many users such as medical schools, diagnostic centers, laboratories, and hospitals. We will also determine and evaluate user communications requirements for planned systems and provide updated projections on a continuing basis. Under communications technology we will: (1) undertake feasibility and technological studies, including cost factors of communications satellites, the implications of parameters on communications services, and the efficient use of the spectrum; (2) conduct requirements studies for tracking data relay satellite systems; (3) conduct research in component technology, such as in parametric amplifiers, VHF phased array receivers, and network communications--signal design; (4) analyze, demonstrate, and evaluate methods of antenna beam shaping, develop technology for efficient satellite communications through multiple beam scannable high gain satellite antennas, and conduct multiple narrow beam shaped pattern antenna research; (5) research and technological development will be conducted in components developed in such areas as cathode tubes, high efficiency klystron tubes, high power tubes, and radio frequency components and high power communications satellite subsystems; and (6) efforts directed toward advanced technological developments.

With the launches of ERTS-A in Calendar Year 1972 and Skylab-I and ERTS-B in Calendar Year 1973, the Earth Resources Survey program for Fiscal Year 1972 will be restructured to be more specifically oriented to application of the type of data expected to be acquired by these satellites; that is, repetitive data of a given scene for studying time-variant phenomena, such as vegetation/soil/water relationships. To accomplish this, intensified effort will be directed at a limited number of sites. Initially, three sites have been selected: Chesapeake Bay, California Feather River Project Region, and the Phoenix Test Site. It is planned to fly over these selected test

sites at 18-day intervals to conduct a data utilization simulation.

In Fiscal Year 1972 we will complete the development of the technology required for handling the large quantities of remotely sensed data expected to be acquired by ERTS-A and Skylab. Type, format, quantities, timeliness, facilities, and equipment required for distribution to the user community will be determined. The Earth Resources Survey Program Review Committee will review and approve the plan for distribution and use of satellite data, and for the application of this data, and related management and budgetary problems.

During Fiscal Year 1972 the number of NASA centers involved in the Earth Resources Survey program will be expanded from two (MSC for aircraft support and GSFC for ERTS matters) to six with the addition of Wallops Station to manage the Chesapeake Bay Project, Ames Research Center to work with local agencies for Earth Resources Survey projects in the California region, the Marshall Space Flight Center to apply their correlation algorithms for computers to earth resources data processing, the Mississippi Test Facility to manage a multidisciplinary study at first for their local area, later expanding to the entire two state region (Louisiana and Mississippi), and at a later time the Lewis Research Center to develop Earth Resources Survey projects in the Great Lakes regions.

An International Workshop on Earth Resources Survey Systems will be sponsored by NASA and other U.S. Government agencies pursuant to President Nixon's invitation at the United Nations in September 1969. The Workshop will be held at Ann Arbor, Michigan, on the central campus of the University of Michigan, May 3-15, 1971, to provide instruction to foreign experts who will eventually apply earth resources data in their own countries.

The announcement of flight opportunity (AFO) for ERTS-A was published in June 1970. Over 300 experiment proposals are expected by April 15, 1971. During Fiscal Year 1972 intensive efforts will be required to manage and fund this activity and to correlate it with our main SR&T program for Earth Resources Survey.

The AFO for Skylab-I was published in December 1970. Similarly a large effort will be required to coordinate this activity with both ERTS-A and the on-going SR&T program.

In Geodesy/Earth Physics emphasis is given to: (1) the early conduct of demonstration experiments leading to an assessment of the capabilities of laser satellite tracking techniques and the very long base-line radio interferometry technique for making accurate measurements of polar motion, earth rotation rate, and earth tides; (2) conceptual studies for a special class of satellites required to support measurements of spatial and time variations of the earth's gravity and magnetic fields, regional mass displacements, polar motion, mean sea level, and deviations of the ocean's surface from

mean sea level; (3) studies to better define requirements for information on solid earth and ocean dynamics needed for development and subsequent verification of utility of models or techniques for earthquake, volcano eruption, and seismic-sea wave predictions or disaster warnings, and for the day by day forecasting of general oceanic circulation; and (4) studies to identify requirements for and uses of accurate marine maps of the ocean floor on a global scale.

In Meteorology, the effort is directed toward establishing the basis for the development, optimization, and application of remote sensing techniques. This includes: (1) analysis and interpretation of satellite data for the improvements and optimization of sensing techniques to provide quantitative measurements of atmospheric structure, composition, dynamics, and related phenomena; (2) development and analysis of radiation transfer models to improve the accuracy and design of remote sensing instrumentation; (3) development of techniques for the improvement, calibration, and test of satellite instrumentation; and (4) aircraft and rocket flight tests of satellite sensors to verify their performance and to develop methods for the interpretation of the measurements.

In Navigation/Traffic Control studies and experimental development will continue on data and voice transmission and position determination techniques via satellite to ships, aircraft, and other mobile platforms. In addition, search, rescue, and collision prevention techniques and the collection and retrieval of data from fixed and moving platforms such as balloons and buoys will continue. Feasibility and concept studies of satellites having application to over-ocean traffic control and navigation as well as continental land areas for air traffic control and collision avoidance will be pursued; development of space and associated technology to position fix and collection of sensor data from automated, fixed, and mobile platforms.

The purpose of the Interdisciplinary Applications is to conduct studies and research relating to several of the applications disciplines, in addition to the development and support of multidisciplinary centers such as the University of Wisconsin and the Goddard Institute of Space Studies. Also included within the program is the conduct of selected advanced missions studies which will define the requirements of future space applications flight missions.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1972 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS

LAUNCH VEHICLE PROCUREMENT PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Launch Vehicle Procurement program has been established to provide launch vehicles and support services for the launch of automated missions. The program includes the procurement of vehicle hardware, launch services, engineering and maintenance support in addition to providing for the improvement of vehicle systems and ancillary ground support equipment. In addition, the program includes supporting research and technology/advanced studies efforts necessary to analyze future mission requirements and to investigate new technological developments. The vehicles currently being procured are: Scout, Delta, Centaur and the Titan III C.

The generalized plan for accomplishing the objectives of the Launch Vehicle program provides for the continued operation of an economic and efficient launch vehicle family which is adaptable to a wide variety of mission requirements. For a typical mission, hardware, i.e., boosters, upper stages, shrouds, adapters, and related equipment, is procured under the vehicle hardware category, all of which is readily identifiable with a specific mission. The funding of vehicle hardware procurement is shown parenthetically in the budget requests of the various spacecraft projects in addition to being identified, in total, in the Launch Vehicle Procurement request. Two other major categories are included in the execution of the launch vehicle program. One is supporting activities wherein the vehicle hardware which has been procured is prepared for launch, including the guidance and control, launch services, and engineering analysis for both pre-launch and post-launch activities. The other category is major product improvement, wherein the launch vehicle and its associated equipment are modernized and modified to maintain reliability and low cost, and to increase performance when the need is demonstrated.

SUMMARY OF RESOURCES REQUIREMENTS:

	1970	1971	1972
Scout	$13,700,000	$14,200,000	$16,500,000
Delta	32,400,000	34,000,000	37,200,000
Centaur	46,019,000	68,000,000	75,900,000
Titan III C	6,700,000	4,700,000	12,500,000
Agena	5,000,000	---	---
Supporting research and technology/advanced studies	4,000,000	4,000,000	4,000,000
Total	$107,819,000	$124,900,000	$146,100,000

Distribution of Program Amount by Installation:

	1970	1971	1972
John F. Kennedy Space Center.....	---	$2,953,000	$3,075,000
Marshall Space Flight Center.....	$527,000	950,000	690,000
Goddard Space Flight Center.....	35,669,000	33,188,000	35,966,000
Jet Propulsion Laboratory.....	490,000	800,000	629,000
Electronics Research Center.....	292,000	---	---
Langley Research Center.....	13,658,000	14,041,000	16,240,000
Lewis Research Center.....	47,453,000	66,274,000	74,887,000
NASA Headquarters.....	9,730,000	6,694,000	14,613,000

The overall plan for launches during this period is:

Vehicle	Calendar Year 1970	Calendar Year 1971	Calendar Year 1972
Scout.....	3	8	4
Delta.....	1	3	5
Centaur.....	1	2	2
Titan III C.....	-	-	-
Agena.....	2	-	-
Total.....	7	13	11

The above table includes NASA Advanced Research and Technology missions but excludes reimbursable launches and vehicles procured for other agencies, private corporations, foreign countries and international organizations, which average approximately six per year.

Scout

	1970	1971	1972
Hardware procurement.....	$3,800,000	$2,900,000	$6,500,000
Supporting activities.....	8,800,000	9,800,000	8,800,000
Product improvement.....	1,100,000	1,500,000	1,200,000
Total.....	$13,700,000	$14,200,000	$16,500,000

Scout is the smallest vehicle in the NASA launch vehicle family. It is a four stage, all solid propellant launch vehicle and is employed for small scientific satellites, space probes, and high speed re-entry experiments. This vehicle has been credited with 58 successes in 71 attempted missions for NASA, DOD, AEC, and foreign countries.

This vehicle is capable of placing a 300 pound payload in a 300 nautical mile orbit. The technical management of this project is directed by the Langley Research Center in Virginia. The prime contractor for the production, checkout, and launch of the vehicle is Ling-Temco-Vought, Dallas, Texas. The vehicle is launched from three launch sites: the Western Test Range in California; Wallops Island, Virginia; and the Italian San Marco platform in the Indian Ocean off the coast of Africa. This later was the site of the successful launch of the NASA Small Astronomy Satellite by an Italian launch crew on December 12, 1970.

In FY 1971, funds are being utilized to initiate new hardware procurements, to support the Scout launch capability at three launch sites, and to complete the Scout first stage motor improvement.

In FY 1972, funds are requested to continue the new hardware procurement initiated in FY 1971 and to continue the support of our engineering and launch capability. A product improvement program will be initiated for modest improvements to the Scout guidance system and for an improved upper stage.

Delta

	1970	1971	1972
Hardware procurement.....	$8,800,000	$9,800,000	$17,900,000
Supporting activities.....	17,500,000	17,000,000	16,400,000
Product improvement.....	6,100,000	7,200,000	2,900,000
Total.....	$32,400,000	$34,000,000	$37,200,000

The Delta launch vehicle has been used by NASA, foreign governments and private industry in 83 launches of scientific and application missions. It has been successful 76 times since the project's inception in 1960. The vehicle consists of three stages -- the first stage Thor booster, the Delta second stage and a solid propellant motor third stage. The current model is capable of lifting 2,000 pounds into a 300 nautical mile orbit from the Cape Kennedy launch site in Florida.

The overall technical management for the Delta vehicle project is assigned to the Goddard Space Flight Center in Maryland. The prime contractor for the Delta vehicle is the McDonnell Douglas Astronautics Company in California. Launch operations of the Delta vehicles are conducted from the Eastern Test Range, Cape Kennedy, Florida and the Western Test Range in California.

Fiscal Year 1971 funds are being used to initiate new hardware contracts for Thor boosters, Delta second stages, solid motor third stages, solid motors for booster thrust augmentation, and the necessary launch services and support to maintain the Delta launch capability. Vehicle product improvements are also being accomplished. These include the adaptation of the Titan III transtage engine to the Delta second stage, development of a

large diameter fairing, and the initiation of conversion of the first and second stage Delta telemetry systems to "S" band frequencies.

Fiscal Year 1972 funds which are requested here will be utilized to continue procurement of hardware and support through contracts currently in force and to initiate new procurements in support of future launches. Moreover, funding support for continuation of the product improvement efforts cited above is planned.

Centaur

	1970	1971	1972
Hardware procurement.....	$17,100,000	$28,800,000	$31,100,000
Supporting activities.....	14,719,000	13,600,000	13,360,000
Product improvement.....	14,200,000	25,600,000	31,440,000
Total.....	$46,019,000	$68,000,000	$75,900,000

The Centaur vehicle is a high performance, general purpose launch vehicle which has been used by NASA to launch Mariner Mars Missions, Orbiting Astronomical Observatories, synchronous transfer orbit missions, including the Applications Technology Satellites, the Intelsat Communication Satellites, and other high energy missions. It is the most powerful vehicle currently used by NASA for automated spacecraft. The Centaur presently uses an Atlas booster as a first stage. A new configuration, the Titan Centaur, is being developed to support the Viking mission and other heavy payload missions which are beyond the capability of the Atlas Centaur. This configuration is planned to be operational in 1974.

The technical management responsibility for this vehicle system has been delegated to the Lewis Research Center. General Dynamics/Convair is the prime contractor for the Atlas booster and the Centaur Stage. Associate contractors are Honeywell, Inc., for the Centaur guidance systems, and Pratt and Whitney Division of United Aircraft, for the Centaur engines. The prime contractor for the Titan III booster is the Martin Marietta Corporation. The five segment solids for the Titan III are manufactured by the United Technology Corporation and the engines for the Titan III core stages I and II are produced by the Aerojet General Corporation.

Hardware procurement and the necessary launch readiness support of three NASA launches during CY 1971 are being funded in FY 1971 along with the procurement of hardware to support missions to be launched in 1972. A Product Improvement program is also being conducted which consists of improved guidance and electronics systems in the Centaur stage, rearrangement of the equipment module, development of a new shroud, and new radiation shielding. A portion of this improvement program will be completed in early CY 1972 and will be incorporated in the Atlas Centaur

vehicles planned for launch in mid-CY 1972.

FY 1972 funds are required to continue the hardware production and sustaining support to meet the mission launch readiness schedules.

Incremental funding in FY 1972 will allow continuation of the major improvement effort initiated in prior years, the Proof Test Vehicle, and the production contracts for the procurement of vehicles to support the Mariner/Venus/Mercury 73, Helios A & B, Viking A & B, and for the initiation of the procurement of the Titan III D Vehicles for the High Energy Astronomy Observatory.

Titan III C

	1970	1971	1972
Hardware procurement.....	$6,700,000	$4,700,000	$12,500,000
Total.....	$6,700,000	$4,700,000	$12,500,000

The Titan III C is a USAF developed four stage solid and liquid fueled launch vehicle. The performance of this vehicle is greater than that of the Atlas Centaur at synchronous altitude making it a more suitable vehicle to use in support of the synchronous altitude Applications Technology Satellites F and G missions.

An agreement with the United States Air Force (USAF) has been reached whereby NASA Headquarters has primary management responsibility for the NASA Titan III C activity. As agreed, the USAF will act as the launch vehicle subsystem manager for the Titan III C under overall NASA mission direction. The vehicles will be procured through the USAF, with Martin Marietta Corporation, Denver Division, Denver, Colorado, as the prime contractor. The United Technology Corporation, Sunnyvale, California and Aerojet General Corporation, Sacramento, California are associate contractors providing solid boosters, and core stage engines. Martin Marietta will provide the mission integration services and along with its associates, will provide the necessary launch operation services.

Fiscal Year 1972 funds are requested for the continuation of hardware procurements and supporting services required for launch of the ATS F & G missions in 1973 and 1975.

Agena

	1970	1971	1972
Hardware procurement.....	$1,751,000	---	---
Supporting activities.....	3,249,000	---	---
Total.....	$5,000,000	---	---

The Thrust Augmented Thor Agena is a two stage vehicle using the same Thor stage as Delta and a second stage Agena vehicle. This vehicle system has been used by NASA for polar orbital missions launched from the Western Test Range in California. During 1970 this vehicle was used successfully to launch the Space Electric Rocket Test (SERT) and the Nimbus IV meteorological satellite. Presently, no NASA missions are planned for launch on this vehicle system; however, since this vehicle is being used by the DOD, it will be available for NASA, if future missions require its usage.

Supporting Research and Technology/Advanced Studies

	1970	1971	1972
Advanced studies.....	$1,280,000	$1,290,000	$2,080,000
Propulsion and energy conversion.	700,000	1,175,000	795,000
Guidance, control and navigation.	1,345,000	1,030,000	790,000
Instrumentation and electronics..	60,000	60,000	60,000
Structure and materials.....	615,000	345,000	250,000
Vehicle engineering.....	---	100,000	25,000
Total.....	$4,000,000	$4,000,000	$4,000,000

The objective of the Supporting Research and Technology/Advanced Studies project is to provide data for decisions concerning new launch vehicle development programs and vehicle improvement efforts required to support automated missions. Efforts include research, technical feasibility studies, systems analysis, preliminary development efforts, and other activities as described in the following paragraphs.

In FY 1971, two advanced studies initiated in prior years were continued. One involved definition of low cost vehicles potentially capable of replacing the existing NASA vehicles used for automated spacecraft during the pre-space shuttle time period. The second study involves definition of a versatile upper stage. The potential applications for the versatile upper stage include a high energy kick stage for Titan Centaur, a replacement for the existing upper stage, an expendable upper stage, for use with the space shuttle, and a planetary orbit insertion propulsion system. In addition, study effort is being initiated to identify the most economical method of meeting small spacecraft mission requirements during the next decade and to investigate the concept of a solar electric propulsion stage for comparison with an integrated solar electric spacecraft design.

Supporting Research and Technology effort during FY 1971 included work initiated to demonstrate the feasibility of utilizing a dual mode propulsion system for planetary exploration. Development of an improved gyroscope for a strapdown inertial guidance system, along with development of a modular guidance computer which would utilize the latest in solid state technology, was continued.

In FY 1972, efforts will be focused on maintaining an effective launch vehicle transportation system for a variety of space applications and scientific missions. Work will be directed at upper stage propulsion and astrionics problems and their interaction with spacecraft systems. Studies of thermionic and nuclear electric propulsion systems will be continued. Studies to identify upper stages for use with the space shuttle prior to the operational availability of the space tug will be conducted. Studies to identify improved main propulsion systems for planetary spacecraft will be initiated. Also, studies will be undertaken to determine the advantages of hybrid rocket motors for launch vehicles and to identify the optimum launch operations procedures involving upper stages utilizing fluorine propellants.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1972 ESTIMATES

OFFICE OF UNIVERSITY AFFAIRS — SUSTAINING UNIVERSITY PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Sustaining University program was established in 1962 when NASA's expanding responsibilities required increased participation of the educational community in the space program. The objectives were to provide adequate laboratory facilities, to increase the number of highly trained people, and to conduct broad multidisciplinary research. Many of these goals have been met, NASA programs have benefited and the universities have been strengthened through their participation.

NASA will continue to support research at universities as needed for NASA's mission with funding requirements to be met from program office R&D resources. The Sustaining University program has been phased to an orderly conclusion.

SUMMARY OF RESOURCES REQUIREMENTS:

	1970	1971	1972
Sustaining university program.....	$7,000,000	---	---
Total.....	$7,000,000	---	---

Distribution of Program Amounts by Installation:

NASA Headquarters.....	$7,000,000	---	---

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1972 ESTIMATES

RESEARCH AND DEVELOPMENT BUDGET PLAN FOR

ADVANCED RESEARCH AND TECHNOLOGY PROGRAMS

Program	1970	1971	1972
Aeronautical research and technology.....	$95,685,000	$102,000,000	$110,000,000
Space research and technology.	119,977,000	107,000,000	75,105,000
Nuclear power and propulsion..	55,269,000	55,200,000	27,720,000
Total.....	$270,931,000	$264,200,000	$212,825,000

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY

CONVERSION OF CURRENT BUDGET LINE ITEMS TO FY 1972 BUDGET STRUCTURE

RESEARCH AND DEVELOPMENT
(Thousands of Dollars)

FY 1972 Budget Line Items	FY 1971 Budget Line Items								
	Total	Basic Research	Space Vehicle Systems	Electronics Systems	Human Factor Systems	Space Power and Electric Propulsion Systems	Nuclear Rockets	Chemical Propulsion	Aeronautical Vehicles
FY 1970									
Aeronautical Research and Technology	95,685	6,200	---	10,768	3,000	200	---	---	75,517
Space Research and Technology	119,977	10,907	30,515	22,563	18,790	16,975	---	20,227	---
Nuclear Power and Propulsion	55,269	2,000	---	---	---	16,952	36,317	---	---
Total	270,931	19,107	30,515	33,331	21,790	34,127	36,317	20,227	75,517
FY 1971									
Aeronautical Research and Technology	102,000	6,600	---	5,800	2,100	400	---	---	87,100
Space Research and Technology	107,000	7,700	30,000	16,600	15,800	16,600	---	20,300	---
Nuclear Power and Propulsion	55,200	3,300	---	---	---	13,900	38,000	---	---
Total	264,200	17,600	30,000	22,400	17,900	30,900	38,000	20,300	87,100
FY 1972									
Aeronautical Research and Technology	110,000	6,200	---	7,100	3,100	400	---	---	93,200
Space Research and Technology	75,105	8,200	22,150	16,255	---	11,500	---	17,000	---
Nuclear Power and Propulsion	27,720	3,400	---	---	---	9,320	15,000	---	---
Total	212,825	17,800	22,150	23,355	3,100	21,220	15,000	17,000	93,200

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1972 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY

AERONAUTICAL RESEARCH AND TECHNOLOGY PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The NASA Aeronautics program for FY 1972 is aimed at providing significant advances in the technology base to insure that this country remains the world leader in the development of military and civil aircraft. A research and technology program, coordinated with the FAA/DOT and DOD, is being continued which will increase aeronautical systems reliability and safety, will reduce obtrusiveness to the environment, and is relevant in the overall sense to this decade's military aircraft and civil transportation demands. Research will concentrate on aerodynamics, flight dynamics, propulsion, operating systems, vehicle systems, life sciences, electronics, materials and structures, and noise reduction for application to future generations of all subsonic, supersonic and hypersonic aeronautical vehicles. Emphasis in FY 1972 will be on propulsion research including engine noise reduction, aerodynamics and vehicle systems. A major new initiative in FY 1972 is the design and development of an experimental short take-off and landing (STOL) turbofan transport research airplane.

SUMMARY OF RESOURCES REQUIREMENTS:

	1970	1971	1972
Experimental STOL transport research airplane.....	---	$1,900,000	$15,000,000
Aerodynamics and vehicle systems.....	$37,439,000	45,000,000	42,000,000
Life sciences.....	3,000,000	2,100,000	3,100,000
Propulsion.....	29,419,000	23,900,000	22,300,000
Operating systems.....	6,996,000	8,000,000	6,500,000
Materials and structures.....	7,646,000	7,400,000	11,000,000
Guidance, control and information systems.....	10,190,000	4,200,000	3,000,000
Power.....	200,000	400,000	400,000
Supercritical technology.....	795,000	9,100,000	6,700,000
Total.....	$95,685,000	$102,000,000	$110,000,000

Distribution of Program Amounts by Installation:

	1970	1971	1972
Marshall Space Flight Center..	$1,223,000	$1,369,000	$1,725,000
Jet Propulsion Laboratory.....	741,000	715,000	750,000
Electronics Research Center...	3,095,000	---	---
Ames Research Center.....	18,708,000	21,586,000	26,355,000
Flight Research Center.....	7,291,000	8,665,000	17,750,000
Langley Research Center.....	27,355,000	32,863,000	29,200,000
Lewis Research Center.....	27,996,000	30,300,000	30,725,000
NASA Headquarters.....	9,276,000	6,502,000	3,495,000

BASIS OF FUND REQUIREMENTS:

Experimental STOL Transport Research Airplane

Wind tunnel tests and simulation.....	---	$600,000	$400,000
Propulsion noise reduction.....	---	1,300,000	5,000,000
Aircraft design and development.....	---	---	9,600,000
Total.....	---	$1,900,000	$15,000,000

Short-haul air transport represents a vital segment of the national transportation system which has not been developed to its potential. STOL capability is essential to this class of transport and turbofan STOL aircraft have been shown in analytical studies to offer attractive economic returns as well as improved transportation services.

The need for a STOL transportation system has been clearly established in studies of the transportation demands of the country. The demand for aircraft of this type has been estimated to have a production value of $8.8 billion through 1985. The economic arguments for the STOL transport are persuasive, but without an initial government development effort, the base of technology upon which industry can proceed with development and production of STOL transport systems does not exist. Design, development, fabrication, and flight testing of the experimental STOL turbofan transport research aircraft is, therefore, an essential step between laboratory testing and the building of prototype transport systems. Development of STOL technology will also contribute significantly to the technical base required in support of anticipated military requirements.

In response to this requirement, a major new initiative is proposed in FY 1972; detailed design and fabrication of an experimental turbofan STOL transport research aircraft. The essential objectives of this experimental research aircraft project are to validate the predicted performance and to permit establishment of realistic criteria for certification of commercial subsonic STOL transport aircraft and for enroute and terminal area operations. Two research aircraft will be built for flight testing in the 1974 through 1976 period. The engines for these aircraft will initially incorporate acoustic treatment for noise reduction, and will subsequently incorporate features developed by NASA's quiet engine program to demonstrate STOL performance at acceptable noise levels. The flight testing will demonstrate and verify navigation and flight path control procedures as well as the operational characteristics of the vehicle.

Specific configuration of the experimental STOL transport research aircraft will be determined on the basis of studies, simulation, and wind tunnel tests being conducted in FY 1971 and continuing into FY 1972. Research over the past years has identified several promising approaches to powered lift systems applicable to transport aircraft. Of these several systems, the externally-blown flap is considered the most promising candidate for early application. This concept, which has been tested extensively in the wind tunnel, involves the simplest departure from conventional design and can use engines currently available. Alternative approaches, however, will also be considered in the studies leading to design of the experimental STOL transport research aircraft.

NASA is working with DOT and is exploring with industry representatives a joint approach to a short-haul transportation system, including the experimental STOL transport research airplane development and flight test program.

The FY 1972 funding request provides for initiation of design, development, and fabrication on the two experimental STOL transport research airplanes, and for continuation of supporting model testing in wind tunnels, propulsion studies, and tests aimed at noise reduction.

Aerodynamics and Vehicle Systems

	1970	1971	1972
Aerodynamics and vehicle systems			
Research and technology....	$32,162,000	$37,100,000	$32,700,000
Experimental hardware.....	5,277,000	7,900,000	9,300,000
Total.....	$37,439,000	$45,000,000	$42,000,000

The objective of this activity is to generate and develop new concepts in aerodynamics and flight dynamics for improvements in safety, efficiency and utility of all classes of aircraft. In the study of vehicle systems

disciplinary technologies are applied to all classes of civil and military aircraft. Emphasis is placed, as required, on flight test programs and experimental hardware evaluations. This combined disciplinary and experimental hardware approach provides the data and information which can be applied by the aircraft industry and Government agencies to the development of safer and superior aircraft, advanced aircraft concepts, regulatory criteria, new operational concepts, and the integration of the pilot/aircraft system.

The research effort for FY 1972 will include the continuation of studies to improve the safety of general aviation aircraft, studies of advanced rotors for helicopters and rotor-driven V/STOL's; studies of air-breathing propulsion system/airframe integration; dynamic problems with application to supersonic and hypersonic aircraft, and flight dynamics studies for each class of vehicle.

This work is to be carried out by means of analytical studies, wind tunnel tests, simulation, and flight investigations. Such studies are also used to aid in the solution of problems of a developmental nature in support of military procurements and the SST, and in response to request for specific assistance from other Government agencies. The studies of developmental problems are an essential element in NASA's research since, like the experimental hardware programs, they identify areas where further generalized research is required. Experimental research and development aircraft and engineering test pilot proficiency aircraft necessary to carry out and support the total aeronautics effort are included.

Aerodynamics and Vehicle Systems Research and Technology

Aerodynamics and Fluid Mechanics

To accurately simulate aerodynamic characteristics of large flight vehicle in small and moderate size ground facilities, work is underway to improve the prediction of boundary layer transition, separation, skin friction, and heat transfer and to determine the way in which various ground test environments influence these characteristics. Work is also in progress to improve methods of computing subsonic, transonic, and supersonic flow fields about complex aerodynamic bodies to find more efficient ways to increase lift, reduce drag, or alleviate adverse interference and heating effects. Advanced computational techniques are being sought, especially for three-dimensional transonic flows, together with methods for increasing the effectiveness of digital and analog computers.

Noise and Sonic Boom

The noise problem requires greater emphasis on basic research aimed at understanding the origin and means of minimization of noise in general and, in particular, at understanding the fundamental principles involved for developing very much quieter aircraft engines. Consequently, research is directed toward understanding in greater depth the mechanisms of noise generation and propagation from engine exhaust jets, rotating machinery (compressors, turbines and lifting rotors), and from inlet ducts in which complicated unsteady, three dimensional flow field interactions in cascade sections occur. Reduction in the level of sonic booms is also urgently needed in order that the full benefit of supersonic flight may be realized by operation over land routes. Research is proceeding on ways to better predict the generation and propagation of sonic booms, as well as on configuration changes for minimizing booms. Analyses are being developed, for example, for the prediction of the effects of maneuvering and the effects of atmospheric conditions on sonic boom formation and transmission. In particular, the complex high intensity pressure field caused by atmospheric diffraction or by maneuvering--which can cause noise levels several times greater than normal sonic booms--will be studied theoretically, in wind tunnels and in flight. Analytic and experimental investigations of aircraft configurations that show promise of lowering sonic boom overpressures below current levels are also being pursued. Programs to obtain threshold Mach number information in stable air masses and under conditions of turbulence are underway for application to transonic transport designs.

Aircraft Flight Dynamics

To fully exploit the operational service performance capability of advanced supersonic, hypersonic, and V/STOL aircraft, and to minimize development costs and times, the anticipated response behavior and pilotability of such aircraft must be accurately predicted in the design stage. The research program in aircraft handling qualities now underway is aimed at providing such information through flight and simulation studies, as well as by applying advanced control theory to achieve increased knowledge and understanding of the pilot-vehicle combination in steady flight, in maneuvers and under conditions of spin and atmospheric turbulence. Attention will be given to the practical improvements possible in basic airframe responses by the use of novel methods of aircraft control. Advanced simulators for such research will be developed by incorporation of the latest in display devices technology and improved simulation techniques which account for aircraft response to air disturbances. Expansion and application of flight dynamics theories to problems of aircraft flight path and dynamic response behavior will continue to be performed utilizing advanced mathematical optimization techniques.

Aerodynamic Loads

Improvements in performance, in safety, and in economy of operation of aircraft require a continued investigation of the aerodynamic loads introduced into an aircraft structure and of the effects of these aerodynamic forces on the structure. For example, response of aircraft to atmospheric turbulence, buffet and other aerodynamic flight loads become progressively more important for large aircraft as a consequence of their greater structural flexibility. An important research objective is the improvement of analytical methods for predicting the elastic response of such aircraft and the development of means for minimizing or alleviating this response. Comparison of flight test data with measurements obtained on aeroelastically scaled models in a transonic dynamics wind tunnel is being carried out to validate a wind tunnel technique for gust response research. This tunnel technique will be used in subsequent studies of other aircraft models to obtain gust response predictions and to evaluate various methods of counteracting flexibility effects by appropriate motions of the control surfaces.

A comprehensive program on buffeting ranging from basic measurements of buffeting pressures on wind tunnel models to measurements of buffet loads on an airplane in flight is underway and will be continued during FY 1972. Buffet measurements on conventional rigid wind tunnel models will be used to obtain a qualitative evaluation of the influence of airplane configuration. Aeroelastic models which simulate the dynamic response of full scale airplanes will also be used for buffet loads measurements and for overall vehicle motions resulting from operation in flight regimes where buffet occurs. Studies to date have indicated that wing-lift devices such as slats and flaps can substantially alleviate wing buffeting during maneuvers. The emphasis in future wind tunnel and flight tests will be to evaluate more fully the buffet improvements possible with such devices.

In order to assure adequate margins of safety from wing and tail flutter, particularly in the transonic speed range where aerodynamic theory is inadequate, a continuing research effort will be maintained consisting of wind tunnel studies of aeroelastically scaled (flutter) models. A specific line of endeavor will involve a study to establish the transonic flutter behavior of advanced wing configurations with supercritical airfoil sections. Potential flutter problems at hypersonic speeds will also receive attention. Past research has led to a reasonably good understanding of the separate influences of many of the factors which are involved in the flutter of skin panels in transonic and supersonic flow. In future studies the emphasis will be on the effect of boundary layer thickness and Mach number on flutter boundaries.

General Aviation Aircraft

To achieve the basic objectives of increased safety, utility and economy for general aviation aircraft, four areas of research are being emphasized.

Efforts will continue in aerodynamics, simplified control and display systems, avionics system integration and evaluation and improved cockpit environment.

Studies in configuration aerodynamics will continue to determine the effect of engine nacelle shape and location in addition to the full scale wind tunnel evaluation of representative airplane configurations. Efforts toward summarizing existing data applicable to general aviation will continue during FY 1972 with the emphasis shifting toward summation of control and stabilization data and the development of prediction techniques for stall and spin characteristics.

In-flight studies using variable stability aircraft as well as ground based simulation efforts are underway and will continue being directed toward defining optimum airplane and control system characteristics. Results of these efforts will be used to initiate the development of experimental reliable low cost devices to achieve these characteristics. Particular emphasis is being placed on the use of direct lift and drag control as a means of simplifying the landing approach and flare piloting task.

Continuing efforts are being directed toward the acquisition of experimental hardware and the adaptation of avionics devices and systems specifically tailored to the requirements of general aviation. During FY 1972 particular emphasis will be placed on the application of mass produced integrated circuit components to the design and fabrication of communications and navigation devices. Fluidic techniques will be used to mechanize a simple, reliable full time wings leveler similar in function to the current electro-mechanical devices, but with the potential for very low cost and considerably increased reliability.

Efforts initiated during FY 1971 in the area of improving the comfort and safety of the cockpit environment have emphasized the reduction of noise levels in the cockpit and the increase in fire protection possible through the use of new developments in fire retardant foam materials. Continuation of this effort during FY 1972 will include laboratory and analytical studies of the structural characteristics of foam reinforced skin leading to the flight validation of the sound attenuation and operational wear resistant characteristics of this type material.

V/STOL Aircraft

The primary emphasis in FY 1972 will be associated with the continued development of the technologies related to jet STOL aircraft, lift-fan V/STOL aircraft and rotorcraft to provide the information required for the selection and development of future V/STOL aircraft and systems. Apart from the flight test of the jet augmentor wing concept on the C-8A airplane, continued emphasis

will be given in studies of this concept to developing improved and analytical high-lift prediction methods, and to obtaining parametric two dimensional data on airfoil sections with different arrangements of flap geometry. The objective is to develop a better understanding of the basic factors in the lift augmentation process and to provide necessary data for a systematic series of airfoil-flap geometries and jet flow conditions to permit the design of jet augmentor-wing aircraft for maximum lift augmentation. Large scale wind tunnel tests will be conducted of a swept-wing jet augmentor model representative of a jet STOL aircraft having greater speed potential than the straight wing C-8A. Preliminary feasibility studies will be made of means to flight test a jet augmentor swept wing on an experimental aircraft representative of an advanced jet STOL transport.

The steady advancements in lift-fan engines have opened new horizons for lift-fan transport configurations to operate in either the VTOL or STOL mode. Research aimed at further improving this technology is described in the Aeronautical Propulsion program. Wind tunnel tests will continue to investigate the integrated performance of representative lift-fan concepts in typical installations such as wings, pods, and along the fuselage. Recent wind tunnel tests of small scale lift-fan aircraft models for systematic stability and control studies, and large-scale models for performance investigation have shown marked improvement compared to earlier configurations concepts. Wind tunnel tests of additional lift-fan aircraft configurations will be conducted in FY 1972. One of the large scale wind tunnel models to be constructed will be representative of a possible lift-fan transport type research airplane. Feasibility studies will continue concerning a research vehicle for flight tests of a lift-fan research aircraft to validate the laboratory investigations and provide flight experience for the design of an operational V/STOL lift-fan transport. In the meantime, flight tests initiated in FY 1968 with the XV-5B aircraft to determine the flight performance, stability, control and handling qualities of a fan-in-wing vehicle, will be completed. Investigations will be conducted on rotor airfoils for improved performance and on rotor geometry variations (blade tip shape, stagger, and span) to reduce blade tip vortex strength, which can significantly affect vehicle vibration and aeroelastic characteristics. For high speed rotorcraft applications, emphasis will be on large scale model tests of wing mounted rotors that tilt in transition from vertical to horizontal flight. Studies are also planned for a rotor test bed experimental vehicle for flight test of advanced rotor and helicopter concepts.

The continued improvement in the high-lift capability of V/STOL aircraft and rotorcraft concepts with attendant increased downwash requires a persistent effort which will be continued in FY 1972 to improve wind tunnel test techniques and to assess the validity of the results. The effects of construction details such as joints, protuberances, structural deflections and

so forth become increasingly important in extremely high-lift concepts such as the jet augmentor wing. The net result is to force greater emphasis on large-scale tests of carefully designed wind tunnel models, and toward proof-of-concept flight tests.

Subsonic/Transonic Aircraft

In addition to the fundamental technology directed toward exploiting super-critical wing technology, there is a body of ongoing research important to the broad spectrum of both military and civil aircraft in the subsonic/transonic speed regime. This includes wind tunnel tests and analysis in support of problems that arise on existing aircraft, as well as generalized and parametric investigations to permit improved design of future aeronautical vehicles in such areas as alleviation of adverse propulsion system-airframe interference effects; obtaining systematic data on advanced airfoils in the transonic regime; obtaining low speed data on such airfoils with high-lift devices; developing improved methods for translating airfoil data to reliable swept wing design in both the transonic and takeoff/landing flight regimes; and conducting both analytical and experimental investigations to provide a basis for optimizing wing planform and twist for the transonic regime. Whereas the state of the art in general has developed satisfactorily through the years to design aircraft to fly safely through the transonic regime, theoretical or analytical methods and parametric experimental data are currently inadequate to optimize design for sustained efficient flight at transonic and low supersonic speeds. Particular emphasis in FY 1972 will be toward developing the necessary wind tunnel data and analytical tools to assess the promise of a low supersonic speed transport concept which would take advantage of a sonic boom cut off.

Supersonic Aircraft

The supersonic aircraft program provides the advanced aerodynamics and flight dynamics technology for the development of configuration designs that lead to the realization of safe and efficient supersonic flight for commercial and military applications and improved maneuvering performance for military aircraft.

In general, the performance and the stability and control studies of supersonic configurations developed by use of automated analytical techniques and wind tunnel experiments will be continued. Emphasis will be placed on improving the transonic maneuvering characteristics of some of these aircraft flying at high altitudes and by evaluating promising design modifications in flight. An evaluation of current procedures for estimating aerodynamic characteristics of large flexible supersonic aircraft will continue in which flight, wind tunnel, and calculated results are compared. Trade-off studies

will be continued to determine the penalties to be paid in terms of loss of aerodynamic stability for gains in performance. Studies will be conducted to determine control requirements for specific missions and to what degree stability can be relaxed.

Advanced concepts in aerodynamic wing design and aircraft component integration will be incorporated in configurations considered for commercial and military missions. The capability will be developed of predicting the flow field, including the influence of lifting fuselage forebodies, at the locations of side mounted supersonic inlets. Problems of inlet-aircraft integration leading to the design of vehicles with high performance and with minimum sensitivity to aircraft attitude changes will be evaluated. In addition, large scale tests for supersonic fighter configurations and commercial transports will be conducted at low speeds to develop high lift systems for landing and take-off flight.

The flight simulator for advanced aircraft will be used in piloted simulations directed at some of the certification problem areas and in the study of some of the supersonic handling qualities problem areas. This simulator will also be used in research more specifically directed at the problem areas of supersonic transport aircraft.

Analytical means will be employed to point out areas of the supersonic fighter aircraft flight envelope where handling qualities problems might be expected, and several ground based simulators will be used to investigate these areas in greater detail. Effects of variations in key stability and control derivatives and stability augmentation system characteristics on pilot opinion ratings of dynamic behavior and ease of control will be determined for high speed flight and in combat maneuvering and tracking tasks.

Hypersonic Aircraft

The long range goal of this program is to provide the technical basis for efficient hypersonic aircraft suitable for a number of potential commercial, military and space missions. The immediate objective is to define and evaluate various airbreathing vehicle configurational concepts which exploit the close-coupled interactions between the various disciplines-aerodynamics, structures, and propulsion.

Analytical procedures will be developed for the design and performance prediction of simplified aircraft configurations. The more sophisticated configurations derived at least in part from these procedures will be evaluated experimentally and selected promising shapes will be tested throughout the speed range. Improvement of the capability to extrapolate from wind tunnel results to flight conditions will continue to be sought. The integration of the propulsion system with an airframe to exploit the

favorable interactions between the vehicle lifting surface and the engine flow field will be of paramount importance throughout these investigations. Jet exhaust interference effects on representative configurations will be evaluated throughout the Mach number range. As prediction techniques are verified, they will be incorporated into a master computer design program -- an extremely useful design tool for evaluating aircraft configurations intended for hypersonic flight.

Two basically different methods for actively cooling the airframe -- internal cooling and slot cooling -- have opened the way for a new class of hypersonic configurations. Configuration research will be conducted for which these cooling concepts may be applied and for which aerodynamic design constraints, such as those associated with delta wings and blunt wing leading edge will be removed.

Experimental Hardware

Jet Augmentor Wing

The jet augmentor wing principle utilizes turbofan air ducted through a spanwise nozzle into a channel formed by a rather complex arrangement of deflected flap segments, and in so doing entrains flow from the wing upper and lower surfaces which greatly augments the lift beyond that resulting from the downward momentum of the ducted flow. Based upon extensive wind tunnel tests, analytical studies, ground based simulation investigations and flight tests of the propeller driven C-8A aircraft, a joint program has been instituted with the Canadian government to modify a C-8A airplane for flight tests of the jet augmentor wing. The Canadian Department of Industry, Trade and Commerce is providing the fan-jet propulsion system and nacelles for the research airplane. The airplane modification initiated in FY 1971 is scheduled for completion late in FY 1972. Related ground based simulation tests initiated in FY 1971 will also be completed in FY 1972 leading to the initial flight tests near the end of FY 1972.

It is anticipated that the modified experimental STOL airplane will have landing and take-off speeds under 65 knots, resulting in the capability of operating from 1,500-foot fields, and will be able to utilize relatively steep-approach and climb-out flight paths to reduce noise levels and exposure times. The flight tests will investigate performance, stability, control, and handling qualities of the jet augmentor wing enabling verification of characteristics indicated in previous wind tunnel tests. The aircraft also will be used for studying certification criteria as well as operational and air traffic problems of other classes of jet STOL aircraft.

Rotating-Cylinder Flap

A twin-turboprop OV-10A aircraft has been modified to incorporate a rotating-cylinder flap. In take-off and landing flight the rear half of the wing pivots downward exposing a cylinder on the upper surface whose high rotational speed tends to prevent separation of the propeller slipstream over the large deflected area and thereby induces much higher lift than possible with ordinary flaps. Based upon early wind tunnel model tests, it is anticipated that the flap modification will reduce the take-off and landing speeds by a third compared to the basic aircraft and the associated take-off and landing distances by a half. Subsequent to tests of the modified aircraft in the 40- by 80-foot wind tunnel in late FY 1971, the airplane will undergo research flight test in FY 1972 to evaluate performance, stability, control and flying qualities.

YF-12

The NASA YF-12 research program consisting of both flight and ground-based tests will continue to obtain information directed principally toward thermal structural loads and deflections, propulsion system airframe interactions, and stability and control. Part of the propulsion effort will be concerned with the internal flow dynamics of the air induction system and the effects of variations in propulsion system operation on the aerodynamic characteristics of the airplane as an entity. Small and full scale models of the inlet system will be tested in the wind tunnel, evaluated and compared with flight results. A model of the YF-12 airplane will be tested in the wind tunnel to determine the changes in the aerodynamic characteristics resulting from propulsion system variations. In the structural research portion of the YF-12 program, aeroelastic studies will consist of analytical calculations and experimental investigations in ground facilities for comparison of results from flight tests to be continued during FY 1972 at the Flight Research Center.

Life Sciences

	1970	1971	1972
Life sciences research and technology.....	$3,000,000	$2,100,000	$3,100,000
Total.....	$3,000,000	$2,100,000	$3,100,000

The aeronautical life sciences effort is directed to determining the limitations and adaptations of man relative to aeronautical systems; develops methods and equipment to enhance human performance and safety in aviation systems; and advances the state of the art of aeronautical simulation technology for its application to air and ground personnel training and proficiency maintenance, and for conducting aeromedical research relative to aeronautical problems.

In FY 1972 research will be initiated in visual requirements for STOL aircraft. An increased emphasis will be placed on STOL noise effects on aircrew and the community. In the area of simulation technology, studies will be initiated to determine the vision and motion requirements for realistic simulation.

Life Sciences Research and Technology

Environmental Effects

Advances in technology have been a major factor in increasing environmental problems. Increasing aircraft operations are contributing to these environmental problems. For aviation, the primary environmental pollutant is noise and this problem is already inhibiting growth in aviation development. The Aeronautical Life Sciences project is developing techniques for predicting the effects of noise on man. The environment which advanced aeronautical systems imposes on man affects him physiologically and psychologically. Some of the elements of this environment are vibration, physical stress, and rapid traversal of time zones. This program will conduct research to obtain quantitative information on human annoyance and physiological damage due to aircraft noise and vibration, and to measure the physiological and psychological effects of other stresses such as fatigue, desynchronosis, disorientation and vision aberrations.

Man Systems Technology

The limitations of aircraft flight instrumentation and displays and of air traffic control equipment and procedures frequently require curtailment of air operations. This program will conduct research and technology to define man's capabilities as an operator of vehicles and as an operator of air traffic control systems, to develop criteria for flight displays and control design, to develop workload standards which will provide design criteria for improving aircraft seat restraint systems, protective equipment, and environmental controls.

Simulation Technology and Applications

The simulation technology and applications effort will develop criteria and standards to improve the utility of aeronautical simulators by defining the visual, motion, aural, and tactile limits of man to provide the information needed to improve data acquisition and monitoring systems, and by analyzing the requirements for and degree of achievement of simulation fidelity.

Propulsion

	1970	1971	1972
Propulsion research and technology.....	$14,552,000	$14,111,000	$11,050,000
Experimental hardware.....	14,867,000	9,789,000	11,250,000
Total.....	$29,419,000	$23,900,000	$22,300,000

The primary goals of this program are to provide advanced technology through analytical and experimental investigations of engine components and engine systems. This program is aimed at improving engine performance, operational capability, safety and reliability, and reduced weight and size. During FY 1972, a great deal of attention will be given to the environmental problems of aircraft noise and pollution. Aircraft noise research will include studies and experiments both small scale and full scale. Particular attention will be given to the problem of aircraft noise for Short Take-Off and Landing (STOL) vehicles. In addition to the noise research associated with the development of the NASA experimental quiet engine program, an extensive research effort will be undertaken to develop jet noise suppressors for supersonic aircraft propulsion systems.

Propulsion Research and Technology

Research will be continued on engine components and unique propulsion system concepts either not readily identified with a specific flight spectrum or identified over a broad range of flight vehicle applications. Analytical and experimental studies will be continued on: advanced bearing and lubrication system concepts, engine shaft seals, and high speed shafting and gearing. Research on pollution is aimed at reducing the amount of smoke and oxides of nitrogen from the exhaust gases emitted from turbojet engines.

Some design compromises in terms of lower engine pressure ratios and lower turbine inlet temperatures permit consideration of less sophisticated and lower cost engine components and lower cost fabrication techniques for use on missiles, target drones, and light general aviation aircraft. Research will be continued on the low cost engine component and engine system area. Research will also be continued on improving the performance of engine components for small gas turbine engines for aircraft applications requiring high performance. This research includes experimental investigations of small axial flow and centrifugal flow compressors, radial inflow turbines, and high temperature combustors and turbines.

In the V/STOL aircraft technology area, research efforts will be focused on studying various high thrust to weight ratio propulsion systems that have the potential of meeting the stringent noise requirements for this class of vehicle. Research will be conducted on: low noise fans and prop-fans, application of advanced composite materials in fan designs, very high bypass ratio engine concepts incorporating low noise engine design principles (blade/van spacing, blade/vane ratio, sonic inlets, variable geometry nozzles, and application of acoustic treatment inside the engine), high workload turbines, and engine components unique to integral and remote driven lift-fan engine concepts.

Advanced supersonic aircraft must operate efficiently at both subsonic and supersonic speeds. These advanced aircraft will require high thrust to weight ratio engines capable of providing good performance at all design conditions which includes those flight conditions (flight maneuvers, gusts, turbulence, etc.) resulting in highly distorted flow entering the inlet and stalling the engine. The research on some of the more distortion sensitive engine components such as inlets, inlet controls, fans and compressors is aimed at developing these components so that they will operate efficiently under all operating conditions. Experimental design techniques have been evolved that substantially increase the operating range of fans and compressors. The application of the casing treatment technique to the fan/compressor hub area and to multistage fan/compressor components will be examined in FY 1972. The trend towards higher temperatures (to 4,000°F) and pressures (to 500 psi) in combustion systems for advanced aircraft engines has necessitated a continuing research effort on combustor liner cooling and development of very short combustors to reduce cooling air requirements. Reducing combustor length minimizes combustion residence time and results in reduced oxides of nitrogen emissions. An increased research effort will be directed at further reductions in the generation of pollutants from high performance combustion systems. The turbine is perhaps the most critical component of advanced high performance engines. Turbine aerodynamic research will be conducted to obtain turbines that perform efficiently under high temperature conditions, having reduced size and weight and required flexibility of operation. Concurrently, turbine cooling research will be conducted to provide reliable methods of predicting cooling performance and turbine blade life, developing cooling methods for cooling blades and vanes at gas temperatures up to stoichiometric temperatures and pressures to 600 psi, developing improved fabrication techniques for cooled turbines, and investigation of methods of reducing cooling air temperatures. Turbine engine systems for advanced supersonic aircraft will require a continual development of the technology relative to seeking and understanding and solution of the dynamic interaction problems (airframe-inlet-engine) associated with supersonic flight. The effects of the dynamic disturbances encountered during supersonic flight operations and the resulting dynamic

interactions will be examined in great detail using newly developed experimental diagnostic instrumentation and measuring devices. The long range objectives of the turbine engine systems research are to develop a reliable three-dimensional simulation test technique that will drastically reduce the amount of experimental work required during the development of advanced engine concepts. A continuing research effort is underway to develop the technology for the design of exhaust nozzles for supersonic aircraft. Particular emphasis will be placed on the performance, cooling, noise suppression, and variable geometry problems that are encountered during operation. In addition, studies will be made of the mutual interaction problems that occur when integrating the nozzle into a complete airframe and propulsion system. The ground test facilities are complemented by a flight test program which is based on the use of a F-106 aircraft with unique modifications for nozzle research. One of the nozzles tested (plug nozzle) indicated a potential for low noise output. Noise tests using a cooled plug nozzle capable of operating in an afterburning jet environment will be conducted in a ground test facility and during an F-106 flyby.

In the hypersonic aircraft technology area, research will be conducted on two and three dimensional fixed geometry inlet concepts with the emphasis on stimulating combustor inlet interactions and developing simulation techniques for inlet testing.

Experimental Hardware

Quiet Engine

A contract was let in July 1969, for the design, fabrication and aeroacoustic evaluation of an experimental high bypass ratio turbofan engine which would be 15 to 20 PNdB quieter in operation than current subsonic transport engines. The program objective was to develop and establish the technology required for the design and development of a turbofan engine which produces a minimum of noise by quieting the noise sources within the engine through basic changes in engine design. The first full scale quiet fan and acoustic model fan have been built and aeroacoustic tests are underway. It is expected that the fan test portion of the program will be completed by about mid-1971 at which time the first engine will be under test. Engine noise results will be available in early 1972 with delivery of the quiet engine scheduled for the end of 1972.

Hypersonic Research Engine (HRE)

In the Mid-1960's NASA undertook a program to design, develop, and fabricate a research engine capable of operating for sustained periods at speeds from three to eight times the speed of sound. Prior to the HRE program, hydrogen fuel combustion in a supersonic stream had been demonstrated only in laboratory type test rigs. This program was to provide a

focus for hypersonic propulsion research during the 1960's, and accomplished this through detailed component research and ultimate integration of the inlet, combustor, and nozzle into a workable propulsion system. The proof of this concentrated research is evident in the test of the first of the two complete models in the wind tunnel. The first, a complete regeneratively cooled flight weight structure, has successfully demonstrated its structural integrity during recent tests conducted in a Mach 7 environment. The second model is a heavy duty, water cooled model which will demonstrate the propulsive performance of the HRE during FY 1972.

New and promising propulsion system concepts are being developed which promise to greatly reduce the amount of fuel required to cool the propulsive structure. This excess cooling capacity could then be utilized for other important functions, such as cooling of the entire vehicle structure. Several concepts are being studied to determine their relative capabilities, and to provide a new technology level on which to concentrate in the 1970's.

Operating Systems

	1970	1971	1972
Operating systems research and technology.....	$6,996,000	$8,000,000	$6,500,000
Total.....	$6,996,000	$8,000,000	$6,500,000

The objectives of this activity are to provide a better understanding of and to solve the interface problems between an aircraft and its operating environment--natural and man-made. Many factors must be considered, such as the location of airports and siting of runways, noise considerations, air traffic control equipment and concepts, pilot workload, aircraft dynamics and flight modes, aircraft operational considerations, wake turbulence and weather conditions. NASA must be involved in research on both the vehicles and the environment in which the vehicles must operate in order to make proper choices between future aircraft characteristics, avionic equipment characteristics, and future air traffic systems which would promote better integration of the aircraft and its pilot with the air traffic environment, allow more operations in bad weather, provide greater safety and dependability in a crowded air space, and enhance community acceptance.

The research effort under this program broadens the traditional aeronautical engineering emphasis upon flight vehicles to include other technology areas such as navigation, guidance, air traffic control, and runway and environmental impact interfaces. Since air transportation systems are complex, the problems must be approached in their entirety rather than from the unconnected viewpoints of single elements.

The role of the aeronautical Operating Systems program is to focus specialized knowledge which exists in NASA upon systems problems.

Operating Systems Research and Technology

Air Traffic Systems

The research in the air traffic systems area will serve to create a technology base and techniques, including technology demonstrations, on which industry can build in developing effective avionic systems. Emphasis is being placed on STOL aircraft operations in the terminal area. This emphasis is urgently required if STOL aircraft are to fulfill their promise of relieving congestion on the runways of major airports and of facilitating city to city short haul travel.

Research will emphasize the application of control theory and will build on particular capabilities of control, guidance, computers, and ground electronic aid systems.

Research will be conducted in the following interdependent areas:

1. Optimum performance during landing and take-off. Climbs and descents must be as steep as possible to minimize noise and to clear obstacles around STOLports; ground rolls should be as short as possible to minimize STOL runway length requirements; the aircraft should clear the area as quickly as possible to meet traffic flow requirements; and curved approaches must be used to avoid sensitive neighborhoods, avoid interference with conventional transport operations, and increase landing rates. Much work remains to be done in the trajectory computations. Techniques which will permit precision, time constrained, steep gradient, curvilinear approaches to the landing under low visibility conditions rely heavily on a high level of mathematical sophistication.

2. Area navigation and use of low altitude airspace. It is generally recognized that the low altitude airspace (up to 3,000 feet over the terrain) is critical to economical STOL aircraft operations. The effective use of this airspace is dependent on the use of area navigation, which involves an onboard computer which would calculate aircraft position continuously from signals derived from both airborne

sensors and ground transmitters. Studies will be made to determine the extent to which the entire course of the aircraft can be automated.

3. All-weather landing capability. Problems of trajectory optimization, position measurement, and control merge in the landing maneuver under low visibility conditions. Closed loop analysis of all-weather landing for STOL aircraft in manual and automatic flight modes will be made, and both hardware and software will be designed and implemented for a technology demonstration.

4. Airport surface guidance and control. Techniques will be studied for providing a means to avoid collisions and to prevent aircraft from becoming "lost" on a major airport in low visibility conditions.

The STOL avionics/air traffic control program which was initiated in FY 1971 has been closely coordinated with DOT/FAA.

A flexible, area navigation system to determine the application of various contending navigation techniques to STOL terminal area navigation and guidance is expected to start flight tests in the summer of 1971. An approach and landing avionics system for STOL aircraft capable of automatic landings using curved approaches with a microwave scanning landing guidance system provided by the FAA is scheduled to commence flight experiments in September 1972 in a STOL aircraft.

Operating Factors

The programs in this research area are aimed at solving problems related to runway surface and atmospheric environments, operational hazards, flight instrumentation, noise and sonic boom effects on buildings and equipment. They involve theoretical analyses and laboratory and flight test experiments to validate current engineering procedures and to explore solutions to aircraft operational problems. The results will provide both the basic technology for safer and more economical aircraft operations and the basic environmental data for application to the design of aircraft.

Atmospheric environmental research includes laboratory studies and theoretical investigations of warm fog modification concepts; the analysis and correlation with atmospheric parameters of turbulence and temperature data collected on test aircraft and from satellites; low level wind shears; and the electromagnetic characteristics of severe storms. Runway surface research includes tire traction experiments planned to assess the ability of various surfaces, tire construction and braking devices to improve aircraft braking, tire wear, and aircraft control on the ground.

In the operational hazards area, the effects of lightning strikes on aircraft electrical systems will be assessed in laboratory experiments. Research is underway to develop a system to measure atmospheric winds

from a remote location, and this system is expected to assist in the alleviation of aircraft trailing vortex and clear air turbulence hazards.

Aircraft noise and sonic boom effects studies will be conducted under carefully controlled conditions to identify and quantify detrimental effects of the overpressure on ground structures and equipment. Sonic boom induced vibrations, noise transmission and building structure damages due to repeated loads are of particular concern. Theoretical studies and laboratory simulator experiments will be used to acquire the needed data. The information will be useful in future structural designs and in the development of operational procedures to minimize detrimental effects.

Materials and Structures

	1970	1971	1972
Materials and structures aeronautics research and technology.....	$7,646,000	$7,400,000	$11,000,000
Total.....	$7,646,000	$7,400,000	$11,000,000

This activity has as its objectives an understanding of materials and the development of new materials and structures to carry the loads, stresses, and temperatures encountered by advanced aircraft.

A broad materials and structures program is necessary to increase the potential of all classes of aircraft. For example, general aviation requires low cost, light weight, easily fabricable materials; while high speed aircraft demand stronger and lighter materials capable of operating at high temperatures and in corrosive environments. The barriers to such developments are a limited understanding of materials, and inadequate structural design techniques and concepts.

In order to better define the problem areas and to hasten the application of recently developed composite materials, a sizeable increase is planned in funding for FY 1972. The principal thrust of this increased effort will be in the design, fabrication, and test of full scale composite reinforced structures and all composite engine components which will be tested in propulsion systems and operating aircraft.

Materials and Structures Research and Technology

Materials engineering ranges from understanding why materials fail to applying new and improved materials to aircraft structures and propulsion systems. An improved understanding of the mechanism for salt stress corrosion of titanium was obtained and in FY 1972 the development of improved titanium alloys will be emphasized. Stronger nickel base alloys were developed as a result of alloying studies. Results of this research will be applied in FY 1972 to developing aircraft structural materials and turbine blade materials. New coatings to protect these new superalloys from oxidation at high temperatures will also be emphasized next year.

Composite materials research has resulted in new high modulus and high strength graphite, boron, and glass fibers. These fibers will be incorporated into plastics in FY 1972 in order to develop low-weight, high-performance plastic composites for both airframe structures and engine components.

The synthesis of non-flammable polymers will continue in FY 1972 because of the encouraging results obtained last year. Several intumescent and foam compositions were developed which markedly reduced fire hazards in experimental aircraft fires.

As a result of basic research on carbons and graphites for nuclear propulsion improved seals for high temperature aircraft engines were recently developed. Additional studies on several new carbons will be made next year with the goal of increasing life times. Basic studies on friction and wear phenomena will continue in order to identify the importance parameters for low friction and wear bearings, seals, and lubricants. Solid lubricants for use in high temperature engines will receive emphasis in FY 1972.

Requirements for long life materials are increasing as the cost of aircraft goes up. Therefore, basic studies of fatigue, fracture mechanics, corrosion, friction and wear will be continued to provide the new reliable materials for the advanced aircraft of the future.

Composite materials applications to aeronautical structures will be studied in a broad program with emphasis on laboratory and service flight demonstrations of the use of composites for selective reinforcement of metal aircraft structures. Suitable modifications to aircraft and primary structural components will be identified, designed, fabricated, and ground and flight tested. The components selected will be primary structures or substructures in high use in aircraft. The modified structures will be designed to achieve significant weight savings without sacrificing current structural performance. For the most part, they will be interchangeable with existing components or assemblies.

As a result of studies partially completed in FY 1971, the FY 1972 program will incorporate the selective reinforcement concept in part of the C-130 wing structure, and in the DC-8 horizontal tail structure. The structural components for these aircraft will be redesigned, fabricated and ground tested. Installation in the aircraft and flight service evaluation will follow.

Applications of structural composites to other aircraft will also be studied. Based on current investigations, the CH-54 crane helicopter fuselage and rotor blades, and various transport aircraft fuselage sections and landing gear components are promising candidates for structural improvement through the application of selective reinforcement.

FY 1972 activities will also include studies to incorporate new structural materials into transport technology and the STOL vehicle project. Research to provide engineering design information on new materials for general aircraft application is planned. Much of this effort will involve fatigue testing of material specimens and representative structural components which incorporate new materials.

The technology of fabricating structural composites will be investigated by means of design and manufacture of typical structural elements employing all-composite materials. Emphasis will be placed on nondestructive testing techniques in order to develop suitable criteria and methods for guaranteeing structural integrity.

Because of the growing significance of lightweight structures to the performance of aircraft, it is important to provide the designer with accurate and efficient methods of structural analysis and design. Studies are continuing to provide these methods through the development of computer methods and programs for accurate analysis and rapid, optimum design of structural components. A special purpose computer program has been developed for the design of lightweight wings which satisfies both strength and flutter requirements. Major improvements have resulted in substantial reduction in computer run time. The effort in FY 1972 will be aimed toward improving other computer programs for the preliminary design and weight determination of aircraft wing structures. Parametric studies will be made, using these programs, to determine the influence of various design parameters on the weight of aircraft structures. The results of these studies should indicate promising avenues for more efficient structural configurations. The effort in FY 1972 will also emphasize further refinement of analyses for cylindrical and conical shells, more accurate failure prediction of imperfect structures, and improved design methods for large components. Optimization techniques will also be developed for large structural components, including fully stressed wing structures. Efforts will also be devoted to determination of pressure distributions from linearized supersonic aerodynamics, prediction of static aeroelastic characteristics, and flutter checks.

Guidance, Control and Information Systems

	1970	1971	1972
Electronics and information systems research and technology.....	$10,190,000	$4,200,000	$3,000,000
Total.....	$10,190,000	$4,200,000	$3,000,000

The objective of this activity is the development of avionics technology which is basic to the needs of modern aviation. A modern aircraft uses avionics in performing every function on board, and many of these functions are critical to flight safety. Since the pilot is and for some time will be a key factor in the safe operation of aircraft, one of the major thrusts of the overall program is the use of avionics to exploit and augment pilot decision-making and mode selecting expertise in the best possible way. One way of doing this is by developing avionics equipment which will relieve him of the menial and routine tasks which now heavily burden him during situations such as approach and landing. Another approach is to design improved situation displays and indicators which help the pilot in exercising his decision-making capability. The increased density of air traffic which is already upon us and the increased performance of modern aircraft also make it mandatory that we develop new sensors for improved navigation and hazard avoidance. These developments are particularly important in flying the steep-angle descents and maneuvering approaches which reduce noise levels and thus make the aircraft and airport a welcome neighbor in the inner city.

Electronics and Information Systems Research and Technology

Research will be continued to augment the present base and develop new sources of knowledge applicable to aeronautical systems. One of the major thrusts in this area is the development of better theory for the control of aircraft. This theory is presently dependent largely upon partial solutions and cut-and-try methods to achieve practical results. The theoretical approaches will be augmented by flight tests of new ideas such as a complete fly-by-wire control system, which offers the advantage of improved ride characteristics, greater safety and reduced weight and drag.

Air traffic control is a relatively new area of research to many universities. During the next year a program of research grants will be started to encourage the university community to draw together its many disciplines which already benefit the aviation community and to focus them as an interdisciplinary effort directed to future air traffic control concepts and problems. This will encourage the development of a technology base directed specifically to air traffic control including curriculum, facilities, and faculty expertise for continuing research work.

Improved sensors will also be developed to improve landing safety and permit the avoidance of hazards in flight. Passive microwave techniques will be used in a new independent landing monitor which gives the pilot a picture of the runway and airfield even under instrument landing conditions and thus permits him to monitor the operation of the primary instrument landing system. For hazard avoidance both lasers and microwave detectors will be designed to probe the air ahead of high flying aircraft to warn of the presence of clear air turbulence, and optical detectors will be further developed to warn of the possibility of collision with other aircraft.

Digital methods will be developed and tested for communicating data both within the aircraft and to the ground via satellite. Digital communication systems offer greatly improved reliability of transmission and greater flexibility in processing of data and mathematical computations. Fly-by-wire control systems have a particularly stringent requirement for reliability of data transmission since they have no mechanical backup system in case of electrical failure, and therefore digital techniques and mode switching will be adapted to the development of such a system.

The use of digital systems also permits more efficient use of large scale integration and microelectronic techniques, with a consequent reduction in the size, weight, and power consumption of avionic equipment. A broad development program will therefore be continued to exploit these techniques and to develop new and improved processes, devices, and practical applications of molecular phenomena.

Work will also continue on the development of the technology which supports NASA and FAA aviation system development. Aeronautical satellites have a particular problem in communicating with aircraft at low elevation angles. These low angles produce multi-path interference which can best be alleviated by the use of directional antennas favoring the direct rather than reflected signal. Antennas suitable for flush installation on jet aircraft will be developed and flight tested, and the resulting data will be furnished to NASA satellite system designers and to the FAA to permit selection of the best overall system characteristics.

Power

	1970	1971	1972
Power research and technology.....	$200,000	$400,000	$400,000
Total.....	$200,000	$400,000	$400,000

Under this activity, important recent advancements in spacecraft electrical system technology will be adapted and extended to provide needed improvements in safety, performance, and economy for future aircraft.

A thorough study of present and future needs in aircraft electrical systems is underway, together with a low level R&D effort toward reducing the weight, complexity and maintenance requirements of aircraft electrical systems.

Ongoing studies are expected to be completed in FY 1972 with little or no build-up in this area, contingent on further identification of problems and review of the study findings.

Supercritical Technology

	1970	1971	1972
Fundamental technology.....	$325,000	$4,670,000	$4,000,000
Exploratory flight research.....	470,000	780,000	1,200,000
Systems studies.....	---	3,650,000	1,500,000
Total.....	$795,000	$9,100,000	$6,700,000

The purpose of this activity is to advance the status of supercritical aerodynamic technology so that it can be applied with confidence to commercial and military aircraft, and to determine compatible advances in other technical discipline areas which, in combination with the supercritical technology, can be utilized to develop a superior next generation transport system in the family of jet transports operating at near sonic speeds. The supercritical aerodynamics technology, under study and test for the past six years, appears to offer the potential of important cruise speed and economic advantages for transport aircraft, and improved maneuverability for combat vehicles. Comparable advances in materials, structures, propulsion, flight controls, and avionics can be combined with supercritical technology to permit the development of new long range air transport systems with significantly improved quality in terms of cost, safety, community acceptance, and contributions to the national economy.

Development of the supercritical technology necessitates considerable large scale wind tunnel and flight testing in the transonic regime, which has heretofore been avoided as a steady-state operating area and is not yet amenable to analytical or small scale laboratory study. The FY 1972 activity consists of fundamental technology effort; exploratory flight research; and systems studies to define the desirable mix of technology advances for the next generation of transport aircraft, and the additional research activity required to accomplish them.

The fundamental technology effort includes both in-house and contractual analytical and test activity in supercritical aerodynamics and in related technical discipline areas, with particular emphasis on propulsion research directed toward large reductions in noise and pollution levels. The exploratory flight research work is a continuation of a flight validation of the supercritical aerodynamic concepts. The systems study activity is a continuation of the 1971 effort in this area, extended to identify specific research requirements.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1972 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY

SPACE RESEARCH AND TECHNOLOGY PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

Space Research and Technology (R&T) for NASA operations in the coming decades require a continuing strong research activity now. Near term projects must use the technology being developed from prior year's research. The FY 1972 Space R&T budget is a balance between the research and technology efforts that will be used in the future, and the more immediate support of the Agency's manned and unmanned program objectives of the present decade.

Research will be continued in the areas of materials and structures, power and propulsion, guidance, control and information systems. There will be a continued emphasis on advancing the technology to produce large amounts of electrical power in space, to develop high specific impulse propulsion systems, including electric propulsion. OART will support the Agency's near term objectives with activity in the critical areas of thermal protection systems, aerothermodynamics, configuration development and entry technology for the space shuttle program. Investigations will be conducted relative to advanced concepts.

SUMMARY OF RESOURCES REQUIREMENTS:

	1970	1971	1972
Space propulsion and power generation	$36,954,000	$36,500,000	$28,600,000
Materials and structures	29,419,000	25,800,000	18,600,000
Guidance, control and information systems	23,473,000	17,500,000	17,055,000
Safety and operating systems	1,448,000	1,900,000	1,700,000
Entry technology	9,893,000	9,500,000	9,150,000
Life sciences	18,790,000	15,800,000	*
Total	$119,977,000	$107,000,000	$75,105,000

*Transferred to Office of Manned Space Flight and is carried under the Space Flight Operations program.

Distribution of Program Amount by Installation:

	1970	1971	1972
Manned Spacecraft Center.....	$8,605,000	$6,282,000	$1,300,000
Marshall Space Flight Center...	10,641,000	10,675,000	10,370,000
Goddard Space Flight Center....	9,190,000	6,540,000	4,475,000
Jet Propulsion Laboratory.....	16,513,000	14,545,000	14,940,000
Wallops Station.....	1,734,000	100,000	---
Ames Research Center.....	12,686,000	12,362,000	7,435,000
Electronics Research Center....	3,556,000	---	---
Flight Research Center.....	1,689,000	2,055,000	1,000,000
Langley Research Center.....	26,927,000	25,125,000	15,380,000
Lewis Research Center.....	19,501,000	21,788,000	16,145,000
NASA Headquarters.....	8,935,000	7,528,000	4,060,000

BASIS OF FUND REQUIREMENTS:

Space Propulsion and Power Generation

Propulsion and power research and technology.....	$36,454,000	$36,225,000	$28,600,000
Space electric rocket test (SERT)	500,000	275,000	---
Total.....	$36,954,000	$36,500,000	$28,600,000
Agena (Launch Vehicle Procurement Program).....	($150,000)	(---)	(---)
Total (including launch vehicles).....	($37,104,000)	($36,500,000)	($28,600,000)

Propulsion and Power Research and Technology

Chemical Propulsion

Activities directed toward providing critical propulsion technology for the space shuttle will continue and should be completed with FY 1972 funding. Investigations in this area will improve the handling of liquid hydrogen near its boiling point, investigate feed systems and pump changes to avoid POGO instability, assure maximum performance and stability from both main engine and reaction control thrusters, and evaluate methods such as low thermal capacitance internal insulation in feed lines to reduce chill-down losses. The performance of components for the attitude control systems for both the shuttle booster and orbiter will be evaluated. The best features of the current ignition, injector, bipropellant valve, and thrust chamber programs will be exercised over a range of operation typical of shuttle duty cycles.

A high performance propulsion system is needed for the multiyear duration planet orbiting and landing missions. Liquid hydrogen would slowly boil away during these long flights. Accordingly, a major goal of this research and technology program is the demonstration of a high specific impulse (400 seconds) space storable propulsion system. Two systems are currently being examined: one of low thrust (1000 pounds) and one of high thrust (5000 pounds). The

low thrust application requires a simple pressurized system, the high thrust applications favor a more complex turbopump. Both require fluorinated oxidizers for high performance. The pressure-fed propulsion concept is under investigation at JPL. As a component technology matures, subsystems will be assembled and subjected to thorough testing prior to integration in the complete propulsion module. The principal propellant combination of interest here is OF_2-Diborane. The higher thrust, pump-fed system utilizes FLOX (a mixture of oxygen and fluorine) and liquid methane and is under investigation at Lewis Research Center (LeRC). In FY 1972, emphasis will be placed on one of the two approaches. In subsequent years this program will assemble a complete propulsion system including structure, tankage and tank supports, tank pressurization systems, passive thermal control systems (super insulation, shadow shields, etc), auxiliary propulsion, and main engine.

The transfer of cryogenic propellants from one vehicle in space to another vehicle is required for many future operations. An example is the refueling of a "Space Tug." The objective of this research and technology program is to provide the technology and design data for efficient and predictable transfer of large amounts of hydrogen under zero gravity conditions. Following extensive ground testing, a flight experiment will be designed, built and orbited to collect data and verify transfer mechanisms. In FY 1972 a portion of the ground testing program and a preliminary definition of the flight experiment will be completed.

Advanced solid propellant rocket technology activity includes two specific motor demonstration programs: a high-performance propellant, restartable motor and a low thrust, long burning time motor. The high energy stop and restart motor is a relatively short term replacement candidate for current upper stages of the Scout or Burner II type. It offers 10% more specific impulse than current solid propellants and the capability of quenching combustion at any time during burning for a coast-phase prior to reignition. This substantially increases the payload that can be injected into a high orbit. In FY 1972, a full scale motor utilizing heavyweight hardware will be test fired. Tests of the low thrust, long duration, planetary-orbit insertion motor at JPL have been very successful. In FY 1972 this motor will be tested using conventional solid propellants, and higher energy propellants will be tested in subscale.

New characteristics of solid propellant and hybrid (solid/liquid) propellant systems, e.g., variable thrust, long burn time, low acceleration motors; sterilizable systems; wide temperature range capability; and ten year storage life in space, will be developed in FY 1972. These advances will extend the utility of low cost solid motors in space missions. More energetic propellants to be used in space vehicles necessitate new binder development, and better processing and handling. Higher performance propellants and restartable systems also require improvements in nozzle durability. Better liner and insulation materials will be developed to minimize inert weight. Propellant mechanical behavior prediction is essential to motor design. The mechanism of fracture and elasticity of propellant materials and development of nondestructive testing techniques that are suited to solid propulsion motor systems are being studied.

Electron paramagnetic resonance methods will be developed to examine fracture mechanisms in polymeric materials. Combustion and kinetics research will supply better data on flame structures and processes, improve combustion modeling and provide information in a form useful to the design engineer.

The goal of liquid propellant rocket technology effort is to provide a sound base for the design of future propulsion systems. In FY 1972 feed system and engine accessory work will examine fluid dynamic effects in fluid inlet systems and in high speed turbopumps in order to understand mechanisms leading toward vehicle POGO instabilities. This work is necessary to prevent resonant coupling between engine thrust and lightweight elastic structures typical of the next generation of high performance rocket systems. Other new tasks will develop ways to improve life of components such as fast acting valves. Experimental and analytical work on thrust chambers and injectors will define heat transfer at the high chamber pressures and temperatures of high performance chambers. Another effort will explore noncircular injection orifices for combustion chambers. Better physical, thermochemical, and kinetic expansion data for propellants will be generated. The chemical effects of long time storage of these propellants in simulated systems will be studied. Additional activity will include work on combustion, combustion driven instability, ignition, and gas dynamics. Better understanding of ignition of the non-hypergolic hydrogen oxygen propellants is vital to restartable shuttle engine and reaction control requirements. Continued work will be directed toward the controlling combustion driven instability by use of acoustic absorbers.

Electric Propulsion

Principal motivation for research in electric propulsion is the potential for significantly increased mission capability and flexibility and reduced size and/or costs as compared with existing systems. This performance advantage arises from the fact that electric thrusters are the highest specific impulse rocket engines known and consequently have the lowest propellant expenditure rates. Using such engines, missions which are totally impractical otherwise, such as north-south station keeping of synchronous communications satellites and orbiters of Mercury, can be executed. Inherent in the characteristics of such systems are additional advantages such as flexible control of flight path during major portions of a mission, ability to use biowastes as propellant, and availability of large amounts of power at destination.

In the area of auxiliary propulsion, work will continue on the one milli-pound thrust cesium bombardment ion engine flight experiment for the forthcoming Applications Technology Satellite (ATS-F). This operational experiment is aimed at verifying and obtaining operational data on an ion engine system suitable for north-south station keeping of equatorial synchronous satellites. Such a system offers a functional capability ideally suited to the requirements of future NASA, Comsat and DOD long life geosynchronous satellites. The experiment will consist of two 150 watt

thruster systems capable of 7° thrust vectoring in order to demonstrate attitude control. The north-south station keeping capability will exceed one year.

Evaluation of the pulsed plasma thruster has verified its suitability for long life missions or those requiring precise maneuvers. The system for example contains no valves which implies enhanced reliability. Consequently, an effort to build and test a thruster suitable to the synchronous meteorological satellites (SMS) precision control and east-west station keeping requirements was initiated in FY 1971. This effort should lay the groundwork for use of such thrusters not only on SMS, but also on spacecraft bound for the outer planets. During FY 1972 additional auxiliary propulsion efforts will continue on hydrazine and biowaste resistojets. Gases residual to life support systems on manned space stations such as CO_2, CH_4 and H_2O can be used as propellants in resistojets to provide atmospheric drag cancellation and attitude control in low earth orbit, reducing propellant resupply requirements.

For primary propulsion applications major program attention is focused on systems based on the mercury electron bombardment thruster. In addition to space tests on SERT I and II, such thrusters have been the subject of a systems technology program aimed at simulating as realistically as possible all required operational functions for a typical interplanetary mission. While the SERT II thrusters fell some 600 hours short of achieving the objective, 4383 hour (6 months) test, a considerable amount of new and important engineering data were obtained. Specifically, ion thrusters were found to have no unmanageable physical or operational interactions with spacecraft and performed as expected in the space environment. The ground test program is proceeding on schedule toward fully automatic closed loop operation in the latter half of FY 1971. This work is expected to continue in FY 1972 with emphasis on solving system problems, improving thruster endurance and performance at lower specific impulses (2800 sec), and testing of improved system components. Both flight and ground test experience have permitted initial planning during FY 1971 of a solar-electric multimission space vehicle program (SEMMS). The SEMMS effort is viewed as the next and final logical step in the technology required to realize the advantages of electric propulsion for exploration missions such as cometary and asteroid rendezvous, Mercury and outer planet orbiters, close-in solar probes and out-of-the-ecliptic at 1 A.U. Analysis of alternative approaches for flight evaluation of an advanced technology multimission space vehicle will continue in FY 1972 toward definition of the single, most promising approach.

Solar Technology

Major emphasis in the solar power program will be on achieving a new capability, i.e., arrays putting out several thousands of volts. Such power systems, if feasible, would be more efficient and reliable as well as

lighter in weight than present systems for communications and earth applications satellites and electric propulsion. Work will be continued on improved radiation resistance, less costly methods of array design and assembly, and improved solar cell efficiency.

Technology readiness of a 30 watt per pound solar array has been nearly achieved. Remaining to be completed are studies on dynamic interactions of large arrays of this type with unmanned spacecraft. Such studies will be completed in FY 1972. Whereas it used to be thought that 1-2KW was the upper limit of solar power systems in space, we now are designing 15 and 25 KW systems. Further increases appear quite feasible. Recent studies conducted by the NASA Research Advisory Committee on Power and Electric Propulsion indicate that there are major improvements possible in solar cell power systems such as increased efficiency and reduced cost. Efforts will be initiated in FY 1972 to better define these improvements and the research program necessary for their achievement. A modest effort will be continued on exploring the behavior of solar cells in deep space, measuring their efficiencies under low intensity sunlight and their radiation resistance at low temperatures.

Chemical Technology

Continuing work in the chemical power program is concerned with improving the cycle life, reliability, and energy density of sealed nickel-cadmium batteries and their adaptation to manned missions. Here, cooling of large blocks of batteries becomes a problem. In addition, the wet-stand life of batteries for long duration deep space missions is being improved. Various inorganic substances are being explored both as battery separators and as fuel cell matrices. The main aim of fuel cell technology is to minimize degradation and, thus, to lengthen operable life.

Test equipment will have been installed and cells will have been procured in FY 1972 in preparation for a program to predict long term cell and battery life by a short duration nondestructive test method. The crypt-analytic technique developed in this program is being explored for medical diagnostic purposes.

Development of a 100 amp-hour cell technology by NASA has given rise to the largest size nickel-cadmium cell produced thus far. Several companies are now making such cells. Modest efforts have begun on building nongassing, fail-safe nickel-cadmium cells, and on pulse charging of space cells to improve life and rates of charge acceptance.

A search is being made for a low temperature, solid electrolyte to be compatible with an alkali-metal anode and an oxygen cathode. Such an electrochemical couple should show a tenfold increase in energy density over conventional cells. The solid separator should insure a much longer shelf life as well.

Power Processing Technology

Ground test and flight experience, coupled with anticipated needs for future missions, emphasizes that further significant advances in technology for electrical power processing and distribution are essential to achievement of projected operational capabilities for more difficult space missions now in various states of preliminary preparation or planning.

Central objectives in this area continue to be the development of an adequate technology base for high power (10-100KW) and for long life (10 years) power processing and distribution systems. Technical difficulties inherent in these objectives are compounded by the concurrent emphasis on minimum weight, particularly for space shuttle and electric propulsion applications.

Studies fully defining the extent of technology requirements for the space station and shuttle are not complete, but it is apparent that general improvements in distribution components (e.g., switches, circuit breakers, relays) and power processors (e.g., inverters, converters, battery chargers) will be needed. Early identification of problems and establishment of commonality, where possible, between station/base and shuttle should reduce development and logistics costs for both vehicles. For the space shuttle, the capability for automatic preflight checkout, inflight monitoring, malfunction diagnosis and correction have been identified as primary electrical system needs. Efforts in these areas will be continued in FY 1972.

Substantial progress has been made in establishing technology readiness for power processors for ion engine applications and extending the power processing technology applicable to low voltage, high temperature sources as for an RTG generator source. This work will continue at reduced levels in FY 1972, phasing out as technology readiness is demonstrated.

Advancements in key power processing components, specifically diodes, controlled rectifiers, power transistors, and magnetics have contributed directly to essential circuit/equipment technology improvements. Device limitations, particularly high energy density capacitors, however, remain a broad problem area not adequately supported at present. An increased program in this area is planned for FY 1972.

Materials and Structures

	1970	1971	1972
Materials and structures research and technology.....	$28,674,000	$25,555,000	$18,400,000
Meteoroid satellite.....	745,000	245,000	200,000
Total.....	$29,419,000	$25,800,000	$18,600,000
Scout (Launch Vehicle Procurement Program).....	(---)	(---)	($1,200,000)
Total (including launch vehicles).....	($29,419,000)	($25,800,000)	($19,800,000)

Materials and Structures Research and Technology

Fundamental materials research is aimed at providing the basic knowledge required for the development of engineering materials. Specifically this program is aimed at understanding the basic properties of the solid state for structural electronic and radiation shielding applications in space. These studies include solid state physics and chemistry of surfaces and of bulk materials, the properties of electronic materials, the effects of radiation on matter and studies of the radiation environment and optical contamination anticipated in space missions.

Research in solid state physics seeks new knowledge of a variety of materials behavior. In FY 1972 atomic scale defect studies will be aimed at producing high strength, high temperature structural materials and high density computer memory materials for increased spacecraft data capabilities.

Semiconductor physics has been aimed at materials for improved solar cell efficiencies and higher operating temperatures. In the past year, basic research at Langley Research Center achieved significant accomplishments of providing the first doping of silicon with beryllium. This new semiconductor material exhibits increased temperature stability and offers strong potential for the development of advanced electronic devices. This research will continue in FY 1972.

Superconductivity research has been and will continue to be directed toward obtaining higher operating temperatures for radiation shielding applications and increased efficiencies of electronic components.

Recent studies of thin film nucleation and growth at Ames Research Center led to the innovation of a new technique to provide electron microscopy with a resolution capability five times greater than conventional methods. This new method will accelerate substantially the progress of NASA research in thin film and other areas of basic surface physics. Surface physics studies in FY 1972 will seek basic knowledge of the interaction of atoms and molecules with solid surfaces to enhance NASA capabilities in thin film technology for electronic devices and the control of surface behavior of materials for structural applications.

The effects of radiation on materials, both structural and biological, exposed to space environment are being investigated. Theoretical models of the space radiation environment have been developed and are being used as the basis for study of the interaction of radiation with space shielding materials in order to identify secondary effects possibly experienced by spacecraft. New and improved radiation detection and shielding concepts will be analyzed and developed in FY 1972 to assure adequate protection from radiation hazards in space missions.

Optical contamination studies seek determination of the magnitude of degradation of optical surfaces. These studies will guide the development of the technology necessary to protect spacecraft systems prior to and during flight. In FY 1972 this research will include theoretical and experimental studies in contamination transport, outgassing behavior of materials, basic surface physics of sticking coefficients and nucleation of various contaminants, the effects of electromagnetic radiation and development of techniques of clearing contaminated optical surfaces in space. During the past year extensive development and utilization of quartz crystal microbalance techniques at Jet Propulsion Laboratory and the Marshall Space Flight Center provided major impetus to perfection of spacecraft environment monitoring instrumentation.

Materials engineering studies for space applications are concerned with how materials behave in the environments of space and space power and propulsion systems. During the past year, substantial progress was made in defining the requirements and limitations of high temperature materials for space shuttle. The fabrication and processing of a dispersioned strengthened alloy was developed for larger sizes and quantities. The mechanical properties of this alloy were determined for the expected temperatures to be encountered in the space shuttle. Its oxidation behavior was also studied. In FY 1972 additional improvements will be pursued in high temperature ductility and oxidation resistance.

Refractory metals which are of interest for the space shuttle and space power systems will continue to be studied for the purpose of improving their oxidation characteristics, either by alloying or the application of protective coatings. Progress has been slow and so this effort will receive greater emphasis in FY 1972.

Composite materials offer considerable potential for reducing the weight of spacecraft and thereby improving their payload capability or increasing their overall performance. Research and development on composites specifically for a space shuttle is being pursued this year. Basic research on the behavior of fiber matrix systems will continue in order to provide the basic knowledge for improving their mechanical properties.

As improvements are made in increasing the strength of metals, ceramics, and composite materials, their ductility or toughness decreases. Such materials then fail in catastrophic manner. Studies on fracture and failure mechanisms have been conducted and will continue in FY 1972. This research is particularly important for spacecraft design for long mission times.

The program of synthesizing new high temperature polymers for ablatives and structural components of spacecraft has produced many successful achievements in the past and promises to do so in the future. Last year a new polyimide with greatly improved mechanical properties was synthesized.

Additional research will be conducted in FY 1972 to determine if this new polyimide can be used as high temperature adhesives. A new class of electrically charged polymers, called Ionenes, were also synthesized last year. It promises to have application to biomedical engineering, an interesting spin off.

The long mission times for advanced spacecraft also pose problems for the designer in regard to the temperature control of space vehicles. Thermal control coatings degrade at such a rate that they are not adequate for many missions of one year or more. Substantial research has been conducted and will be continued in FY 1972 to improve coatings by an order of magnitude. Research and development of alternative devices, such as heat pipes, will be initiated in FY 1972 to broaden the technology base.

The protection of spacecraft from meteoroids also becomes more important as mission times increase. Research in the past on this problem has only been modest. The advent of space station, shuttle and planetary probes demands an increased emphasis in FY 1972 and beyond.

Research and technology activities for space structures cover a broad spectrum of investigations to explore the potential of applying advanced concepts and materials, develop improved techniques for structural analysis and design, and provide advances in methods for determining the dynamic loading and response of complex structures. In FY 1972 emphasis will be given to the most critical structures problems associated with the space shuttle, planetary vehicles, and other types of future space systems which will require substantial advancement in technology to achieve the necessary levels of efficiency and integrity.

Significant progress has been made in establishing the feasibility of structural arrangements utilizing composite materials to reinforce metal components. Studies have indicated that appreciable weight savings are possible without excessive cost increases with this approach which makes effective use of a minimum amount of high cost composites. Applications of boron-epoxy and graphite-epoxy with aluminum and titanium alloys are particularly attractive candidates for shuttle, primarily structures such as beams, trusses, and stiffeners in areas which are relatively cool. For pressure vessels, previous efforts have demonstrated that small metal tanks can be effectively reinforced by overwrapping with glass filaments. Use of advanced filaments show promise of greater effectiveness for reinforcing large tanks of aluminum, titanium, or nickel alloys which would have important advantages for load-bearing main propellant tanks in the space shuttle. These concepts for composite-reinforced metal components will also have important application to many other aerospace structures. In FY 1972 studies of these concepts will be expanded. Larger scale components will be fabricated and tested to investigate fabrication and reliability problems, and to permit realistic assessments to be made of the weight and cost effectiveness for full scale applications.

Efforts will be continued on the development of concepts for larger, lightweight erectable communication antenna structures for missions to the outer planets. Recent work has identified promising concepts and materials, and in the coming year a 15 foot model of a conical antenna will be fabricated and tested to confirm the potential of the concept for application to much larger antennas. Research will also be continued on efficient aeroshell structures for planetary entry missions beyond Viking.

Structural analysis and design requirements of large and complex space vehicles, such as the reusable shuttle, will put a premium on advanced techniques to achieve the needed degree of ingenuity, accuracy, and efficiency. Extensive efforts are under way to provide methods of analysis with the requisite capability for accurate determination of the strength and rigidity of structures which embody the latest design concepts and materials combinations.

NASTRAN, the comprehensive structural analysis computer program previously developed in this program, will continue to be maintained and improved. Advanced computer analysis techniques such as NASTRAN will be applied and new analysis methods for structural optimization will be developed to facilitate the selection of the most efficient structures with the required levels of integrity and reliability for the design conditions. Laboratory testing of large scale components will be conducted under realistic combinations of loads and temperatures to confirm the reliability of the analytical methods as well as to demonstrate the structural integrity. For the space shuttle, specific emphasis will be given to evaluation of alternative approaches to the integration of the entry thermal protection system with the primary structure to establish the most optimum design arrangements. The advanced methods of analysis and design will be applied to a variety of space vehicle structures in addition to the shuttle to define types of structures for future systems which will provide the desired weight, cost, and reliability. These studies will also facilitate the establishment of more comprehensive and effective structural design criteria. This effort will be continued to provide uniform criteria and acceptable practices which describe the levels to which space vehicles should be designed.

The dynamic loading and response of space vehicle structures is important not only because it directly relates to integrity of the structure, but it also determines the intensity of vibratory inputs to all the equipment and personnel aboard. New and more severe dynamic problems are imposed by the concepts and missions associated with advanced vehicles such as the space shuttle. The typical configurations and mission characteristics planned for the shuttle pose a combination of critical dynamic factors which require intensive investigation to provide an adequate technology base for coping with potential problems.

Previous efforts have established the basic techniques for utilizing small scale dynamic models and have demonstrated the validity of this approach to obtain accurate data in a timely and cost effective manner. Various types

of models are being used to investigate the most important structural dynamics problems for the space shuttle. Preliminary data have been obtained on some parameters which could strongly influence decisions on shuttle configuration and design requirements. One such area is flutter due to interference between lifting surfaces of the booster and orbiter before separation. Wind tunnel test results with aeroelastic models have shown how the flutter speed is seriously affected by the close proximity of these surfaces. Research in other problem areas is underway and emphasis will be given in the coming year to particular shuttle problems such as response to ground winds, flight winds, engine and aerodynamic noise, buffet, and stage separation loads. Studies will also be concerned with methods of avoiding or attenuating critical dynamic instabilities due to interactions between the structure and propellants as occur in POGO oscillations. Many of these dynamic studies also have application to other types of space vehicles.

Research will continue on a variety of loading and response problems with attention to high frequency dynamic behavior of space structures. Improvements are needed in the understanding and treatment of aerodynamic noise effects and structural response to transient and random vibration inputs. Studies will consider advanced analytical and experimental methods for predicting the dynamic response of space structures such as a rotating space station which could not be adequately tested in the laboratory using available techniques.

Meteoroid Satellite

The meteoroid satellite, initiated in FY 1969, will be launched in FY 1972 to measure the effectiveness of a promising meteoroid protection device referred to as a meteoroid bumper in the actual space environment. These measurements, together with measurements of meteoroid velocity and meteoroid impact flux on the satellite, will provide data for the design of meteoroid protection systems and correlation with ground-based meteoroid experiments. In addition to the launch of the satellite, the activities to be carried out in FY 1972 will be the analysis of data obtained and the preparation of a report on the preliminary results.

Guidance, Control and Information Systems

	1970	1971	1972
Electronics and information systems research and technology	$23,173,000	$17,500,000	$17,055,000
Electronics and information systems projects.....	300,000	---	---
Total.....	$23,473,000	$17,500,000	$17,055,000

Electronics and Information Systems Research and Technology

Maximum return of information from space exploration requires a continuing effort to improve the bandwidth and efficiency of space vehicle-to-ground communication links. Optical communication systems offer substantial improvements over current microwave links both in terms of tracking accuracy and data rates. In FY 1971, primary emphasis has been placed on the study and development of optical power generators (lasers), detection system and experimental evaluation of the effects of the earth's atmosphere on optical data links. Balloon tests of optical propagation systems have been made and results are being evaluated. Aircraft tests are being prepared to evaluate the effects of a moving vehicle on optical communication systems. In FY 1972, development of satellite to ground experiments will be initiated to demonstrate the feasibility of optical communications as high capacity data transfer systems.

The large investment in current microwave networks requires that maximum returns be sought through improvements and innovations in the techniques by which data is handled. Research and development of more efficient spacecraft antennas, higher power signal generators and advanced coding techniques is in process and will continue in FY 1972. Conversion of the current S-band system to higher frequencies to improve data handling capacity will be evaluated in an X-band experiment now being developed for flight on a future mission.

Concomitant with the demand for higher data rates is the need for more efficient and effective processing of accumulated data both on the ground and in space vehicles. Techniques for mass data storage are being investigated with principle emphasis on optical systems. Experimental storage media have been developed. In FY 1972, emphasis will be placed on the development of techniques for the read in and read out of data into these media. Long duration missions such as the grand tour and station require data processing systems with long, reliable operating lives. Techniques for self test and repair of computers have been developed. Hardware to demonstrate these techniques is being developed and will be evaluated in FY 1972.

The evolution of the computer into small, compact data processing units makes the automation of many functions, formerly done through complex wiring into a large central computer, both feasible and practical. Multiplexed data bus techniques are being developed for the space shuttle and station. Automated inflight and ground-based checkout techniques are being developed to insure the flight worthiness and improve the reusability of space transportation systems such as the shuttle. These efforts will continue in FY 1972.

Data compression techniques provide substantial reductions in the amount of data to be transmitted from space vehicles to ground. In FY 1972, emphasis will be placed on the development of mathematical techniques for extracting significant information from large masses of accumulated data. Video data compression, pattern recognition and adaptive or self learning techniques will be explored in an effort to increase the on-board processing of data.

Precise guidance and control is a fundamental requirement of all spacecraft whether they be orbiting platforms for scientific observations of the earth and its environment, transportation systems such as the space shuttle, or interplanetary vehicles serving as carriers of experiments and sensors to examine the extremes of the solar system. A prime effort in the current program has been the development of simulation facilities to generate guidance and control laws for the space shuttle vehicles. In FY 1972, techniques developed through ground-based simulation will be evaluated in flight tests to demonstrate their feasibility and applicability in typical shuttle operations. Long range interplanetary flights require the use of approach guidance to insure accuracy of spacecraft maneuvers in the vicinity of target planets. The feasibility of approach guidance was demonstrated via simulation on Mariner VI and will be tested in an experiment now being prepared for flight on a future mission. In FY 1972, research will center on the optimization of on-board sensors and techniques for mechanizing approach guidance as a standard system in future interplanetary spacecraft.

Current guidance and control systems rely on moving devices such as gyros, motors and accelerometers to sense and control the motion of space vehicles. Development of components with no moving parts to improve the reliability and accuracy of these systems is a continuing objective of this program. A small, compact laser gyro is being developed and will be evaluated in flight tests in FY 1972. Brushless motors have been developed in varying sizes for a number of possible space applications. Current efforts center on the application of this technology as torquers for the large control moment gyros used to stabilize manned space vehicles such as Skylab and the space station. This effort will continue in FY 1972. Digital control systems offer precision and flexibility far superior to current analog technology. In FY 1972, emphasis will be placed on development of direct digital sensors to replace the current practices of converting from analog to digital systems for data processing and back to analog systems for execution of controlled functions.

Large space telescopes offer man the capability to examine the extremities of space without the physical limitations imposed by earth's atmosphere. To realize this capability, however, techniques for assembling and operating these instruments in the space environment must be developed. Research is continuing on the development of 2-3 meter active optical systems which can maintain diffraction limited performance in space. Principal emphasis in FY 1971 has been placed on the study of thin mirror techniques and the actuators necessary to control the surface quality of these mirrors. In FY 1972, comparative evaluations of thin mirrors, segmented mirrors and temperature compensated, large solid mirrors will be initiated to select the best technique for future space telescope missions. Instrumentation to maximize the effective use of space telescopes is being developed. In FY 1972, development of highly sensitive ultraviolet radiation detectors and precision optical gratings will be emphasized.

Development of advanced components and circuit technology is necessary to satisfy the requirements for more reliable, long life electronic systems in space. Research on new applications of solid state materials to electronic component functions is continuing. In FY 1972, primary emphasis will be placed on solid state display devices and high density memories. Solid state microwave components and highly sensitive detectors for imaging systems will be developed for use in Station and planetary missions. Development of large scale integrated circuit processing techniques will continue with emphasis on methods for attaining higher switching speeds and more reliable techniques for interconnecting these devices in electronic assemblies.

Electronics and Information Systems Projects

The only effort currently active in this area is the Radio Attenuation Measurement project. This project was initiated in FY 1965 to define the extent of loss of radio communications during the atmospheric entry phase of space flight and to establish techniques to overcome this loss. Two previous flights demonstrated the capability of water injection to reduce and, in some cases, eliminate the blackout phenomena. The third and final flight in this project, RAM C-III, was successfully completed on September 30, 1970. Its objective was to perform comparative evaluations of the effects of injecting water and an electrophilic liquid (Freon E-3) into the plasma sheath. Prior flights indicated water helped to restore communications by cooling plasma. Theoretical studies indicated electrophilic liquids would act to neutralize free electrons and reduce the density of the plasma. Results of the flight showed that at altitudes above 200,000 feet, the freon is approximately four times more effective than water in reducing radio frequency attenuation. Below that altitude, the two liquids were about equally effective. No additional flight activities are planned in this project.

Safety and Operating Systems

	1970	1971	1972
Safety management information system.....	$650,000	$1,000,000	$1,000,000
Safety research and analysis.....	798,000	900,000	700,000
Total.....	$1,448,000	$1,900,000	$1,700,000

Safety Management Information System

The Safety Management Information System program is the Lewis Research Center aerospace safety data bank which is composed of the Lewis information storage and retrieval system (LISR) and the data bank. The basic information systems capabilities of the aerospace safety data bank were implemented in August 1970. Even in its initial implementation this system represents a most flexible and powerful data management capability. Several large files

are presently being loaded into the system. Negotiations are underway for the acquisition of a communications processor to provide on-line capabilities for many users on a dial-up basis. Subject areas of safety-related information already in storage will be expanded.

Safety Research and Analysis

Spacecraft Fire Protection

Comprehensive studies are underway or planned for the detection of developing fire hazards and the automatic extinguishment of those fires that do occur. Presently available fire detection systems for spacecraft fall short of meeting desired standards either because they are too slow to detect the hazard, or require an initial fire size for detection which is too large to be acceptable.

The emphasis is being placed on fire detection by the NASA Spacecraft Fire Hazards Steering Committee because only adequate fire extinguishants for spacecraft exist. The remaining problems in the fire extinguishment field relate to improvements and the engineering of such systems for spacecraft application.

Space Nuclear System Safety

More and more space system missions will be carrying nuclear materials in the form of fuel elements for reactors and/or isotope heat sources for space electric power and propulsion systems.

The overall aim of the aerospace nuclear safety activities is to insure the safe application of nuclear energy during the prelaunch mission and post mission phases and to protect personnel associated with the application as well as the general world population. Extensive analyses and tests are required to insure that adequate safeguards have been designed into the systems.

Oxygen Handling in Aerospace Programs

The program for the review of oxygen handling and utilization in aerospace systems (spacecraft, aircraft, and supporting ground equipment) has been organized. A critical review of oxygen technology and its application is in progress.

The goal of this program is to provide updated standards, criteria, and recommended practices for the design, fabrication and assembly, preparation, and operation of oxygen systems.

Safety of Liquid Methane as Aircraft Fuel

Advanced aircraft need heat sink capability, particularly at the hot end of the engine. The use of liquid methane (liquid natural gas) is particularly attractive for this purpose. The improved engine efficiency and lower engine weight associated with the use of methane improves the flight safety and economics of the airplane.

In order that methane can be used safely in aircraft systems and in ground support equipment servicing the airplane operation, considerably more information is required on the physical properties of methane in its liquid and gaseous state to enable engineers to devise safe aircraft and ground handling fuel systems.

Safety of Hydrogen-Fueled Airbreathing Engine for Shuttle

Present concepts of airbreathing engines for the shuttle consider hydrogen as the engine fuel. The only known use of hydrogen for powering aircraft was conducted as a demonstration at the Lewis Research Center in 1958. Considerable work will be required if a practical hydrogen system is to evolve for the shuttle. These problems are intimately involved in the safety of the shuttle. The particular safety problems lie in the realm of hydrogen system pressure control, metering, heat transfer, air condensation, hydrogen venting, pressure perturbation associated with system start-up, safe chill down procedures, leaks, fire detection and fire control.

Aircraft Static Pressure Measurements

During the past two years several aircraft accidents have occurred during what seemed to be a routine approach to landing.

Evidence has suggested that the aircraft, in each case, was in airworthy condition until the moment of impact. Therefore, suspicions and doubts have been raised about the reliability and accuracy of barometric altimetry systems.

Several agencies (National Transportation Safety Board, FAA and NASA) have sponsored a series of flight experiments that would explore, under realistic operating conditions, the nature of altitude anomalies and the causes of altitude misinformation.

Entry Technology

	1970	1971	1972
Lifting-body flight research program	$1,110,000	$1,200,000	$700,000
Space vehicle aerothermodynamics program	8,783,000	8,300,000	8,450,000
Total	$9,893,000	$9,500,000	$9,150,000
Scout (Launch Vehicle Procurement Program)	(---)	($1,200,000)	(---)
Total (including launch vehicles)	($9,893,000)	($10,700,000)	($9,150,000)

The Entry Technology program is composed of two parts: (1) Lifting-Body Flight Research program and (2) Space Vehicle Aerothermodynamics program. The program is an applied research and technology program focused on space vehicle flight through the atmosphere of earth and other planets. The objectives are to: (1) conduct research on problems associated with the cruise, approach, and landing phases of lifting-body re-entry spacecraft; (2) establish and carry out a research program focused on requirements for aerothermodynamic design of the reusable manned space shuttle; and (3) conduct research on the complex problems associated with unmanned spacecraft entry into planetary atmospheres. The main thrust of the research program in FY 1972 is focused on spacecraft re-entry technology associated with the aerothermodynamics and thermal protection system design of the manned space transportation system.

Lifting-Body Flight Research Program

An important facet in the technology development of manned space transportation systems is the base of information on lifting-body type vehicles available from comprehensive wind tunnel investigations performed over the past fifteen years and piloted flight research carried out over the past seven years. The current Lifting-Body Flight Research program resulted from early recognition that spacecraft horizontal landing in the manner of conventional aircraft would be a requirement for efficient operation of future manned space transportation systems. Wind tunnel and analytical research on lifting-body concepts began in the mid-1950's and culminated in the initial flights of the M2-F2 and HL-10 designs in 1966. Because of the closely allied interest of the Air Force in lifting-body vehicles, the Lifting-Body Flight Research program has been a cooperative NASA and USAF venture since its inception. The program currently includes an Air Force design designated the X-24A.

The objectives of the flight program are to investigate the flying and handling qualities and piloting problems of spacecraft concepts representative of promising manned re-entry vehicles during the terminal phase of space flight from low supersonic speeds to landing. Of equal importance in the program is the necessity to evaluate in flight the suitability of vehicle control systems especially adaptable to lifting-body type vehicles. As of December 1970, 77 flights have been completed with three different vehicle concepts. All three vehicles have flown in a rocket powered mode in addition to numerous unpowered glide flights. The HL-10 and X-24A have been flown at supersonic speeds. The HL-10 has essentially completed its planned flight program and is now on standby basis. Currently, the X-24A has been flown to a Mach number of about 1.3; however, the flight envelope will be extended to speeds approaching Mach number 2 to obtain important stability and control data and to extend the general piloting experience at these higher speeds. The M2-F3 has made four flights to date and is performing valuable service as a test bed to investigate a new spacecraft

reaction control system. The Lifting-Body Flight Research program will employ both the M2-F3 and X-24A in FY 1972 to firmly establish the flight and landing characteristics for this class of manned lifting spacecraft and to gain additional pilot experience.

Space Vehicle Aerothermodynamics Program

An active aerothermodynamic research program associated with problems of launch, re-entry, and flight of spacecraft in the earth's atmosphere has been underway for several years. In the past, this program has supported to the fullest extent the Mercury, Gemini, and Apollo programs in all phases of aerothermodynamics. Also under this program exploratory wind tunnel and feasibility studies were conducted on early concepts of reusable booster and spacecraft configurations (including the Ms and HL-10 configurations) with emphasis in recent years directed toward current manned space shuttle concepts. The requirement for multiple reuse of large spacecraft and boosters, together with the necessity for operational economy, is a decisive factor in the design of the space shuttle. Particular impact is felt by design requirements of the thermal protection system which is critically tied to service life and turn-around time. This, and other problems such as spacecraft-booster separation, emergency abort, maneuverability and handling of both the fly back reusable booster and orbiter spacecraft contribute to a critically needed technology base if a successful space transportation system is to be developed. Research efforts in FY 1972 will be closely tied to these problems. Extensive wind tunnel investigations will be undertaken as well as analytical efforts to provide a sound basis for solution to these problems.

Research will be continued in FY 1972 on aerothermodynamic problems of unmanned planetary probes with a major effort directed toward development of a technology base for a Jupiter probe. The planet Jupiter is the largest planet in the solar system and, like the Sun, appears to be composed largely of hydrogen and helium. Jupiter is of intense interest to astronomers and life scientists since its atmosphere is like the primordial atmosphere often postulated for earth at the time life began. Future program plans may include vehicles to be sent into Jupiter which will enter the Jupiter atmosphere at speeds as high as 5 1/2 times the speed of Apollo upon return to the earth from the moon. The high entry speed will require new heat protection concepts to protect the probe from heating levels two to three orders of magnitude greater than that experienced by Apollo. Research in FY 1972 will concentrate on this complex heating problem, utilizing both theoretical and experimental work in our research Centers. As part of this effort, existing facilities will be upgraded to achieve radiative and convective heating levels necessary to adequately simulate Jupiter probe heating.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1972 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY

NUCLEAR POWER AND PROPULSION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The overall aim of the Nuclear Power and Propulsion program is to provide the technology and flight qualified space nuclear power and propulsion systems to meet the current and future needs of the nation's space objectives. Significant advances in space power and propulsion will become increasingly important as the space program undertakes more ambitious missions. While the detailed nature and specific pace of post Apollo activities have yet to be determined, the general outlines contain objectives that require increasing amounts of energy for both power and propulsion. Nuclear energy is expected to play an increasing part in fulfilling these needs. This program is conducted in cooperation with the Atomic Energy Commission.

The program is composed of three parts, nuclear power, nuclear propulsion, and electrophysics. The objective of the NASA nuclear power effort is to obtain the experimental and analytical data needed for the evaluation and development of the energy conversion equipment to be used in advanced nuclear electric power generating systems as well as to obtain necessary data required for the proper integration of nuclear power systems into practical spacecraft systems.

Nuclear propulsion objectives are to provide the technology for development of a reusable nuclear rocket system, to extend the technology of fission propulsion to the useful physical limits for space propulsion and to explore the feasibility of fusion energy sources for space missions. Development effort on the NERVA 75,000 pound thrust flight weight engine has been reduced, but work will continue on selected long lead time components to preserve the capability to move forward with this highly efficient rocket development when the need arises.

The objective of electrophysics research is to provide new knowledge of wave (gamma to infrared) and particle (electron-nucleus-atom-molecule) interactions underlying the advances in design and construction of magnetoplasmadynamic fission and controlled fusion space power and propulsion systems which may pave the way for significant advances in future space vehicles.

SUMMARY OF RESOURCES REQUIREMENTS:

	1970	1971	1972
Nuclear power research and technology	$16,952,000	$13,900,000	$9,320,000
Nuclear propulsion	36,317,000	38,000,000	15,000,000
NERVA	(27,120,000)	(32,000,000)	(9,900,000)
Nuclear propulsion research and technology	(7,682,000)	(5,000,000)	(5,000,000)
NRDS operations	(1,515,000)	(1,000,000)	(100,000)
Electrophysics	2,000,000	3,300,000	3,400,000
Total	$55,269,000	$55,200,000	$27,720,000

Distribution of Program Amount by Installation:

Manned Spacecraft Center	$100,000	---	---
Marshall Space Flight Center	1,819,000	$1,600,000	$1,000,000
Goddard Space Flight Center	350,000	213,000	60,000
Jet Propulsion Laboratory	3,684,000	3,594,000	3,200,000
Ames Research Center	250,000	340,000	475,000
Langley Research Center	350,000	565,000	525,000
Lewis Research Center	14,578,000	12,670,000	9,135,000
Space Nuclear Systems Office	33,568,000	35,300,000	13,325,000
NASA Headquarters	570,000	918,000	---

Nuclear Power Research and Technology

The primary objective of the nuclear electric power generation effort is to obtain the experimental and analytical data needed for the evaluation and development of the energy conversion equipment to be used in advanced nuclear electric power generating systems and certain related nuclear heat source activities, as well as to obtain necessary data required for the proper integration of nuclear power systems into practical spacecraft systems. The AEC portion of this program is concerned with the research and development on isotope and nuclear heat sources which will be utilized with NASA power conversion equipment.

During FY 1971, the SNAP-19 RTG's, which were built by AEC for Nimbus III and launched on April 14, 1969, continued to furnish useful power to the weather equipment aboard the spacecraft. The Goddard Space Flight Center, which managed the Nimbus III program, is conducting studies to assess the role of more advanced RTG's, such as envisioned by the AEC multi-hundred watt technology, for future advanced earth observation satellites.

AEC-developed SNAP-27 power sources were placed on the moon during the Apollo 12 and 14 lunar landing missions. The SNAP-27 carried on Apollo 12 passed its design life of one year of operation on the moon on November 19, 1970, and continues to exceed its design power by providing 73 watts to the various experiments emplaced on the moon by Astronaut Bean. Additional SNAP-27's are planned for the remaining Apollo lunar landing missions.

During FY 1971, technical support was provided for Pioneer F and G and Viking Mars Lander missions which will use modified SNAP-19 RTG's now under development by the AEC.

During FY 1972, work will be continued to identify and resolve RTG/spacecraft interactions and problems and to improve the utility of scientific instrumentation aboard RTG-powered spacecraft as well as to determine the stability and long-term performance and reliability of RTG's.

The Brayton cycle power conversion technology effort continued to show good results during FY 1971. A Brayton power system using electrical heat completed its planned 2500-hour test under vacuum conditions in the Plum Brook space power facility. The test provided performance data over a range of turbine inlet temperatures from 1230°F to 1600°F and a power range from 3 to 12 KWe. Net system efficiencies higher than 25% were obtained under design conditions. This high system efficiency is very desirable to minimize requirements for costly isotopes. In addition, many thermal cycles have been run without any apparent damage to the system's unique gas bearings. To reduce costs, automatic, unattended running of a turbine-alternator-compressor and heat exchanger assembly has been accomplished, and more than 1400 hours of unattended operation have been demonstrated. During FY 1972, testing of a Brayton engine and components will be continued in preparation for power system testing with a high temperature heat source under development by the AEC.

A more efficient Brayton cycle conversion system will replace the mercury Rankine system in the tests planned with zirconium-hydride reactor in the Plum Brook space power facility. These investigations may include other available power systems in addition to the Brayton cycle. The reactor/Brayton system is being designed to operate over the power range from 15 to 100 KWe and can utilize the same rotating unit with advanced reactors operating at temperatures up to 1600°F. During FY 1972, assembly of components of this system for later tests will be conducted.

The advanced alkali metal Rankine and thermionic reactor efforts are aimed at the two objectives of very low specific weights and very low radiator areas in the power range from hundreds of kilowatts to a few megawatts. Eventual applications will be for very high power earth orbital and electrical propulsion uses. The Rankine system is a turboalternator system which builds upon the experience in both the mercury Rankine and Brayton cycles but extends operation to higher temperatures than have yet been achieved. The thermionic

system uses static converters for the direct production of electricity at even higher temperatures. In some concepts, the thermionic reactor might be a useful power system below 100 KWe for early nuclear electric propulsion uses or earth orbital requirements.

The advanced Rankine effort continues to emphasize the development of a sound component technology base. During FY 1971, testing of various components were continued. A full scale 300 KWe potassium boiler tube completed 2750 hours of stable performance. The potassium boiler feed pump completed 10,000 hours of endurance testing with no signs of deterioration. The three stage potassium test turbine completed 5000 hours of operation with only minor erosion observed. Work in FY 1972 will emphasize material and component technology necessary for assessment and test of this system.

During FY 1971, much progress in the thermionic technology effort was achieved. It produced needed information on emitter fuel combinations, ceramic-metals seals, radiation effects on insulator materials, joining of refractory materials and overall diode and system assessment. During FY 1972, research and development will be continued on a broad range of problems including in-pile characteristics of fuels, emitters and insulators, materials research, and assembly techniques.

Nuclear Propulsion

The overall aim of the nuclear propulsion effort is to provide a significant increase in propulsion capability for future space activities. A major objective has been to develop a 75,000 pound thrust engine, NERVA, for incorporation in a reusable nuclear stage. Apart from NERVA, the effort includes several research and technology activities. The objectives of these activities are: (1) to provide support to NERVA development, (2) to provide for the continued improvement of nuclear rocket performance, (3) to provide the base of information for the development of a nuclear stage, and (4) to investigate the feasibility of advanced propulsion concepts.

The advantages of nuclear propulsion over chemical propulsion result from its high payload performance, propulsion efficiency and versatility. In the types of missions involving high energy and large payload, specific impulse becomes an extremely important performance requirement. It will provide approximately twice the specific impulse of the best chemical rockets. NERVA could be incorporated in a reusable nuclear stage as an integral part of a new capability for space transportation and used to move men, spacecraft and supplies between earth orbit and lunar orbit and between low earth orbit and geosynchronous orbit. The same engine also could be applied in single use application, e.g., as the primary propulsion for a nuclear stage on a high payload, fast trip to one of the planets. In both instances, the increased

propulsion energy that can be made available by NERVA can be used for any of a variety of purposes, such as to increase payloads, reduce trip times and to provide greater reliability for the completion of the mission.

Studies of reusable stages are in progress by several contractors under the supervision of the Marshall Space Flight Center. The NERVA reusable nuclear stage is visualized as an integral part of new systems for space transportation. Stage design, therefore, must be compatible with the other units of the system, e.g., the space tug, orbital space stations and especially the space shuttle.

NERVA. The 75,000 pound thrust NERVA engine is a long-duration, multicycle propulsion system which can be operated at a specific impulse of 825 seconds over a range of thrust levels with an endurance goal of 10 hours. The principal features of the engine design include the use of dual turbopumps for redundance, a full flow turbine drive cycle, internal and external shields, and a regeneratively cooled nozzle with an uncooled nozzle extension.

During FY 1971, the NERVA engine baseline design was completed and active component detailed design and development was initiated based upon design requirements derived during the baseline design definition phase. Detailed specifications for the engine and the major components and subsystems have been issued by the NERVA contractors and these have been reviewed and approved by the Government. Detailed design and trade-off studies formed a major portion of the work of the current year. In addition, some component tests were conducted. Some examples were full scale reactor cluster, hot-end and core-periphery simulated corrosion tests, and engine system component tests such as turbopump bearing tests and nozzle tube thermal tests. These component development activities to date have been aimed principally at evaluation of alternate approaches to design features of the reactor and engine components. Considerable emphasis was placed on obtaining materials data, fabrication methods, etc., which were needed to better define the baseline engine.

In 1972, effort on NERVA will be limited to a few of the critical long lead time engine components and materials and radiation testing. Emphasis will be on the design, fabrication and testing of the turbopump and its associated bearings and impellers, and the graphite nozzle extension. Engine performance specifications will be completed. Material testing will continue in both radiation and nonradiation environments. Work toward the fabrication of the first development engine will be deferred.

Nuclear Propulsion Research and Technology. The funding in this portion of Nuclear Propulsion supports research on advanced nuclear rocket propulsion concepts. Exploratory research will continue on systems which theoretically offer higher performance than the solid core NERVA system. The major thrust to this work is to identify and attack the key problems associated with establishing the feasibility of these systems for space propulsion applications.

The advanced fission systems under investigation are the gas core, coaxial flow and nuclear light bulb reactor concepts, and the fluidized, dust bed reactor concept.

The important engine characteristics that bear on the feasibility of the coaxial flow system are the uranium loss rate, the critical mass requirements, the absorption of intense thermal radiant heat flux by seeded hydrogen and reactor dynamic behavior. Cold flow, induction heated gas flow experiments, criticality experiments and reactor analyses are the major tools of research in this area. Calculations are made to interpret the research results in terms of engine performance.

The technical objectives of current research on the nuclear light bulb are to develop a plasma heat source which will duplicate the thermal environment of an engine, to demonstrate that a transparent wall can survive in the combined thermal/nuclear environment of a closed cycle reactor, and to demonstrate that seeded propellant can be heated by thermal radiation to the temperature of interest for propulsion.

Research on the dust bed reactor concept is aimed at demonstrating the feasibility of a rotating fluidized bed reactor through combined experimental and analytical programs which attack the key conceptual problems. Potentially, high temperature and high specific impulse can be achieved up to the limits of fuel particle melting and sintering properties. Research in the immediate future will be directed toward the definition of the relationships between the fluid mechanics, core geometry, heat transfer and neutronics in order to establish a conceptual design for use in future analyses.

Nuclear Rocket Engine System Technology. The research activities conducted in this area are aimed at providing improved components and materials for solid core nuclear rocket engines as well as a general base of information on the design, operation, reliability and maintainability of nuclear rocket engine components in the nuclear space environment.

During FY 1972, the emphasis of research on nuclear rocket engine components will be on failure physics, the prediction and detection of failures for all components of a propulsion system, and on providing the components technology and control system techniques for advanced high power density and high specific impulse propulsion systems. The work on hydrogen properties evaluation will be directed toward the characterization of hydrogen slushes, colloids and gels; fluid mechanics; and heat transfer analyses to determine the advantages of each from the standpoint of storability and handling. Solid (frozen) hydrogen will also be studied to determine the feasibility of utilizing this state of hydrogen for space missions.

In addition to the above, experiments will be conducted in a test reactor to study radiation damage to inorganic solid film lubricants and various reactor structural materials.

Nuclear Vehicle Technology. The objective of this activity is to provide the technology and define the requirements for the design and development of a reusable nuclear stage. The effort includes the investigation of orbital maintainability, reliable long life instrumentation, techniques and designs for the delivery of nuclear stage modules to orbit, and the investigation of advanced stage structures. A start was made on technology in all of these areas, in FY 1971. This effort will be continued in FY 1972.

The maintainability effort is concentrated in two areas: one, dealing with stage systems which are maintainable in orbit, including instrumentation to provide information on systems requiring maintenance, and secondly, devices to perform the maintenance, i.e., teleoperators. The reusable stage, delivered to orbit by the space shuttle suggests approaches to maximize the tankage delivered per flight, such as orbital assembly of tanks, or automatic erection of collapsed structures. Such an approach may permit the launch of more than one tank in the space shuttle. In addition, other on-going programs will be continued. These include radiation effects testing of a limited number of promising astrionic and stage structural components, and planning and analysis of a propellant heating experiment based on the reusable nuclear stage tank size.

Nuclear Rocket Development Station Operations. This project provides for NASA's share of the cost of general support and station operations for the Nuclear Rocket Development Station (NRDS). NRDS is the national site for the ground static testing of nuclear rocket reactors and engines.

The NRDS will be put on a maintenance only basis in FY 1972. This is being done to allow future resumption of testing as needed.

Electrophysics

The Electrophysics research is conducted primarily within the NASA laboratories with complementary efforts at industrial and university laboratories. A new research result was achieved in an experiment concerned with power from a magnetodynamic plasma arrangement. It was shown that the argon gaseous plasma is at the proper conditions for the radiation of visible laser light in the axial direction. Work is continuing to obtain laser radiation in the transverse direction, and to explore the possibility of utilizing copper plasma for greater output.

Investigations will be continued of electron pairing phenomena to achieve higher transition temperature (Tc) superconductors. If achieved, such a new superconductor will reduce greatly the size and cost of accompanying cryogenic equipment for the superconductor. Magnets composed of higher Tc superconductors will be used in controlled fusion and magentoplasmadynamic space power and propulsion systems. Also there will be industrial uses such as magnet coils for motors, generators and transformers and as superconductors for electrical transmission lines and cables.

Laser research will emphasize efforts to achieve higher energy radiation from uranium plasma, flowing CO_2-N_2-He gas and chemical reactions. Chemical type lasers have the potential of simplifying greatly the laser system as no external incident energy is needed to start the laser process. It is conceptually possible that laser radiation of sufficient energy may be radiated to a space vehicle and be converted within the space vehicle for usable power. On the topic of medium energy nuclear physics, a newly modified cyclotron will be used to conduct experiments to bring experiment and theory into closer relationship regarding nuclear collisions. Newer and purer isotopes may be produced which can also be used for medical diagnosis of cancer and heart ailments.

OFFICE OF TRACKING AND DATA ACQUISITION

TRACKING AND DATA ACQUISITION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The purpose of this program is to provide responsive and efficient tracking and data acquisition support to meet the requirements of all NASA flight projects. The Tracking and Data Acquisition program is a direct and vital counterpart to the total flight program of NASA through which the conduct of all space flight missions is carried out. In addition to NASA flight projects, support is provided, as mutually agreed, for projects of the Department of Defense, other Government agencies, and other countries and international organizations engaged in space research endeavors.

Support is provided for manned and unmanned flights; for spacecraft, sounding rockets, and research aircraft; for earth orbital and suborbital missions; for lunar and planetary missions; and for space probes.

Types of support provided include: (a) tracking to determine the position and trajectory of vehicles in space, (b) acquisition of scientific data from onboard experiments, (c) acquisition of engineering data on the performance of spacecraft and launch vehicle systems, (d) transmission of commands from ground stations to spacecraft, (e) communication with astronauts and acquisition of medical data on their physical condition, (f) communication of information between various ground facilities and mission control centers, and (g) processing of data acquired from the space vehicles. Such support is essential for achieving the scientific objectives of all flight missions, for executing the critical decisions which must be made to assure the success of these flight missions, and, in the case of manned missions, to insure the safety of the astronauts.

Tracking and data acquisition support is provided by a worldwide network of NASA ground stations and an instrumentation ship, supplemented by appropriate instrumented aircraft and ground stations of the Department of Defense. These facilities are interconnected by a network of ground communications lines, undersea cables, high frequency radio links, and communication satellite circuits which provide the capability for instantaneous transmission of data and critical commands between spacecraft and the control centers in the United States from which the flights are directed. Facilities also are provided to process into meaningful form the large amounts of scientific and engineering data which are collected from flight projects. In addition, instrumentation facilities are provided for support of sounding rocket launchings and flight testing of aeronautical research aircraft.

The Research and Development appropriation provides funds: (a) for the operation and maintenance of the worldwide facilities; (b) for the procurement of equipment and for modifications to facilities to support continuing, new, and changing flight project requirements; and (c) for the investigation and development of advanced tracking and data acquisition equipment and techniques.

SUMMARY OF RESOURCES REQUIREMENTS:

	1970	1971	1972
Operations.....	$225,181,000	$217,300,000	$210,000,000
Equipment.....	41,109,000	59,800,000	42,500,000
Supporting research and technology.....	11,710,000	12,900,000	11,500,000
Total.....	$278,000,000	$290,000,000	$264,000,000

Distribution of Program Amount by Installation:

Marshall Space Flight Center	$1,560,000	$400,000	$300,000
Goddard Space Flight Center.	204,367,000	205,200,000	189,200,000
Jet Propulsion Laboratory...	52,258,000	64,300,000	55,000,000
Wallops Station.....	6,456,000	6,250,000	6,250,000
Flight Research Center.....	1,875,000	1,850,000	1,500,000
Langley Research Center.....	880,000	1,250,000	950,000
NASA Headquarters.....	10,604,000	10,750,000	10,800,000

BASIS OF FUND REQUIREMENTS:

The FY 1972 request, in total, represents a decrease of nearly 10 percent from the FY 1971 level. This decrease reflects the effect of changes in certain flight mission profiles which have allowed support reductions as well as the significant effort that has been applied in reviewing support requirements of previously launched flight projects with the objective of reducing support requirements for specific programs and identifying facility reductions consistent with these requirements. The decrease also reflects the sustaining character of the equipment program in that the request provides for maintaining a network capability to meet only the support requirements of approved programs.

Operations

	1970	1971	1972
Manned space flight network....	$78,904,000	$69,100,000	$67,100,000
Satellite network.....	44,450,000	45,700,000	43,500,000
Deep space network.....	34,863,000	39,400,000	38,000,000
Other instrumentation.....	5,275,000	5,500,000	5,100,000
Communications.....	45,140,000	39,800,000	37,200,000
Data processing.....	16,549,000	17,800,000	19,100,000
Total.....	$225,181,000	$217,300,000	$210,000,000

Continuing adjustments in network support requirements have resulted in an overall reduction in the funds requested for network operations. The experience gained in support of the Apollo program, along with a stretchout in schedule, has led to the closure of the tracking station at Guaymas, Mexico, and reductions in support requirements in the areas of logistics, programming, and communications services. As a result of the continuing review of scientific requirements for the acquisition of data from scientific, applications, and planetary spacecraft, further reductions in data acquisition support are underway. These actions include significant reductions in support to the OAO-A2, OGO, ATS and Pioneer spacecraft. In addition, there has been a continuing effort to improve station operating procedures and equipment utilization at both the stations and control centers to provide more cost effective support.

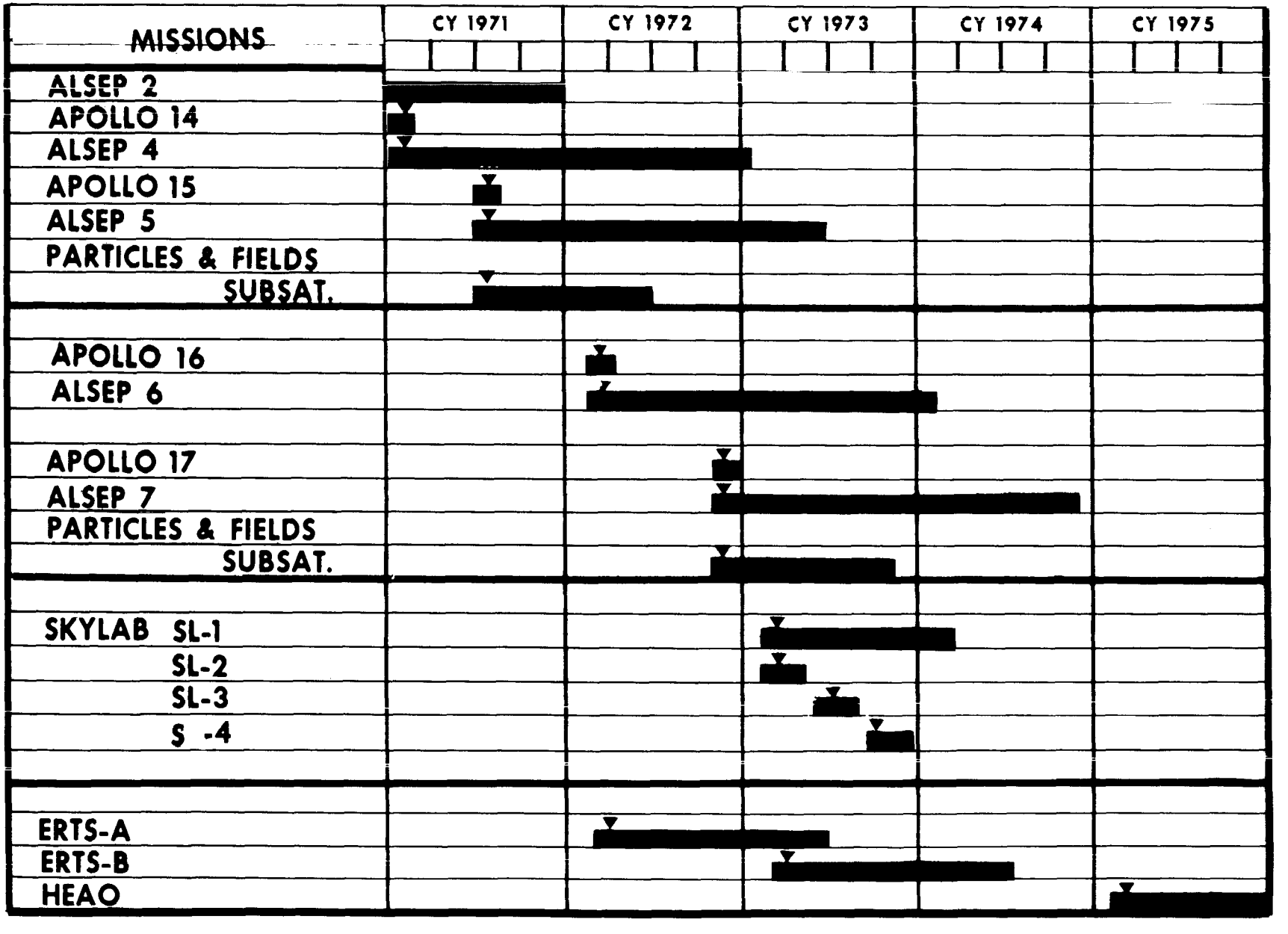
The only increase within network operations is in the funding request for data processing operations. This increase is necessary to provide for the operations and logistics of the ERTS data processing facility which will be required to handle large amounts of imaging data.

Manned Space Flight Network Operations

The Manned Space Flight Network has been designed to collect and communicate real time information regarding the precise location of both the Command and Lunar Modules as well as the Saturn launch vehicles, onboard equipment and experiments, and most importantly, the physical condition of the astronauts. The Manned Space Flight Network presently consists of 11 prime stations, four instrumented aircraft and one instrumentation ship. The network is configured to provide data in real time to the Mission Control Center at Houston, Texas, so that immediate decisions affecting the mission may be made. In addition, information from scientific experiments, both onboard the spacecraft and deployed for long term operation on the surface of the moon, is collected and processed for post flight analysis.

OFFICE OF TRACKING AND DATA ACQUISITION

MANNED SPACE NETWORK WORKLOAD



This worldwide network of stations was established initially for support of the Mercury program in early 1959 and has been periodically updated and modified to meet the requirements of the several manned space programs. As the programs became more complex, the levels of precision involved in program support correspondingly increased requiring additional capability in the network. Consequently, the Manned Space Flight Network has evolved into a highly sophisticated electronic tracking, command, communication, and telemetry system which has been successfully operated in support of the various manned missions. Throughout the manned space program, the network has continually supported the exacting requirements for tracking accuracy and reliable communications, including real time television. The tracking accuracies and reliable communications achieved by the network have contributed significantly to the precise navigation required for the pinpoint lunar landings.

The network consists of: (a) eight 30-foot diameter antenna stations located at Cape Kennedy; Bermuda; Ascension Island; Grand Canary Island; Carnarvon, Australia; Guam; Kauai, Hawaii; and Corpus Christi, Texas; and (b) three 85-foot diameter antenna stations located at Madrid, Spain; Canberra, Australia; and Goldstone, California. In addition, four instrumented aircraft, one instrumentation ship, and three 85-foot diameter antenna stations of the NASA Deep Space Network as well as the 210-foot diameter antenna facility at Goldstone provide support for Apollo. While the network provides support primarily for manned missions, selected stations of the network also provide support to unmanned deep space and earth orbital projects of NASA and the Department of Defense.

Along with the scheduled Apollo missions, the network is currently supporting the Apollo Lunar Surface Experiment Package (ALSEP) left on the moon's surface by the Apollo 12. The future landing missions will also carry ALSEPs resulting in a continuing and significant workload on the network. During FY 1972, the network will be required to support two lunar landing missions, each including an ALSEP and a ROVER and one of which will include a Particles and Fields Subsatellite, plus two ALSEPs left by previous landing missions, and a large number of unmanned missions. This overall workload is depicted on the accompanying chart.

Due to the experience gained in the successful support of Apollo missions there have been a number of adjustments in support requirements which have permitted reductions in the number of ships, aircraft, and stations. Most recently the station at Guaymas, Mexico, was closed. These adjustments in support requirements have also permitted reductions in the areas of programming, computations, and network support which are reflected in the FY 1972 request.

Satellite Network Operations

The principal function of the Satellite Network is to support NASA's un-

manned scientific and applications satellite programs. The network includes the electronic stations of the Space Tracking and Data Acquisition Network (STADAN) operated by the Goddard Space Flight Center, supplemented by the optical tracking network operated by the Smithsonian Astrophysical Observatory. The STADAN stations provide a ground system which (a) tracks each satellite, (b) determines the status of onboard systems, (c) commands the satellite functions, and (d) acquires stored or real time data from the satellite. The optical stations provide specialized services in precision orbital tracking.

The STADAN consists of ten ground stations located at Fort Myers, Florida; Mojave, California; Rosman, North Carolina; Fairbanks, Alaska; Quito, Ecuador; Santiago, Chile; Winkfield, England; Johannesburg, South Africa; Tananarive, Madagascar; and Orroral, Australia. In addition, a mobile facility is being renovated at Mojave, California, prior to relocation for ATS F and G support.

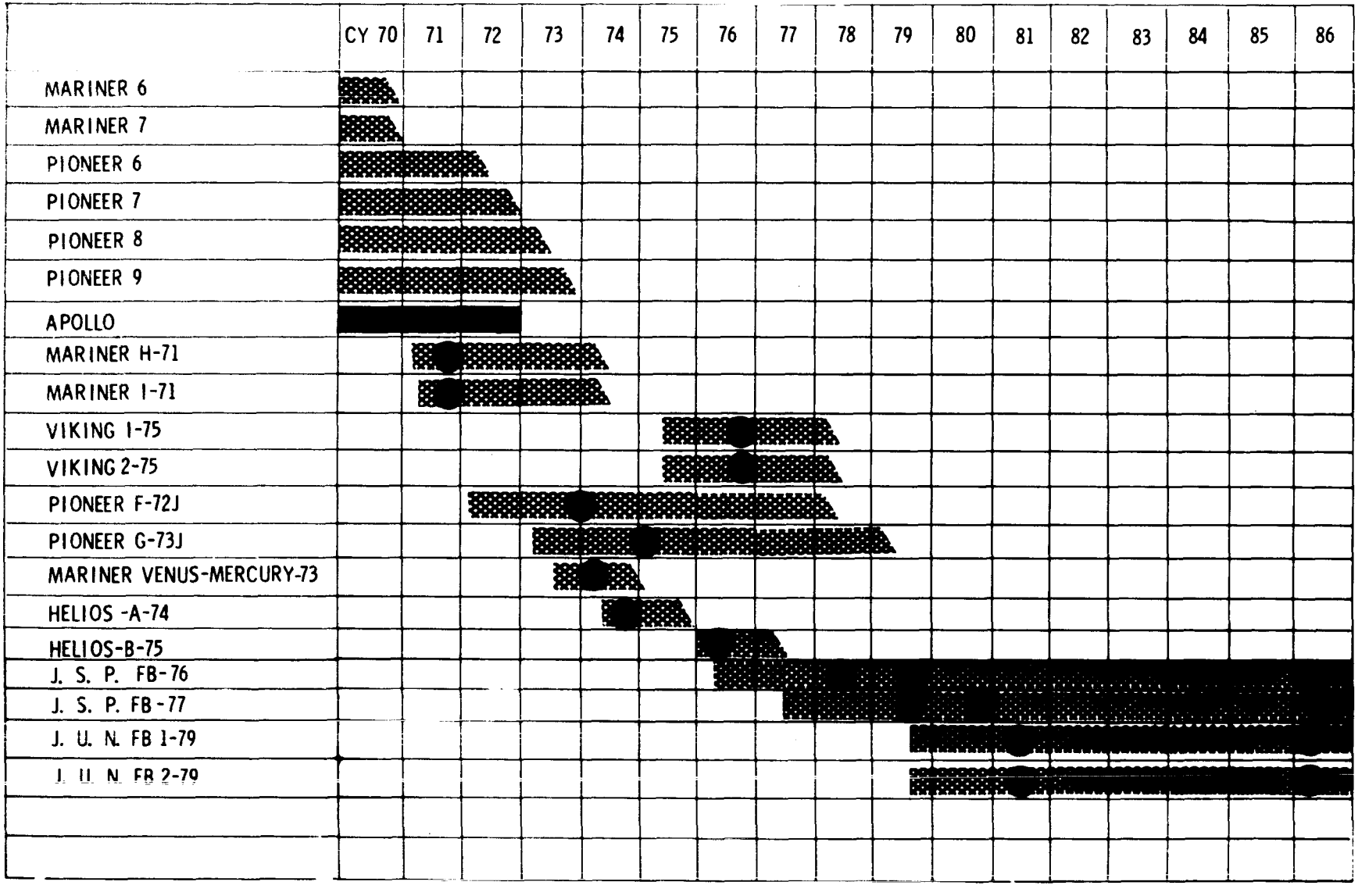
Since the early days of NASA, there have been continuing reviews of the scientific requirements for the acquisition of data from spacecraft in orbit. These reviews have been intensified in recent years. As a result, several stations have been closed and operations have been reduced at other locations. Further reductions in support will be necessary in FY 1972 in order that the support requirements of high priority satellites can be met. Currently under consideration are curtailment of data acquisition support to the OAO-A2, OGO and ATS spacecraft. Savings resulting from these and similar actions are reflected in the FY 1972 request which in total is below the FY 1971 level.

The number of satellites requiring support in FY 1972 is expected to be slightly below the number that is presently being supported, but the average workload will continue to be approximately 40 satellites representing a total of some 235 experiments. With eleven new satellites scheduled for launch in FY 1972, it will be necessary to make continuing adjustments in priorities of all satellites supported in order to assure adequate coverage within the network capability. Of the new satellites to be launched, the ERTS-A and OAO-C missions will impose a substantial workload on the network due to their unique support requirements.

Deep Space Network Operations

The primary function of the Deep Space Network is to support planetary and interplanetary space flight missions. These missions range to extreme distances, hundreds of millions of miles from the earth. As a result of these great distances, the facilities in this network must be able to perform critical functions at extremely low signal levels. As flight distances continue to increase, to the vicinity of Jupiter, for example, techniques and equipment designs are required in this network which truly push the state of the art in long distance communications.

DEEP SPACE NETWORK LOAD



The Deep Space Network: (a) provides tracking data which are used to determine and make corrections and changes to spacecraft trajectories, (b) acquires engineering telemetry data concerning performance of the spacecraft, (c) transmits commands to the spacecraft, and (d) receives and records the scientific and engineering data which are acquired from the spacecraft. The network stations are located at Goldstone, California; Woomera and Canberra, Australia; Madrid, Spain; Johannesburg, South Africa; and Cape Kennedy, Florida.

The control center for the Deep Space Network is the Space Flight Operations Facility (SFOF) located at the Jet Propulsion Laboratory in Pasadena, California. The SFOF: (a) receives information transmitted via ground communications from stations of the Deep Space Network, (b) processes the data, (c) displays the resulting information so that mission directors and associated project personnel can analyze mission performance and make critical decisions in near real time concerning functions to be executed by the spacecraft, and (d) sends instructions to the stations for commands that must be transmitted to the spacecraft.

During FY 1971, the Deep Space Network workload consists of four Pioneer spacecraft, the two Mariner 1969 spacecraft in the extended mission phase, the Apollo manned lunar missions, and the two Mariner 1971 spacecraft. The major portion of this workload, reflected in the accompanying workload chart, will continue on into FY 1972 along with support of the Pioneer F mission which is scheduled to be launched in the third quarter of FY 1972.

Extensive network engineering, programming, and computational support is necessary to meet the support requirements of the cruise, encounter, and orbital phases of the two Mariner 1971 spacecraft and the Pioneer F Jupiter fly-by mission. The complexity of this support for Mariner 1971 is related to the requirement for the network to support two orbiting spacecraft simultaneously in real time for an extended period. The FY 1972 request includes funds for the highly complex support for Mariner 1971 and the Pioneer F. It also includes funds for the engineering and computational support in preparation for the Pioneer G mission to Jupiter, the Mariner/Venus/Mercury 1973 fly-by mission, the Viking 1975 mission, and the Helios missions. In addition, the Deep Space Network facilities will continue to be used in ground based radio science experiments on a noninterference basis to the flight missions. The Pioneer 6, 7, 8, and 9 spacecraft are in an extended mission phase and support for these missions will be reduced in FY 1972. As a result, the overall workload will allow for a slight decrease in total costs for DSN operations.

Other Instrumentation Operations

Instrumentation systems are operated and maintained in support of sounding rocket programs conducted by Wallops Station, Virginia; and for flight

research programs of the Flight Research Center, California, and the Langley Research Center, Virginia. General purpose tracking, telemetry, data handling, recording, timing, plotting, and communications systems are provided as well as special purpose fixed and mobile optical and sound ranging (acoustical) equipment. The budget request for FY 1972 reflects a reduction in the level of support as compared to prior years.

The instrumentation at Wallops Station is operated by NASA contractors and by other Government agencies such as the National Oceanic and Atmospheric Administration, the National Bureau of Standards, the U.S. Navy, the U.S. Air Force, and the Military Sea Transportation Service.

Specialized mobile telemetry and optical equipment are maintained and operated at selected sites along the eastern seaboard, at White Sands Missile Range, and on the Bermuda Islands to support rocket flights from Wallops Station. Some of this down-Range support is operated by the Langley Research Center, which also provides telemetry stations (one fixed and one mobile) in support of its aeronautical flight programs.

The Flight Research Center operates the Aerodynamic Test Range consisting of facilities at the Edwards Air Force Base and the up-Range site at Ely, Nevada. These facilities are composed of precision radar tracking, telemetry and communications equipments which are used to support high performance aircraft research and development programs of both NASA and the Air Force. Programs supported by the Aerodynamic Test Range include various aircraft and lifting body projects, including the F-111, F-104, HL-10, X-24A, C5-A, and YF-12.

Communications Operations

NASA's global communications network (NASCOM) interconnects the NASA tracking and data acquisition facilities in operational support of all NASA projects and projects of other agencies that are supported by NASA tracking networks. It interconnects such facilities as telemetry and command control sites, launch areas, test sites, and mission control centers. The Goddard Space Flight Center operates the network and serves as its major switching point. In the interest of economy, reliability, and full utilization of circuitry, subswitching centers have been established at a number of domestic and overseas locations.

The FY 1972 budget shows an overall decrease in funds from the FY 1971 budget. While a scheduled rate increase will impact the cost of leasing domestic circuits, economies in the network will result in lower overall costs. The costs of communications satellite service in support of Apollo in FY 1972 will be reduced due to greater flexibility in the call-up and termination of circuits.

Other reductions include lower international communications tariffs and a decrease in the number of operating personnel at overseas switching locations.

Wideband communications are being installed between the Madrid switching center and the primary switching center at the Goddard Space Flight Center to consolidate all the communications circuits between these two locations. This consolidation has increased the overall efficiency of those circuits, and at the same time has provided the capability of handling larger amounts of data.

Data Processing Operations

Information received in the form of tracking and telemetry data from satellites and space probes must be processed into a form that is useful both to those performing the real time control of the space vehicle and those responsible for analyzing the scientific data acquired by the spacecraft. Support must be given to a wide variety of programs which vary from the small Explorer satellites to the large and complex Solar and Astronomical Observatories, and Applications Technology Satellites.

Tracking data are processed to provide orbital elements which are used to supply stations with predictions on future passes of the spacecraft over the stations, and to provide position information that can be used by the scientific experimenters to determine where in the trajectory of the spacecraft the scientific measurements were made. Telemetry data must be processed to: (a) separate the information obtained from various scientific experiments aboard the spacecraft, (b) consolidate information from each experiment, (c) apply the necessary scaling factors and calibrations, (d) determine spacecraft attitude, and (e) correlate these measurements with the position data mentioned above. Processed data are the primary product of the spacecraft missions and it is through reduction and analyses of these data by the experimenters that a better understanding of earth and space is achieved.

Upcoming projects require extensive premission orbit studies, including spacecraft position predictions and mutual visibility analyses. Studies are also required to work out operational methods and procedures to be used during the actual mission operations of these complex spacecraft.

The FY 1972 budget request is based upon the workload which will result from previously launched satellites that will require continued support, plus additional satellites that are scheduled to be launched during the period. The data processing workload is under continuing scrutiny along with the scientific requirements for acquisition of data from spacecraft. Beginning in the first half of FY 1970, data acquisition from a number of

lower priority spacecraft has been either completely terminated or severely curtailed. These reductions are making possible the support of new satellites launched in FY 1971 without increases in data processing capability.

In FY 1972, a major facility to support the Earth Resources Technology Satellite (ERTS) will be placed in operation. It is the large quantity of data from this series of spacecraft, and the new facility required to process the imaging data, that results in the increase in the budget from FY 1971 to FY 1972. As noted above, the collection and processing of data from older satellites have been reduced whenever possible in an attempt to offset this increase.

Equipment

	1970	1971	1972
Manned space flight network....	$11,422,000	$12,700,000	$9,100,000
Satellite network.....	9,598,000	18,100,000	13,900,000
Deep space network.....	13,168,000	20,700,000	13,000,000
Other instrumentation.....	3,937,000	3,600,000	3,300,000
Communications.....	1,816,000	3,500,000	2,200,000
Data processing.....	1,168,000	1,200,000	1,000,000
Total.....	$41,109,000	$59,800,000	$42,500,000

The tracking and data acquisition support requirements placed on the networks establish needs for equipments which are essential to provide the continual on-going support to approved programs. Funds for equipment are required to replace obsolete and wornout items, to modify existing systems to maintain compatibility with changes in flight mission objectives and associated spacecraft instrumentation, to increase the support utilization and efficiency of existing systems, and to complete or provide new systems required to support specific flight missions of approved programs. In FY 1972, emphasis will continue on sustaining the existing capability of the networks along with augmentations of equipment to meet the requirements of upcoming planetary programs (Pioneer G, Mariner/Venus/Mercury and Helios). Some equipment additions will also be required for ERTS, RAE-B, Nimbus, ATS-F, and other approved scientific satellite programs.

Manned Space Flight Network Equipment

The Manned Space Flight Network equipment program encompasses the procurement of equipment and services necessary for (1) incorporation of additional systems in the existing network to meet new requirements for manned space flight missions and appropriate unmanned missions, (2) modification of existing equipment to improve the network's operational effectiveness and

efficiency, and (3) sustaining the network's continuing capability for reliable mission support.

During FY 1971, activity in the equipment program has been primarily devoted to completion of modifications of the network's capabilities for support of the more sophisticated later Apollo lunar exploration missions and modification of network systems for support of the upcoming Skylab and Earth Resources Technology Satellite missions. These modifications will be completed in FY 1972. Additional improvements in network system capabilities are not planned in FY 1972 and the primary activity during the year will be devoted to sustaining the network in a continuing state of support readiness.

Support of the remaining Apollo lunar landing missions, the Apollo Lunar Surface Experiments Packages deposited on the lunar surface by Apollo 12 and later Apollo missions, the Particles and Fields Subsatellites which will be injected in lunar orbit by Apollo 15 and 17, and the first Earth Resources Technology Satellite mission requires a continuing effort to maintain the quality and reliability of the network's systems and subsystems. Accordingly, funds are requested for equipment to be used in verification of system performance, for correction of operational deficiencies, for replacement of failure prone equipment with more reliable units, and for some minor facility modifications and repairs. Funds are also requested for provision and modification of test equipment, and for equipment modifications resulting from changes in support requirements from one mission to the next.

Satellite Network Equipment

The Satellite Network equipment program is directed toward meeting two basic objectives: (1) sustaining an adequate level of proficiency to meet the basic, composite support requirements of on-going missions, and (2) adding some specific network systems to meet the unique support requirements of approved individual flight projects.

In the sustaining equipment category for FY 1972, funds are requested to complete two equipment programs for which procurement was initiated in FY 1971. These equipments are necessary in the multimission environment in which the Satellite Network operates.

One procurement is for general purpose command encoders. Command encoders are needed which can generate and verify a wide variety of command programs that must be sent to many different spacecraft. Commands are necessary to maneuver the spacecraft, to switch scientific experiments on and off, and to issue corrective instructions to onboard electronic systems.

The second procurement is for Station Technical Operations Control (STOC) consoles. These systems will enable the stations to meet the significantly increasing requirements for real time data handling necessitated by the more

sophisticated onboard experiments. These experiments require that quick-look data be transmitted from the station to the control center in real time for status monitoring and decision making purposes. In addition, STOC centralizes routine operations at stations and provides a rapid checkout capability. Station equipment is thus made available more quickly to support successive satellite passes, thereby increasing the utilization of existing equipment.

In FY 1972, funds also are included for the on-going functions associated with maintaining a global network. These include procurement of test and calibration equipment, provision for minor facilities repairs and alterations, and minor small equipments to provide proper interface between existing and newly implemented subsystems.

The new capability category includes those equipments which are needed to meet new requirements for recently approved projects or new missions within on-going programs. In FY 1972, mission control consoles and displays and special control center software and hardware will be procured for the Earth Resources Technology Satellite (ERTS) control center. Also, in FY 1972, a control center capability for the Atmosphere Explorers -C, -D, and -E will be provided by augmenting existing equipment with computer peripherals and various control and display systems. The Atmosphere Explorer missions are characterized by a variable orbit which requires a high degree of ground control to properly perform its mission. Similarly, funds are requested for minor augmentation and modification to existing station and control center systems for such missions as the Applications Technology Satellite F and Nimbus E.

Deep Space Network Equipment

The request for funds in this category covers the procurement, modification, and implementation of hardware into the Deep Space Network. It includes funds for the additional capability required for supporting upcoming approved planetary missions as well as sustaining-type effort to keep the network operating in a reliable and effective manner.

To provide the necessary support for upcoming approved planetary missions such as Pioneer F and G, Mariner/Venus/Mercury '73, Helios, and Viking, a phased implementation plan utilizing a modular hardware approach has been underway for the past two years. Under this plan, general purpose systems for the major functions such as tracking, telemetry, data handling, and mission control are being implemented throughout the network. As general purpose systems, they serve as a base for subsequent modular additions to meet the specific support requirements which will evolve for future planetary missions. This program will be continued in FY 1972 with emphasis on providing the capability required for Pioneer G, Mariner/Venus/Mercury '73, and Helios.

As part of this program, during the past year a major effort was undertaken to provide data handling and display capabilities at a limited number of stations and at the Space Flight Operations Facility (SFOF) at Pasadena, California, to meet the Mariner '71 and Pioneer F requirements. Equipment under procurement for this purpose will have the capability of handling a wide range of spacecraft telemetry and command telecommunication requirements and is being designed to allow for minor modular augmentations as more advanced techniques for the handling of higher volumes of data become necessary for later missions. Funds requested in FY 1972 will provide for the provisioning of this capability at the remaining network stations. This item was partially deferred from FY 1971 as a result of budget constraints.

Included in the FY 1972 request are funds for the procurement of additional telemetry decoding modules to work with the specialized data formats to be used by the Pioneer G and Helios spacecraft. Procurement of these modules was started in FY 1971 for five stations to meet the more immediate Pioneer F requirements.

Funds are requested in FY 1972 for a new planetary ranging system for implementation at the three 210-foot antenna sites. This system will provide Doppler tracking and spacecraft ranging data at planetary distances which are required for the precise navigation of planetary missions. This is particularly important for multiple-planet swing-by missions typified by the Mariner/Venus/Mercury '73 mission where increased tracking accuracies over great distances are necessary.

FY 1972 funds are also requested for continued work on a dual S/X-band receiver system to be implemented at the Goldstone 210-foot antenna facility for support of Mariner/Venus/Mercury '73. This mission will have, in addition to the standard 2,300 Megahertz (S-band) telemetry system, an experiment operating in the 8,400 Megahertz (X-band) frequency spectrum to test the applicability of using X-band in subsequent planetary missions to obtain an increased data return. It is expected that the use of X-band will produce a tenfold increase in data rates. This technology is vital to the missions to the more distant planets to assure recovery of visual imaging and other science data over the great communication ranges.

Also contained in the FY 1972 request are funds for sustaining the network in support of the on-going program which will include the on-going Pioneer spacecraft, Mariner '71, Pioneer F, and Apollo. Longer critical support periods such as the Mariner '71 90-day orbital period require increased network reliability and integrity. This necessitates a continuing program to replace obsolete or high maintenance components, modules, subsystems, and to update equipment to provide the required reliability. Items normally procured for this effort are electronic modules and assemblies for the major equipment systems, module level spares, minor mission to mission changes, test and calibration equipment, simulation equipment for checkout

and training purposes, and power distribution equipment.

Other Instrumentation Equipment

A wide variety of fixed and mobile equipment is used to provide instrumentation support of sounding rockets and re-entry vehicles launched from Wallops Station and other locations, and for aeronautical flight research projects conducted by the Flight Research Center and Langley Research Center.

At Wallops Station, funds in FY 1972 are required to sustain existing capability by the provision of maintenance and spare parts, and the procurement of nonrecoverable flight hardware such as onboard antennas, transponders, and support instrumentation.

Two telemetry ground stations are operated by the Langley Research Center to support aeronautical research programs such as collision avoidance and noise abatement. The aircraft used in these programs are flown from the Wallops and Langley airfields. Funds are requested in FY 1972 to procure specialized checkout and display equipments which are necessary to adapt the ground stations to the requirements of specific flight missions.

The Flight Research Center's Aerodynamic Test Range consists of stations at Edwards, California, and Ely, Nevada, which support various aircraft and lifting body projects such as the F-111, F-104, HL-10, X-24A, C5-A, and YF-12.

During FY 1972, funds will be required for the procurement of maintenance and repair parts and for equipment modifications. Radar and telemetry display equipments require continuing modifications during the course of flight test programs due to changing requirements.

Communications Equipment

The FY 1972 budget request includes funds for the on-going sustaining effort to maintain the integrity and reliability of the NASA Communications Network (NASCOM) and to meet new requirements for approved projects. The budget further provides for funds for equipment which will improve the efficiency of the network.

The sustaining effort includes replacement spares, computer interface equipment, test and calibration equipment, and error detection equipment for routine monitoring of data circuits. Equipment will be installed to record wideband data for analysis to determine data quality. For projects with high data rates such as ERTS and Skylab, equipment is needed to switch and interface with control centers, with the terminal points of the wideband

circuits at overseas locations, and with the major switching centers. These equipments will increase the overall efficiency of the wideband communications channels since they permit channels to be switched and timeshared between users thereby reducing the overall number of wideband channels required to meet approved program requirements.

Data Processing Equipment

The operational data processing equipments require a continuing program of minor redesign, modification, and improvement, as well as normal maintenance and repair. While the data processing lines are designed to be as flexible as possible, changes and updating are necessary to meet the new requirements of approved flight projects and to accommodate mission to mission changes within existing projects. Some additional changes are required to improve the processing speed of the data processing systems and thus minimize the need for acquisition of new processing equipment. The FY 1972 budget includes funds to provide the components necessary for these modifications and to provide for normal sustaining items such as logic modules and components, replacement spares, and modifications associated with equipment reconfigurations.

Supporting Research and Technology

	1970	1971	1972
New systems.....	$890,000	$1,730,000	$1,400,000
Integrated systems analysis, development, and test.....	3,241,000	3,560,000	3,060,000
Antenna subsystems.....	1,362,000	1,260,000	1,100,000
Receiving and transmitting subsystems.....	2,663,000	2,220,000	2,080,000
Data handling and control.....	1,540,000	1,590,000	1,340,000
Data processing and reduction..	801,000	940,000	870,000
Spacecraft subsystems.....	880,000	1,050,000	950,000
Network performance and operations technology.....	333,000	550,000	700,000
Total.....	$11,710,000	$12,900,000	$11,500,000

The purpose of the OTDA Supporting Research and Technology (SRT) program is to translate tracking and data acquisition requirements of future space missions into the ground support instrumentation capabilities and network operating techniques needed to successfully support these future flight projects. The SRT program provides the funds for the investigation, study, and development of hardware systems and operating techniques needed not only for support of specific projects but also for achieving a cost-effective and reliable overall tracking and data acquisition capability to support the total mix and variety of flight projects.

Work will continue in FY 1972 on technology for achieving greater efficiencies and economies in network support of the flight programs; particularly on the automation of selected station and network functions, on the wideband data communication concept to minimize the data handling functions now required at the individual stations, and on the application of mass data storage technology to the central data processing functions.

Effort will continue in FY 1972 on the data relay satellite approach to tracking and data acquisition support of earth orbiting satellites. This program is keyed to operational requirements along with an increased support capability for the era of the space shuttle and its associated scientific and applications investigation programs.

In FY 1972, work will continue on achieving effective and economical support of the advanced planetary missions. These future planetary programs need ground instrumentation to handle higher telemetry rates and to obtain data for improved tracking accuracies, all of which are transmitted over record distances. In addition, the missions themselves will be more complex in that they will require multiple spacecraft support, extremely reliable command links, and special techniques to measure and correct for the influence of charged particles in space on signal propagation and tracking accuracies. Network and mission control techniques to cope with these future problems are planned for study and development in FY 1972.

The foregoing activities highlight the major efforts planned for FY 1972 within the funds requested for Supporting Research and Technology. The program for SRT comprises these and other efforts in eight task areas as follows:

New Systems

All of the OTDA-sponsored studies on the Tracking and Data Relay Satellite System (TDRSS) are included in the New Systems category. Work will continue in FY 1972 on preliminary development and definition of the system with emphasis on both spacecraft configuration and cost factors. A Delta launched relay satellite configuration will be used as the base for studying overall system trade-offs against other promising relay satellite configurations. Data from this study will be used in determining the optimum configuration of such a system.

Integrated Systems Analysis, Development, and Test

Work under Integrated Systems Analysis, Development, and Test is being conducted to test and evaluate subsystems and techniques in a real or simulated network operating environment prior to implementation in the stations and control centers. FY 1972 effort includes studies to consolidate and optimize the networks for cost-effective support of future earth orbiting

missions, developments and tests of the spacecraft transponder for the S- and X- band experiment on the Mariner mission in 1973, advances in orbit determination techniques, and work on problems in radio interference and operational frequency management.

Antenna Subsystems

In the category of Antenna Subsystems, work will continue at a somewhat reduced level on studies of new techniques and developments in antenna feeds, drives, controls, and other components needed for making existing antennas capable of meeting future flight program requirements. Development of multi-frequency feeds and digital control techniques for rapid changeover from mission to mission will continue.

Receiving and Transmitting Subsystems

Development of Receiving and Transmitting techniques and related hardware needed for effective support of future missions will include, in FY 1972, the design and test of dual frequency ranging and tracking components, high power and low noise components, exciters and modulators.

Data Handling and Control Subsystems

Under the general category of Data Handling and Control Subsystems, telemetry, command, and computer programs, are being developed along with the functional interfaces required by network managers and mission directors to make the most effective use of the networks in support of the flight missions. Plans for FY 1972 include the development of software for proper interface of STOC with other functional elements of the stations, developments needed for high reliability data handling, and new data coding techniques for improving the data return for advanced planetary missions.

Data Processing and Reduction Subsystems

Work will continue on data processing and reduction subsystems to develop the data processing and control center subsystems and computer programs needed for cost-effective processing and reduction of data which are gathered in the performance of the missions. Effort in FY 1972 includes studies for applying mass storage technology to reduce data handling costs and to provide more rapid access to the acquired data by the users. Work to develop a multiple mission telemetry and command capability for the Deep Space Network will continue and will include a central monitoring and control capability.

Spacecraft Subsystems

In order to promote the application of aerospace data standards in the development of common usage spacecraft equipment for both telecommunications

and onboard data management, the SRT program sponsors a relatively modest effort in spacecraft subsystems development. In FY 1972, development will continue on a solid state, VHF transponder and also on a unified frequency S-band transponder for general application in unmanned scientific application satellites. The development of a dual-frequency (S/X) transponder for planetary mission tracking will be completed in FY 1972. Developments will be continued for a modular-type, onboard central processor for onboard data management for use in unmanned spacecraft.

Network Performance and Operations Technology

In this task area, the performance and limitations of the networks as a total system are determined and overall operating techniques are studied for improving the cost-effectiveness of tracking and data acquisition support. In addition to the ongoing effort in post flight analysis and systems evaluation, work will be initiated in FY 1972 to study the impact of the use of wideband communications on data management.

OFFICE OF INDUSTRY AFFAIRS AND TECHNOLOGY UTILIZATION — TECHNOLOGY UTILIZATION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

This program provides for the Nation's scientific, engineering, educational and medical communities, awareness and access to new scientific and technological and managerial developments that become available as a result of the conduct of NASA's mission oriented research and development programs. This program implements the basic principle that scientific, technological and management knowledge developed with public support be made available to the public for its benefit in as expeditious and efficient a manner as possible. New developments of use to the aeronautics and space industry are applied almost automatically within that industry. These same innovations have potential benefit as well to the nonaeronautics and space community. It is the primary purpose of this program to develop and establish systems and mechanisms to identify, evaluate, publish and transfer these innovations to the general public.

The primary objectives of the NASA Technology Utilization program are: (1) to increase the return on the national investment in aerospace research and development by encouraging additional uses of the knowledge gained in those programs; (2) to shorten the time gap between the discovery of new knowledge and its effective use in the marketplace; (3) to aid the movement of new knowledge across industry, disciplinary, and regional boundaries; and (4) to contribute to the knowledge of better means of transferring technology from its points of origin to its points of potential use.

SUMMARY OF RESOURCES REQUIREMENTS:

	1970	1971	1972
New technology identification and evaluation.....	$650,000	$435,000	$625,000
Publication.....	1,020,000	490,000	665,000
New technology dissemination.....	2,775,000	2,585,000	2,230,000
Program evaluation.....	555,000	490,000	480,000
Total.....	$5,000,000	$4,000,000	$4,000,000
Distribution of Program Amount by Installation:			
NASA Headquarters.....	$5,000,000	$4,000,000	$4,000,000

BASIS OF FUND REQUIREMENTS:

New Technology Identification and Evaluation

Technology utilization officers at NASA field installations and specialists from universities, research institutes and private industry search through selected areas of scientific and technical endeavor, and identify and document those inventions, innovations, improvements, and discoveries that have potential utility to the nonaerospace sector of the economy. These discoveries are evaluated according to potential nonaerospace use criteria by competent technical personnel at nonprofit research institutes and at NASA field installations, prior to final documentation and dissemination.

Publication

The systematic publication through announcements of single innovations to major surveys of contributions to the state-of-the-art in broad technology areas continues to be an important element of the transfer of technology. This is accomplished through preparation of reports and comprehensive surveys by private and nonprofit contractor sources. These reports are disseminated broadly through various governmental mechanisms and the private technical trade media.

New Technology Dissemination

This program element is accomplished by the employment of regional dissemination centers that store, retrieve and interpret the new technology developed by NASA and work to transfer this new technology to industry. Biomedical application teams are also employed to assist medical and clinical researchers in defining and solving medical problems by adaptation of NASA technology. In addition, government-developed computer software is evaluated and disseminated to industry. Technology applications teams are developing cooperative programs with several other agencies such as the Air Pollution Control Office and the Water Pollution Control Office of the Environmental Protection Agency, Law Enforcement Assistance Administration, Social Rehabilitation Service of HEW, Small Business Administration and others. These joint efforts are designed to bring applicable aerospace technology to bear on technical problems in areas of major national concern such as environmental quality, law enforcement and rehabilitation of the handicapped.

Program Evaluation

Independent research institute personnel are continually evaluating technology transfer mechanisms and feeding the new knowledge so gained into the Technology Utilization program.

U. S. GOVERNMENT PRINTING OFFICE : 1971 O - 411-081