National Aeronautics and Space Administration

BUDGET ESTIMATES

FISCAL YEAR 1971

Volume II

RESEARCH AND DEVELOPMENT

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1971 ESTIMATES

RESEARCH AND DEVELOPMENT

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT

GENERAL STATEMENT

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

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

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

MANNED SPACE FLIGHT

The largest portion of the budget request, although substantially less than in previous fiscal years, continues to be in support of the Manned Space Flight activities. The historic flight of Apollo 11, on July 20, 1969, accomplished the national goal of landing men on the moon and returning them safely to earth. Having met its initial objective, the program continued with Apollo 12 in November 1969 in its quest to expand man's knowledge, not only of the moon, but through a study of the moon, of the earth, the sun, and the solar system. Seven more Apollo landings are presently scheduled, two in 1970, two in 1971, one in 1972, and two in 1974. Modification of basic Apollo procured hardware is planned to provide greater scientific return through improved experiment payloads, longer stay-times, and increased mobility while on the lunar surface.

The Space Flight Operations program focuses on the development of future space systems for conducting manned missions in near earth orbit supporting a variety of experiments and other activities in space. The Space Flight Operations program missions will commence with the Apollo Applications Saturn Workshop launch scheduled for 1972. This is to be the precursor to a

space station and will investigate new technological concepts, conduct experiments, and develop operational techniques applicable to the Station. The flight program for Apollo Applications consists of the following basic missions: (1) initial launch of the Saturn Workshop into orbit on the first two stages of a Saturn V; (2) activation of the Workshop and Apollo Telescope Mount (ATM) by the first flight crew launched to orbit in a modified Apollo Command and Service Module on a Saturn IB; (3) revisit and reactivation of the Workshop for up to 56 days; and (4) a second revisit also lasting as long as 56 days. The space station effort will concentrate on completion of the station module and experiment definition studies now underway and on initial station design. Definition and preliminary design of a recoverable and reuseable Space Shuttle to reduce the cost of space activities and provide convenient and economical transportation to and from earth-orbit is also proposed in this budget.

In the area of 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 the technical information upon which to base future program decisions.

SPACE SCIENCE AND APPLICATIONS

The FY 1971 Research and Development budget provides for the expansion of an applications program which permits the utilization of space technology for the practical benefit of man and the continuation of a space science program designed to increase human knowledge through space research.

The expanded applications program includes research on Meteorological phenomena and their prediction, utilizing Tiros, Nimbus, and Synchronous Meteorological Satellites in addition to Sounding Rocket probes.

Applications Technology Satellites are being used to demonstrate and test techniques in communications, navigation, and air traffic control.

The Earth Resources Survey activity will utilize aircraft and satellites to test sensors and techniques for increasing our knowledge of the earth's natural resources.

Measurements, on a global basis, of the size and shape of the earth and its features will continue using Geodetic satellites.

In addition, studies will be initiated in FY 1971 to (1) determine the proper project approach for U. S. participation in the Global Atmospheric Research Program (GARP) - a worldwide, international program directed toward obtaining data for increasing our understanding of the general circulation of the atmosphere and aiding in long-range weather prediction, and (2) study and design of a spacecraft system with the capability of improving navigation and traffic control services to ships and aircraft from over-ocean areas.

The scientific program encompassed within this activity is largely geared to extending man's knowledge of the solar system and the physical phenomena and interactions between and among the components of this system. In addition, investigations relating to our galaxy and other stars, galaxies and nebulae are conducted.

Investigations of phenomena associated with the earth and its interaction with its environment will be continued using: Geophysical Observatories already aloft, a series of small special purpose explorers, aircraft, balloons, and sounding rockets. Solar studies will continue with additional Solar Observatories.

The exploration of the planets will be extended with the launch of two Mars orbiting spacecraft in 1971, Jupiter probes in 1972 and 1973, a Venus/Mercury flyby in 1973, and two combined Orbiter-Lander systems (Viking) to Mars in 1975.

Investigations of phenomena occurring beyond the solar system will continue utilizing Astronomical Observatories and explorers, sounding rockets, aircraft, and ground based observations.

Funds are also included for additional scientific planning of lunar missions and biological studies and for analysis of data returned from previous flights.

ADVANCED RESEARCH AND TECHNOLOGY

The Advanced Research and Technology effort is a continuing program aimed at providing the essential technological base for significant future aerospace missions, such as Space Shuttle and Space Station. This effort covers the spectrum of activity from basic research to improve our fundamental scientific knowledge, through applied technology to improve our practical capability for developing advanced systems applicable to both space and aeronautical activity. The specific areas of effort in the program are Basic Research, Space Vehicle Systems, Electronics Systems, Human Factor Systems, Space Power and Electric Propulsion Systems, Nuclear Rockets, Chemical Propulsion and Aeronautical Vehicles. During FY 1971, specifications for all of the nuclear powered rocket engine components will be completed and the preliminary design review of the engine system and components will be conducted. The aeronautics program includes increased emphasis on aircraft noise reduction, flight test of V/STOL concepts, and a broad range of applicable research of importance to the nation's position of leadership in aeronautics.

TRACKING AND DATA ACQUISITION

The objective of the Tracking and Data Acquisition Program is to provide the ground 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 1971 at a reduced level. Activity in support of the planetary program will increase compared to the current year's level in preparation for the workload in the early to mid seventies.

Funds in FY 1971 for replacement and improvement of equipment and for facility maintenance will remain at a constrained level to provide the on-going network support required for previously approved projects. The major augmentation in FY 1971 is for the capability required to support the approved planetary program in the 1971 - 1975 period. The Supporting Research and Technology effort will continue at a constrained level but will include a small increase for studies on the Tracking Data Relay Satellite System (TDRSS) and on X-band telecommunications techniques.

SUSTAINING UNIVERSITY PROGRAM

The Sustaining University Program has brought the educational community into the space program through new laboratory facilities, training of highly capable individuals, and the carrying out of multidisciplinary research which has made unique contributions to space activities. This involvement will now be phased out in an orderly manner, and university participation will be primarily devoted to project oriented efforts.

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: (a) assuring that all new knowledge is identified, collected and evaluated, and (b) announcing and disseminating this new knowledge to assure its wide application and utilization.

FINANCING

The FY 1971 Research and Development program plan discussed in this budget totals $2,606,100,000, a reduction of $507,665,000 below the FY 1970 program of $3,113,765,000.

Research and Development expenditures for the current fiscal year are estimated at $3,150,000,000 and at $2,638,000,000 for FY 1971, a reduction of $512,000,000.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1971 ESTIMATES

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

BUDGET ACTIVITY	OFFICE/PROGRAM	Fiscal Year 1969	Fiscal Year 1970	Fiscal Year 1971
	MANNED SPACE FLIGHT.....	$2,177,500,000	$2,031,745,000	$1,474,200,000
1a	Apollo.....	2,025,000,000	1,686,145,000	956,500,000
1b&c	Space flight operations.	150,000,000	343,100,000**	515,200,000
1d	Advanced missions.....	2,500,000	2,500,000	2,500,000
	SPACE SCIENCE AND APPLICATIONS.....	453,238,000	519,718,000	565,700,000
2a	Physics and astronomy...	128,850,000	111,835,000	116,000,000
2b	Lunar and planetary exploration.....	87,923,000	151,013,000	144,900,000
2c	Bioscience.....	37,900,000	19,670,000	12,900,000
3	Space applications.....	98,665,000	128,400,000	167,000,000
*	Launch vehicle procurement.....	99,900,000	108,800,000	124,900,000
	UNIVERSITY AFFAIRS			
6b	Sustaining university program.....	9,000,000	7,000,000	---
	ADVANCED RESEARCH AND TECHNOLOGY.....	278,220,000	272,302,000	264,200,000
4&5	Basic research.....	20,220,000	18,902,000	17,600,000
4	Space vehicle systems...	31,349,000	30,670,000	30,000,000
4&5	Electronics systems.....	34,460,000	33,500,000	22,400,000
4&5	Human factor systems....	19,402,000	21,900,000	17,900,000
4&5	Space power and electric propulsion systems....	38,787,000	34,450,000	30,900,000
4	Nuclear rockets.....	33,502,000	36,500,000	38,000,000
4	Chemical propulsion.....	25,752,000	20,480,000	20,300,000
5	Aeronautical vehicles...	74,748,000	75,900,000	87,100,000
6a	TRACKING AND DATA ACQUISITION.....	279,672,000	278,000,000	298,000,000
6c	TECHNOLOGY UTILIZATION....	3,800,000	5,000,000	4,000,000
	TOTAL BUDGET PLAN.....	$3,201,430,000	$3,113,765,000	$2,606,100,000

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

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

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

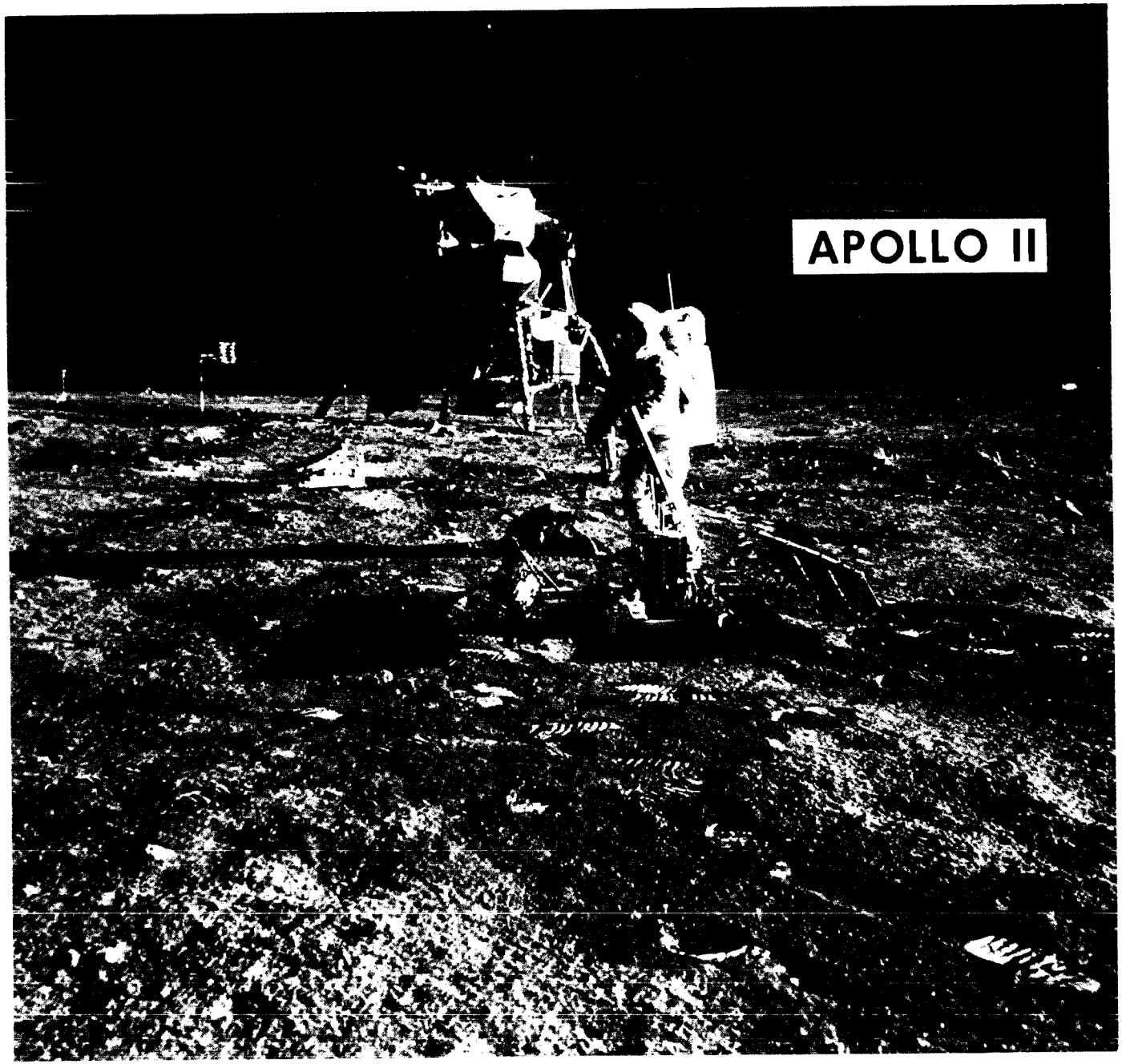
FISCAL YEAR 1971 ESTIMATES

RESEARCH AND DEVELOPMENT BUDGET PLAN FOR

MANNED SPACE FLIGHT PROGRAMS

Program	Fiscal Year 1969	Fiscal Year 1970	Fiscal Year 1971
Apollo.....	$2,025,000,000	$1,686,145,000	$956,500,000
Space flight operations....	150,000,000	343,100,000*	515,200,000
Advanced missions.....	2,500,000	2,500,000	2,500,000
Total.....	$2,177,500,000	$2,031,745,000	$1,474,200,000

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


APOLLO II

OFFICE OF MANNED SPACE FLIGHT APOLLO PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

Having accomplished the national goal of landing man on the moon and returning him safely to the earth, Apollo continues to expand man's knowledge, not only of the moon, but through study of the moon to better understand the earth, sun, and solar system. The moon is a most unique laboratory. It is the only planetary body, other than the earth, which man can investigate and study in detail. It thus provides a comparative basis for a greater comprehension of the earth, and the processes that affected the development of our planet. The moon's value to man further increases with the growing indication that it was not formed through tearing away of a portion of the earth, but rather had its own individual development. By possessing detailed information from two different and apparently independently formed planetary bodies, scientists can now develop an increased understanding of the other planets in the solar system.

Apollo 11 and 12 have discovered that the moon can be a most remarkable chronicle of the early years of the solar system and a record of events since that period. Nearly all rocks found on the earth fall within the age range of a few million years to 500 million years, with the oldest being about 3.5 billion years. The lunar dust found at Tranquility Base was dated as being 4.6 billion years old. The meaning of this very old age is not clear at this time and further work is continuing. The crystalline rocks returned by the Apollo 11 astronauts were formed approximately 3.7 billion years ago by some volcanic event. A preliminary dating of the rocks from the Ocean of Storms site of Apollo 12 indicates that these may have been formed one billion years after those in the Sea of Tranquility. Both the Apollo 11 and 12 landings were made at sites in the lunar maria which are characterized by their flatness and a lack of rough surface features such as mountains or major craters. Many now believe, based on the analysis of Apollo samples, that the maria were formed by the flooding and cooling of a vast sea of lava. Future Apollo missions, beginning with Apollo 13, will include highland areas of the moon, which are believed to be older than the maria and where rocks dating back to the very beginning of the moon may be discovered.

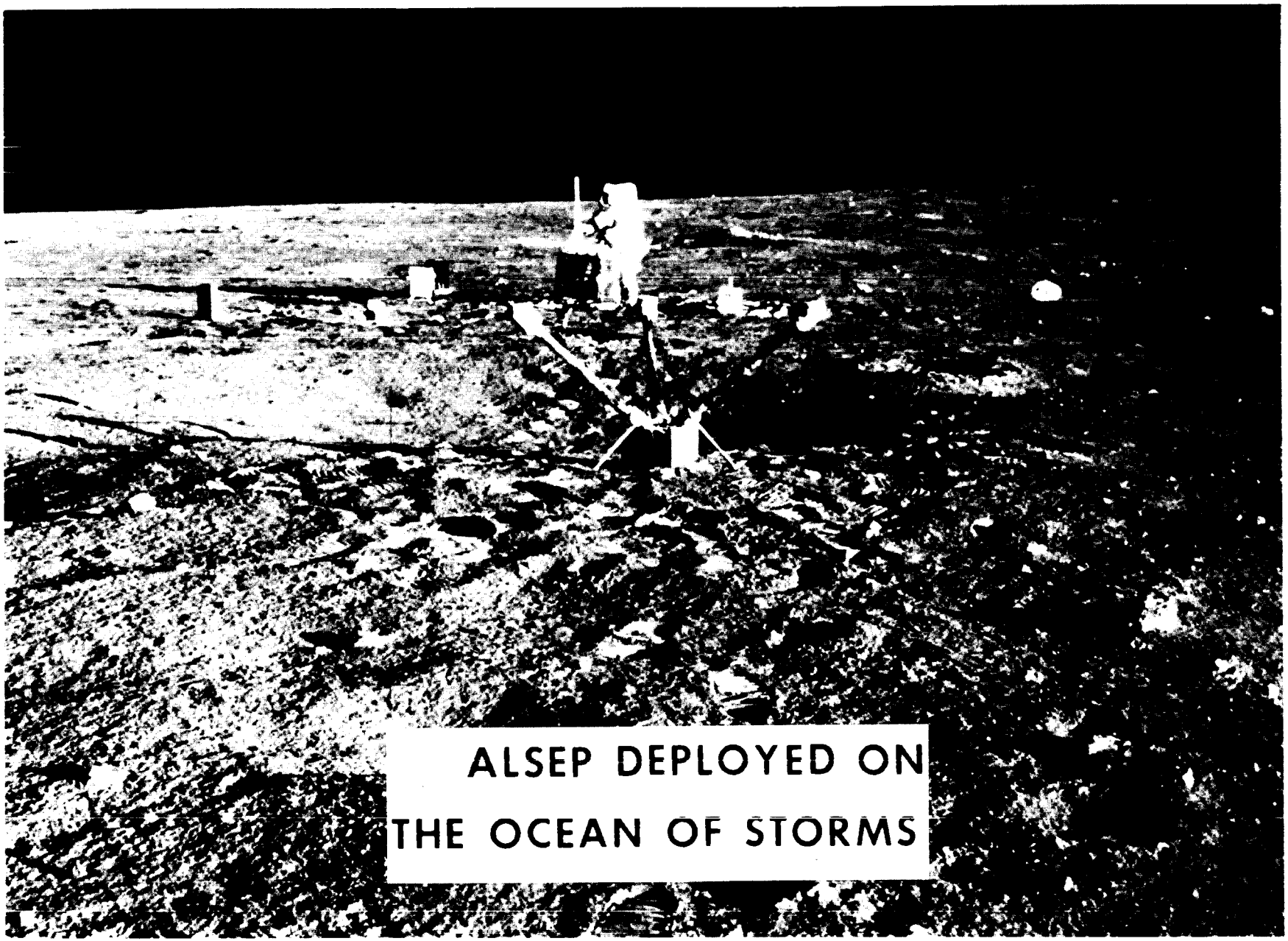
The moon appears to have preserved the history of its past since its very beginning, while on earth continuing geological phenomena combined with changes in climate and the biological processes have obliterated much of the earth's early history, and all of the first billion years.

Another discovery resulting from the analysis of the Apollo 11 rocks is that the moon, lacking an atmosphere, has been directly exposed through the eons to solar radiation, and has preserved the history of that radiation in its surface materials. By analyzing samples of the lunar surface and subsurface, scientists believe a record of the sun's activity over hundreds of millions of years can be developed, and man may be able to correlate the onset of ice ages or periods of near tropical warmth with changes in solar activity. The most recent ice age covering the northern United States was less than 15,000 years ago, and significant climatic changes have occurred in this millennium. From a study of lunar rocks, we may be able to associate patterns of solar activity with these major cyclic changes in the earth's climate.

The density of the surface material returned from Tranquility Base is approximately the same as the density postulated for the entire mass of the moon. This is quite different from the density distribution on earth, where surface rocks are about four times less heavy than the material in the center. The relationship of this finding with the nature of the internal structure of the moon is under review. Other surprising data bearing on the internal structure of the moon includes the seismic signals, as recorded by the Apollo 12 seismometer, that resulted from the impact of the Lunar Module ascent stage 45 miles from the landing point. The vibration from this impact lasted nearly 50 minutes, and took almost seven minutes to build in intensity. The implications of this finding are still under study, and the phenomenon will be subjected to further analysis when the third stage of the Apollo 13 launch vehicle is impacted onto the moon in April.

Scientists studying the Apollo surface samples have reported discovering three new minerals, unknown on earth. Very small amounts of the elements copper, silver and gold have also been reported as well as very small rubies. Although it is highly unlikely that exploitation of such valuable resources will take place in the near future, their discovery tells us much about the composition and evolution of the lunar material.

There has been some scientific theorization that new "naturally occurring" elements may be discovered on the moon. These elements, the product of fission, would possess very heavy atomic weights. Another interesting finding was the high concentration of titanium and other refractory elements, and the relative depletion of volatile elements such as lead and bismuth in comparison to earth rocks. No evidence of surface water having ever been present at Tranquility Base was detected. The surface of the moon also appears to contain a significant amount of material believed to have come from a particular type of meteorite called carbonaceous chondrite. These meteorites are extremely rare on earth, and are important for their high concentration of carbon. Carbon molecules form the underlying basis for all living organisms on earth, and the structure and arrangement of carbon molecules in nonterrestrial material is of great interest.



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During quarantine, terrestrial plants and animals were exposed to the lunar samples to observe any effects. An unexpected result was that some terrestrial plants thrived on a nutrient enriched with lunar soil and grew much larger than their counterparts planted in the control nutrient. The cause of this surprising growth is being investigated.

These initial results from man's first detailed study of material from another planetary body are his first step toward understanding the overall character of the moon, both past and present.

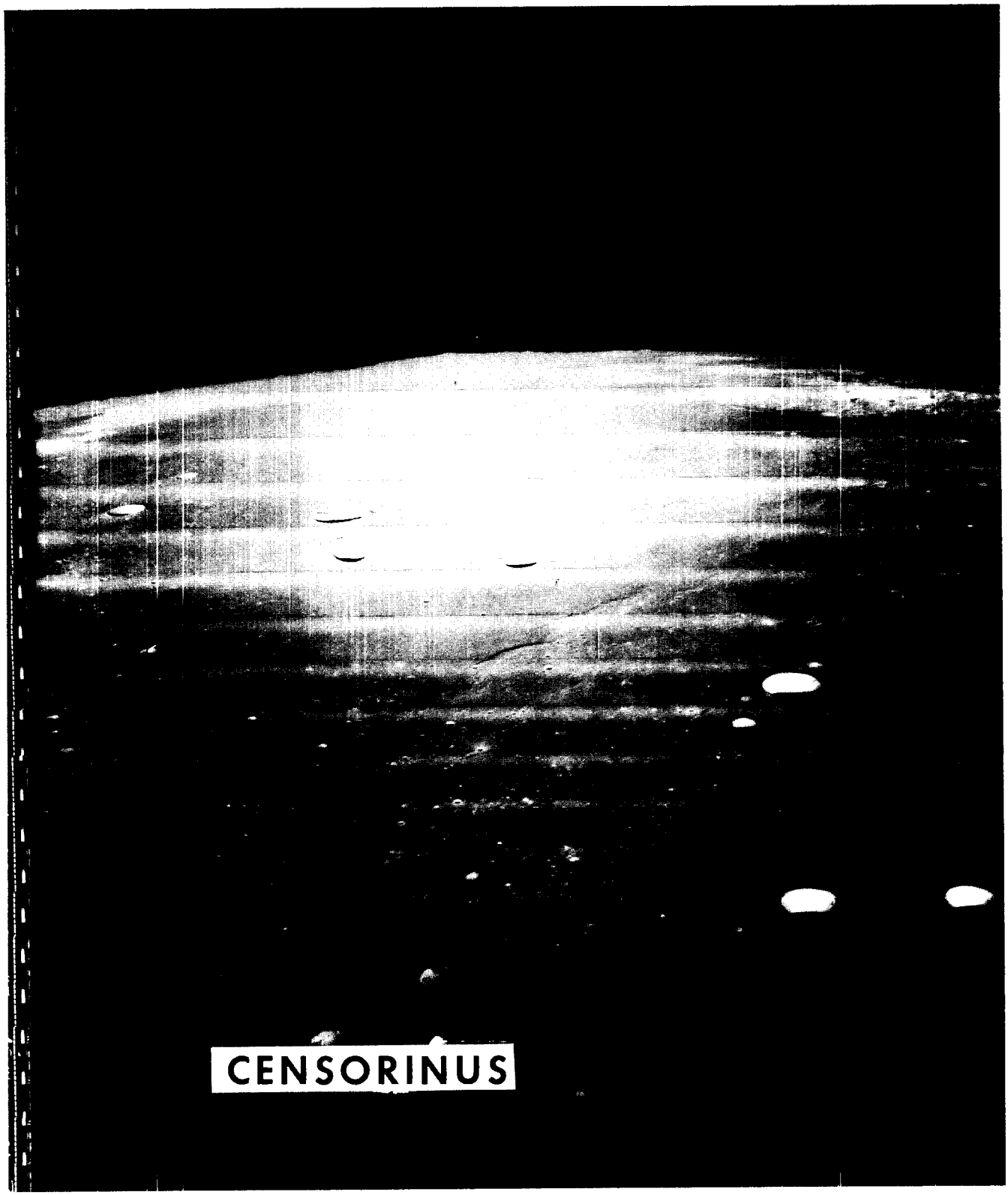
This greater understanding of the moon can also promote a greater understanding of the earth. The moon is invaluable not only because it has apparently preserved its history so well, but in so doing has provided a comparative basis by which man may examine the early history of the earth, and the earth's evolution. The laser reflector placed on the moon by the crew of Apollo 11 has been used to determine the relative earth-moon distance to an accuracy of one foot. Measurements using this reflector may prove that the earth's continents are drifting apart, and have been doing so for several hundred million years. Over a period of years, accurate distance measurements will give us precise information on the Chandler Wobble of the earth's axis which is thought to be related to major earthquakes and thus, possibly make such events predictable.

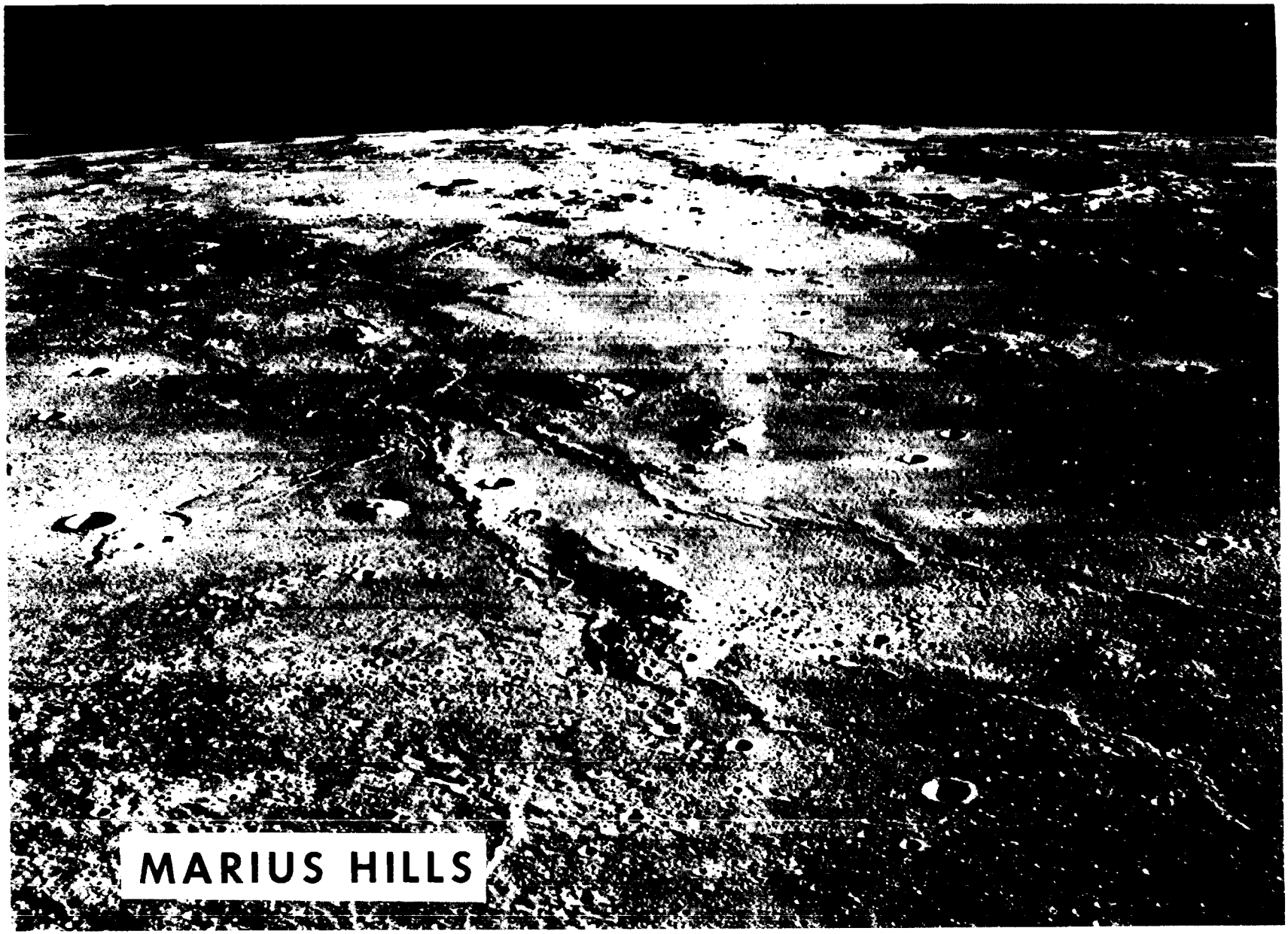
A more complete understanding of the moon will be produced by visiting different sites, each characterized by a major surface feature. Among the candidate sites selected for future Apollo missions are: Fra Mauro, the site for the Apollo 13 mission this April, which is a hilly upland area believed to be material ejected from a nearby mare as a consequence of impact; Littrow, a mare region, adjoining the Tarus Mountains and a "Mascon" associated with the Sea of Serenity, and containing domes and a wrinkle; Censorinus, a highland site and the location of a fresh impact crater; Descrates, a highland with many long grooves and furrows reminiscent of volcanic regions on earth; the Marius Hills, a major ridge system with volcanic domes and cones; Copernicus, a major crater nearly 60 miles in diameter, with a central peak rising to a height of 2,500 feet, a crater floor with domes and flow areas, and crater walls towering about 13,000 feet above the floor; Hadley-Apennine, featuring a sinuous rille reminiscent of a stream bed on earth at the foot of the 20,000 foot high Apennine mountain front; and Tycho, a large fresh impact crater in the highlands and the location of the Surveyor VII spacecraft.

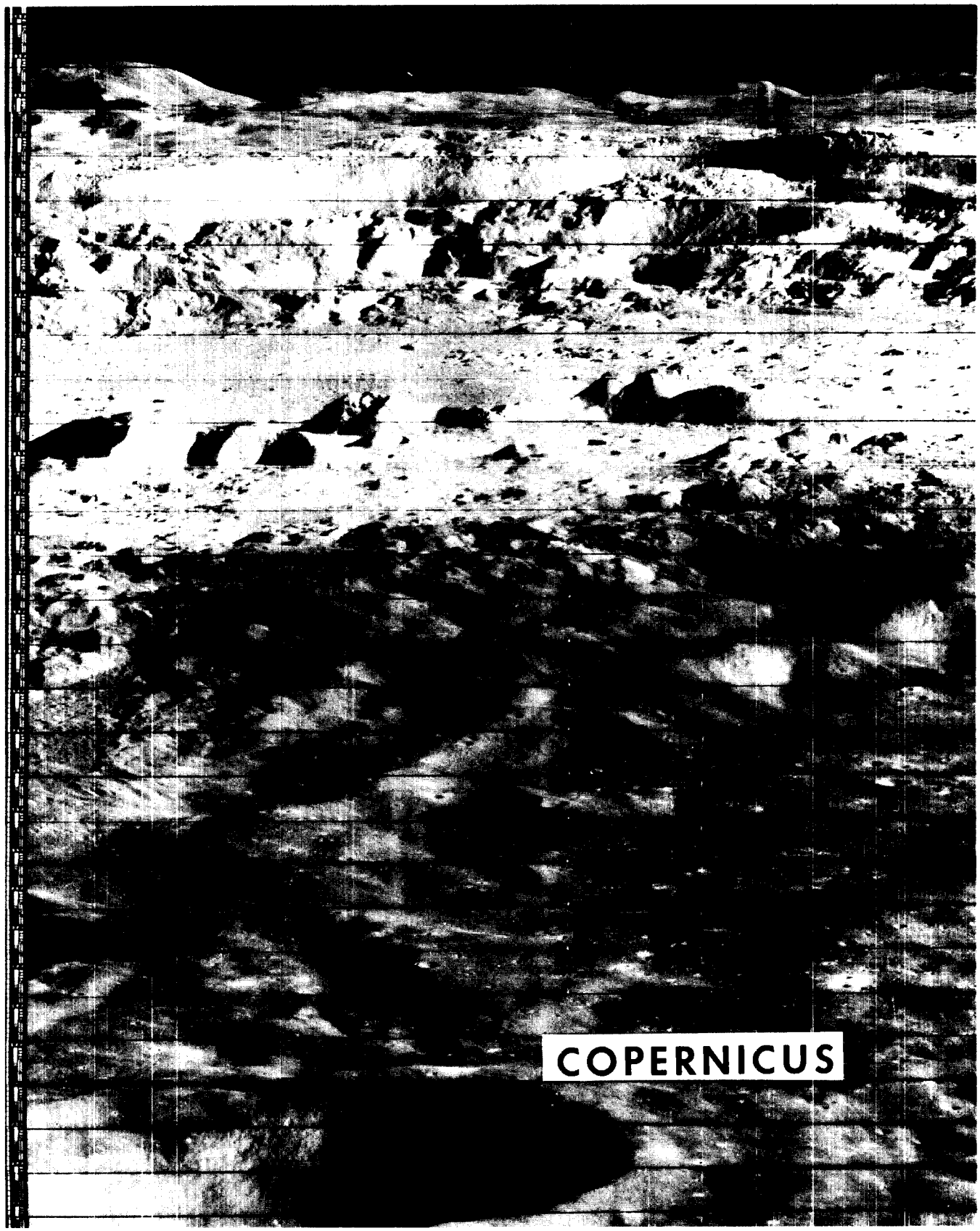
Each of these sites is characterized by surface topography that is much rougher than the relatively smooth landing areas selected for Apollo 11 and 12. The Apollo 12 flight successfully proved the capability of the guidance and control system of the Lunar Module to land at a precisely targeted point. This accuracy is essential if successful landings are to be made at these future sites.

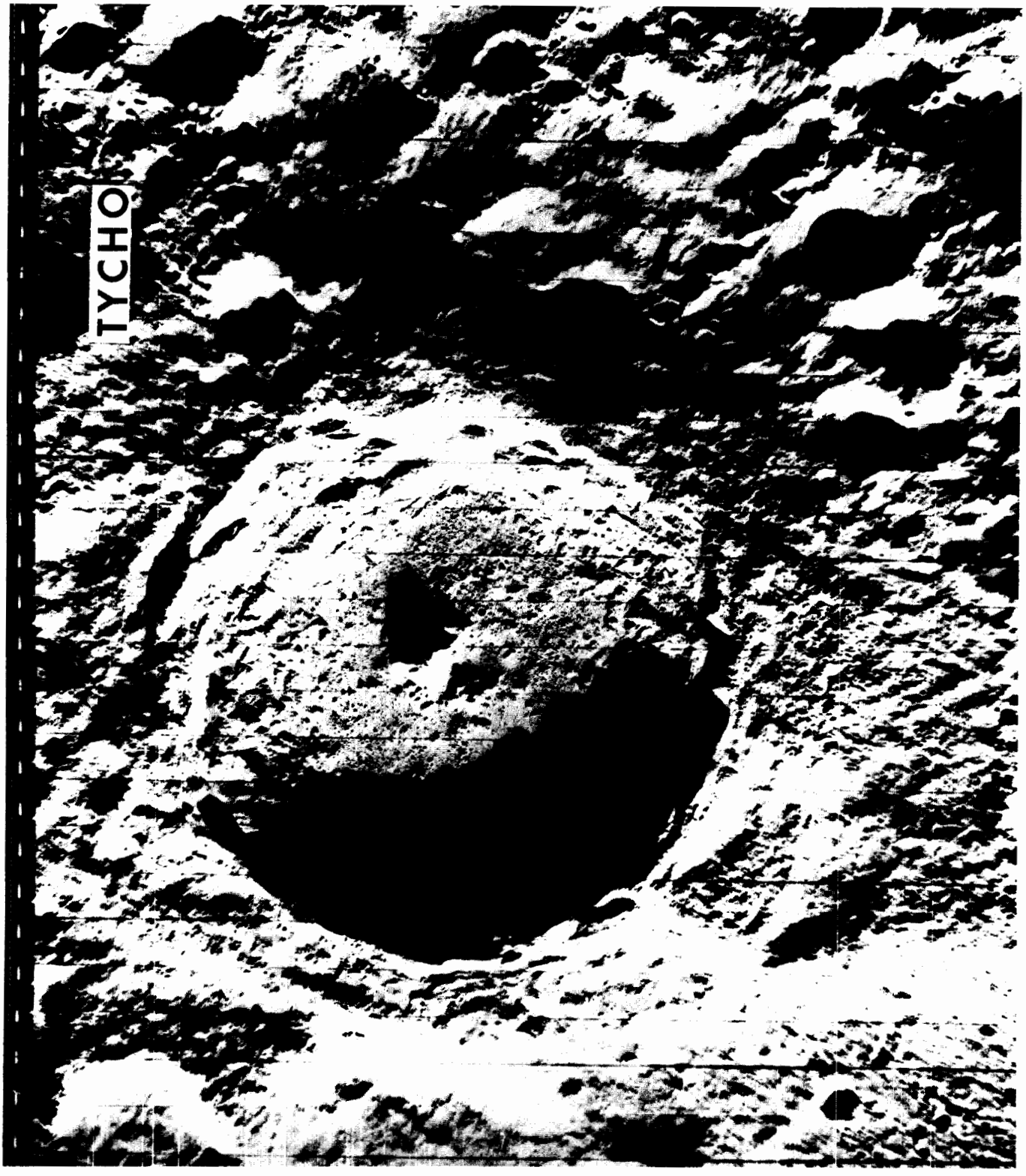
Some of the sites are also located at areas quite distant from the lunar Equator, the region to which the initial Apollo landings were restricted.

FRA MAURO
FRA MAURO


CENSORINUS


MARIUS HILLS


COPERNICUS



RD 1-10

Because of earth-moon positions, the Apollo spacecraft will be able to land at several of these sites only during a one to two month period every year. This will require a continuing precision of the entire Apollo team to meet these very exact launch windows.

A lunar roving vehicle is being developed to assist the astronauts in exploring the moon. It will be especially valuable in exploring the later sites where important features are somewhat dispersed over a large area.

The lunar surface experiments during the next several Apollo missions will complement those already landed on the moon, so that a network of geophysical stations can be established. This will be essential for such things as learning the nature of the moon's structure, for the location, speed, and pattern of seismic waves that can only be derived through simultaneous measurements at seismometers in different locations. During the last series of Apollo missions, the initial experiments may be modified to better record the conditions discovered on the surface, and will be supplemented by additional experiments for measuring physical phenomena existing on the moon. The return to earth of substantial quantities of lunar surface material will continue to be a prime objective in all lunar landings. Lunar surface experiments will also be complemented by several sets of orbital experiments to be included in a scientific instrument subsystem on the Apollo Command and Service Module. These experiments will measure the moon's magnetic field, survey the surface temperature and indicate areas with pronounced thermal anomalies; perform geodetic measurements; map the topographic features of the surface; delineate subsurface structure and indicate the relative abundance of certain elements existing on the moon's surface.

This last series of Apollo missions will contribute greatly to man's understanding of the moon, and thereby increase his knowledge of the earth and the solar system. Man will have investigated the form, regional setting, and subsurface nature of major lunar surface features and the relationships between regions of the moon. Through a chemical analysis of lunar samples, man will be assisted in his investigation of the origin and history of the moon. On an overall basis, we will begin to understand the internal structure and processes of the moon, including seismic activity, heat flow, and generation of gases from the moon's interior. By surveying and measuring the lunar surface we can provide the basis for comprehending the overall surface structure and interrelationship of regions and major surface features. Finally, we will begin to understand the interaction of the moon with the space environment including phenomena such as the solar wind, micrometeorites, and other environmental components.

Seven more Apollo landings are presently planned: two in 1970, two in 1971, one in 1972, and two in 1974.

SUMMARY OF RESOURCES REQUIREMENTS:

	1969	1970	1971
Spacecraft.....	$913,127,000	$778,978,000	$402,500,000
Saturn V.....	535,710,000	484,439,000	231,000,000
Operations.....	533,887,000	422,728,000	323,000,000
Saturn IB.....	42,276,000	---	---
Total.....	$2,025,000,000	$1,686,145,000	$956,500,000

Distribution of Program Amount by Installation:

John F. Kennedy Space Center, NASA.....	$382,800,000	$258,318,000	$205,000,000
Manned Spacecraft Center.	1,014,856,000	873,540,000	465,300,000
Marshall Space Flight Center.....	586,065,000	512,010,000	248,000,000
Goddard Space Flight Center.....	50,000	200,000	---
Jet Propulsion Laboratory	100,000	664,000	---
Ames Research Center.....	---	50,000	---
Electronics Research Center.....	---	10,000	---
Langley Research Center..	---	1,410,000	---
NASA Headquarters.....	41,129,000	39,943,000	38,200,000

BASIS OF FUND REQUIREMENTS:

	Spacecraft		
Command and service module.	$356,902,000	$282,821,000	$95,500,000
Lunar module.....	299,240,000	231,433,000	102,900,000
Spacecraft support.....	198,682,000	170,764,000	137,000,000
Guidance and navigation....	42,703,000	33,866,000	24,200,000
Science payloads.....	15,600,000	60,094,000	42,900,000
Total.....	$913,127,000	$778,978,000	$402,500,000

The three spacecraft modules - the Command Module, the Service Module, and the Lunar Module - developed for the Apollo program have, in every flight mission, successfully proven their capabilities. The Command Module has been manned six times, including four flights to and from the moon. Astronauts have flown the Lunar Module four times, and performed two landings on the lunar surface. During all these flights, the Apollo spacecraft has responded to the environment of space and the complexity and difficulty of the assigned missions with near perfection. Within 13 months of the first manned flight of the Command and Service Module, and within nine

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months of the first manned flight of the Lunar Module, these spacecraft had twice carried man to and from the surface of the moon, in a remarkable demonstration of successful design, engineering, and reliability.

Command and Service Module (CSM)

The Command and Service Modules were developed by the North American Rockwell Corporation. Four unmanned CSM's were successfully flight tested before the crew of Apollo 7 conducted the first manned operational test in October 1968. Since then, astronauts have flown five additional CSM's with all but one journeying to the moon. Two more CSM's, for Apollo 13 and 14, are presently at the Kennedy Space Center being readied for their flights to the moon later this year.

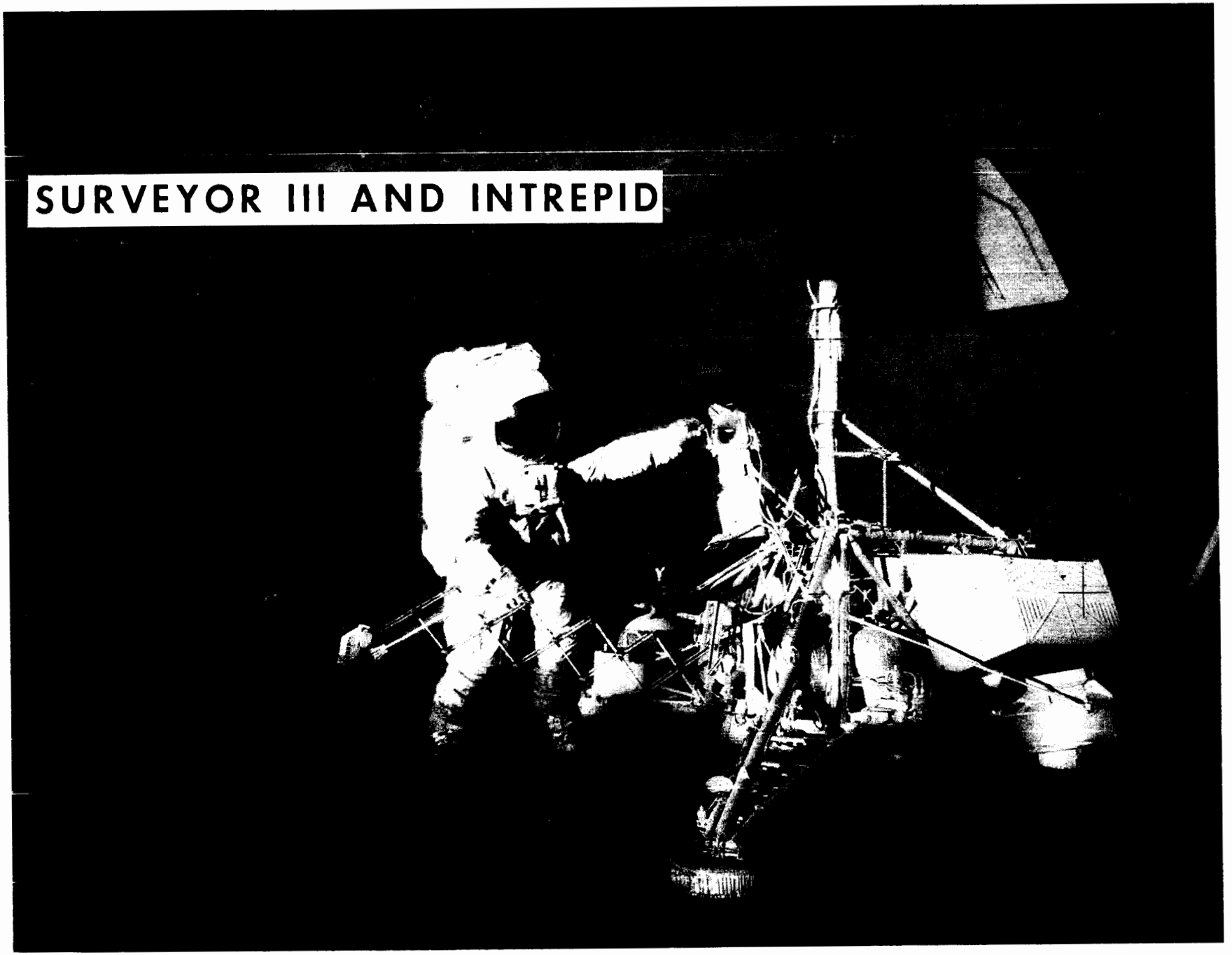
Modifications will be made to four Command and Service Modules to provide them with the capability of conducting extended lunar missions. These modifications include: increasing the cryogenic storage capability of the hydrogen and oxygen tanks to provide for a 16 day mission; installing a scientific instrument subsystem to conduct experiments while the CSM is in lunar orbit; adding controls and displays, and wiring harnesses for cryogenic management and the scientific instrument subsystem; and providing within the Command Module, equipment and stowage provisions for the support of extravehicular activity, science experiments, additional crew supplies and consumables, and scientific data to be returned to earth.

The scientific instrument subsystem will be located in one quadrant of the Service Module and will be an integral platform upon which the orbital experiments can be placed. These experiments will vary with each mission. It will feature a pyrotechnically jettisonable door, an instrument deployment mechanism, and an individual data system. The design and engineering of the basic structure, power system, and thermal controls for the scientific instrument subsystem are nearing completion, and fabrication and assembly of the first flight unit was recently initiated.

During FY 1970, and FY 1971 the remaining Command and Service Modules will be in various stages of production, and checkout or in storage. These Command and Service Modules will be used for lunar missions, and in the Apollo Applications program. For the CSM's used in the AAP, the Apollo program is funding completion of spacecraft structures and Apollo Applications is funding development, production, and integration of modified subsystems, and the checkout of these modified spacecraft. Spacecraft will be placed in storage at various stages during the production process to assure the most effective and economic production cycling possible within this schedule.

Lunar Module (LM)

The Grumman Aerospace Corporation developed the Lunar Module. Five Lunar Module flights have been conducted, the first being an unmanned test


SURVEYOR III AND INTREPID

in January 1968. This successful flight permitted the first manned flight in February of 1969, by the crew of Apollo 9. The Apollo 10 astronauts in May 1969, took the LM to within 50,000 feet of the surface of the moon. Citizens on every continent and in nearly every country witnessed the ultimate demonstration of LM's capability in the July and November, 1969 lunar landings. The next two Lunar Modules assigned to land on the moon are presently at the Kennedy Space Center where a checkout of their systems is underway.

Major modifications to four Lunar Modules are underway to give the LM the capability of remaining on the lunar surface for up to 54 hours, or one and one-half times the present capability. These modifications will increase both the payload weight to the surface and the lunar sample weight returned to earth; and expand the range and hover capacity of the LM, allowing it to land at sites that feature difficult terrain and locations remote from the more easily reachable sites on the lunar equator.

The design changes to the Lunar Module to incorporate this extended capability include: larger propellant tanks for the descent engine; additional oxygen and water storage; additional electrical power; provisions for carrying the lunar rover; improved cabin habitability and crew life support for the increased staytime; and the necessary structural modifications to support the 10 percent increase in total Lunar Module weight, and to accommodate the relocation of components and installation of new components.

Modifications to the Lunar Module ascent and descent engines to provide increased performance will also be designed and tested through mid-1971 and modified engines will be installed in the last four LM's. Three Lunar Module test vehicles will undergo static, dynamic, and propulsion tests during FY 1970 and FY 1971 to verify the Lunar Module modifications.

During fiscal year 1971, final assembly, checkout, and modification of the last four Lunar Modules will be in progress. One additional Lunar Module is expected to be delivered to the Kennedy Space Center in FY 1970. As with the CSM, the production of the Lunar Modules may be rephased and the spacecraft stored, to provide for the most effective and economical production cycle.

Spacecraft Support

Funds for Spacecraft Support provide for test operations, crew equipment, spacesuits, logistics, integration, checkout and reliability efforts, operation of the Lunar Receiving Laboratory, and instrumentation. Among the test activities conducted are: spacecraft development testing, thermal vacuum testing, component and subsystem reliability and verification testing, and electronic systems compatability testing. Testing during FY 1970 and FY 1971 will be directed toward supporting the modifications being made to the Command and Service Module and Lunar Module.

Another major task during FY 1970 and FY 1971 will be to modify the astronaut Portable Life Support System (PLSS) to greatly increase the amount of time the astronauts can spend on the lunar surface. The PLSS is a self-contained terrestrial environmental system that helps protect the astronaut from the extremes of heat and cold that exist on the lunar surface, and provides him with oxygen to breathe, and purges the carbon dioxide that is exhaled. The modified PLSS will substantially expand the distance the astronauts can traverse on the surface. In the event of a malfunction of the PLSS while at some distance from the Lunar Module, a Secondary Life Support System (SLSS) will be available. The SLSS will provide the necessary life support to enable the astronaut to return to the Lunar Module. The SLSS is needed for the increased emergency operation time associated with the extended surface traverses. The SLSS will replace the current emergency system which has a short operating time and limits lunar surface activity to the close vicinity of the Lunar Module. Component and system design of the modified PLSS has begun, and design verification testing will be completed by the end of CY 1970. During FY 1971, fabrication of both flight units and systems test units will be accomplished, with both retrofitting of previously developed PLSS' and delivery of new additional systems beginning by the end of the fiscal year. Design of the SLSS began in FY 1970 and design verification testing will be conducted at the end of this fiscal year. Fabrication of systems qualification units and flight units will be underway during FY 1971.

The present Apollo lunar surface suit will also be modified to provide the astronauts with greater mobility at the waist. This will assist them in their activity on the lunar surface by allowing them greater ease and mobility of operation, particularly in stooping more easily. Design and testing of these modified suits are underway during the current fiscal year and a thermal vacuum test will be conducted at the Manned Spacecraft Center in FY 1971. Production of the suits will begin in FY 1970, and will continue in FY 1971.

Other areas funded by spacecraft support associated with crew requirements include survival equipment, food, extravehicular activity equipment, personal hygiene systems, and bioinstrumentation.

Funding in FY 1971 provides for the operation of the automatic checkout equipment (ACE) stations located at contractor plants and at NASA test and launch sites and which are used for the separate and combined checkout of spacecraft systems. Engineering changes to update the equipment for spacecraft modifications and spare components to maintain the operational equipment will also be funded.

Another area of spacecraft support is the development and procurement of specialized flight and mission instrumentation. Typical equipment includes: signal conditioners, sensors, transmitters, antennas, ground support equipment, and radiation measuring devices. A major task in this area

is the development of a lunar surface communications unit which will operate when the astronauts are no longer within line of sight of the Lunar Module. Surface and orbital television systems are also funded by spacecraft support.

An increasingly important area funded by spacecraft support is the operation of the Lunar Receiving Laboratory at the Manned Spacecraft Center in Houston, Texas. This laboratory, beyond its special quarantine capabilities, is also a unique facility for conducting special scientific studies in the areas of geology, chemistry, physics and biology. All lunar samples are examined, studied, and catalogued here before being released to the scientific community throughout the world for detailed study. The scientists at this laboratory perform the preliminary determinations as to the nature of the samples, and assure that the principal investigators receive material properly associated with their investigations. The laboratory also serves as the central forum for compiling the results of the detailed studies.

Logistic funding in FY 1971 is needed for transportation of spacecraft between installations, and procurement of spacecraft fuels and propellants.

Guidance and Navigation

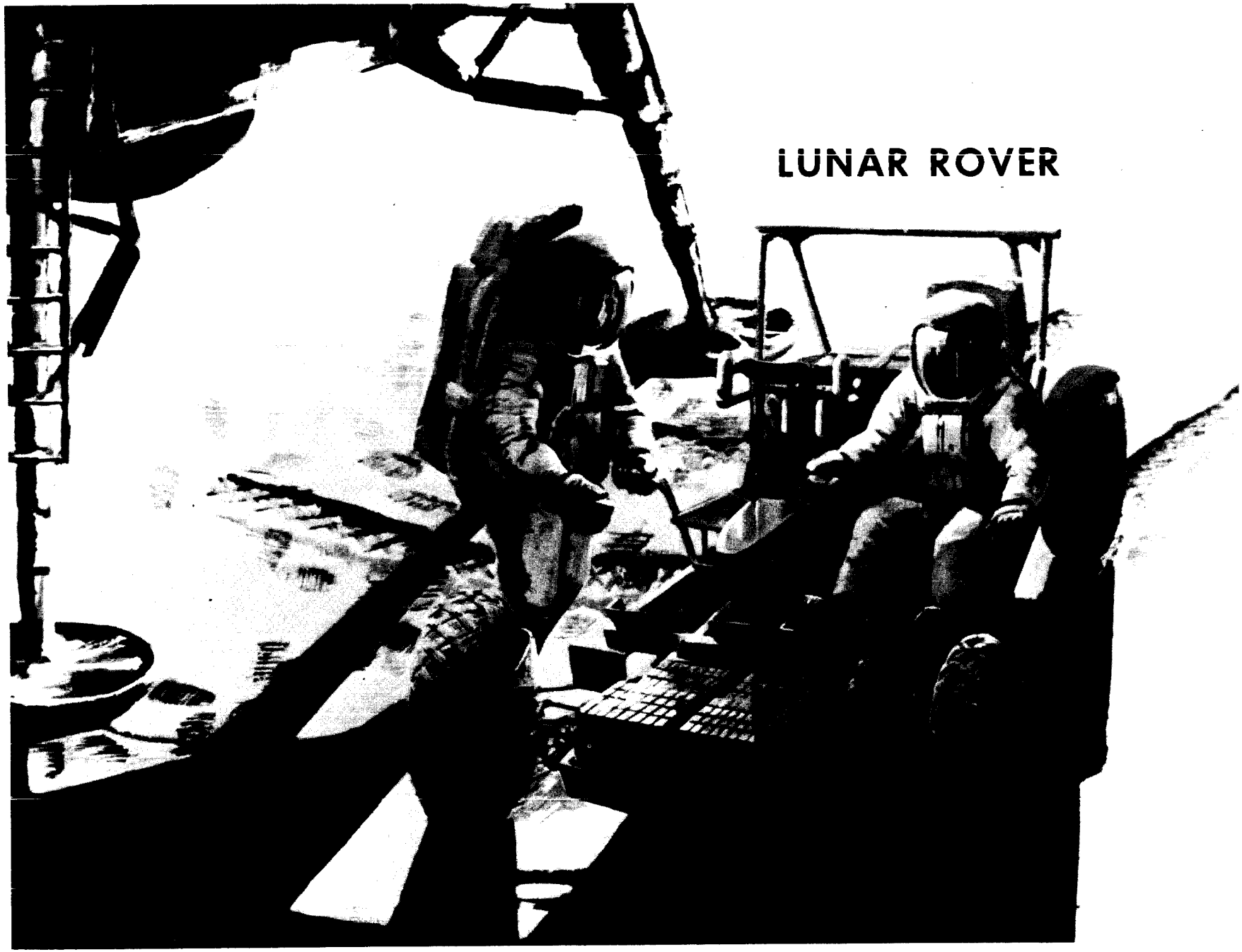
The Guidance and Navigation system units for the Apollo spacecraft were designed by the Massachusetts Institute of Technology and were produced by the A. C. Electronics Division of General Motors, with major subsystems produced by the Raytheon Company, and the Kollsman Instrument Corporation. All Guidance and Navigation units for both the Command and Service Module and the Lunar Module have been produced and delivered.

Fiscal year 1971 funding will be applied to the development and testing of flight programs to accommodate the forthcoming series of Apollo missions with their landings at difficult sites involving very complex trajectory and orbital paths. Pre-launch checkout of delivered units, analysis of flight data, and engineering and technical support for resolution of any problems, will also be supplied.

Science Payloads

Having demonstrated that man can land on the moon and safely return to earth, future Apollo missions will increasingly be directed toward greatly expanding man's knowledge of the nature of the moon, its evolution and processes, and relating these to man's better understanding of the earth and the solar system. Science will be the principal objective of these missions.

To assist man in this exploration, a lunar roving vehicle is under development. The lunar rover, weighing about 400 pounds and powered by battery driven electric motors, will permit the astronauts to venture from five to


LUNAR ROVER

fifteen kilometers from the Lunar Module. The rover will be capable of a top speed of 10 miles per hour, and can carry two astronauts with their tools about the moon as they collect samples, place instruments, and conduct experiments. The rover, beyond expanding the radius of exploration for the astronauts, increases the quality of the science that can be conducted on a mission by quickly transporting the crew to areas of great scientific interest. Engineering and fabrication of the rover is underway and assembly of test and training units will soon commence. Testing of the lunar rover will be conducted in FY 1971, and the first rovers for use on the moon will be in various phases of assembly during the fiscal year.

Apollo 11 astronauts deployed three experiments, and of these the passive seismic experiment which was powered by solar energy has been turned off.

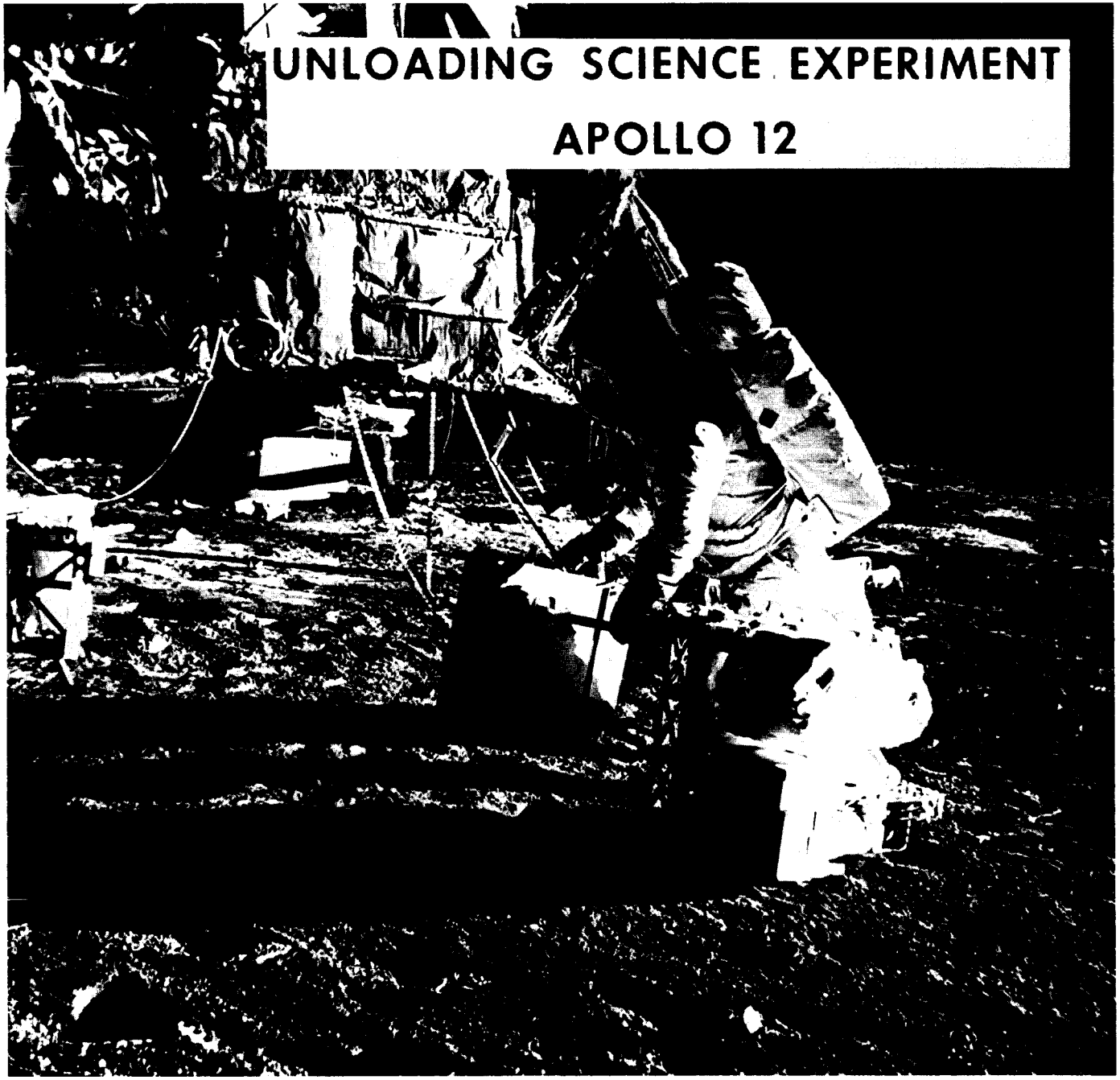
The crew of Apollo 12 deployed the first Apollo Lunar Surface Experiments Package (ALSEP) on the moon. The ALSEP, with a central station for collecting and transmitting data back to earth and supplied with electrical power from a nuclear fuel element, has a planned operational life of one year.

The remaining Apollo missions will deploy additional ALSEP's on the lunar surface. Among the instruments deployed will be seismometers, ion detectors, magnetometers and particle detectors. Continuing operation of previously placed ALSEP's will permit establishment of a scientific network that can lead to increasing our basic understanding of the moon. The next three missions will carry ALSEP's similar to that carried on Apollo 12, although with somewhat different experiment groupings. Development and production of scientific equipment for the following two missions, Apollo 16 and 17, will be initiated in FY 1970 following final review of the proposed experiments. Studies of experiment package experiments for the final two missions will be undertaken during 1971.

Prototype lunar orbital science experiments for the last Apollo missions are being developed, and production of the flight experiments has begun. The initial group of lunar orbital experiments are scheduled to be completed and delivered to the North American Rockwell Corporation for integration into the CSM by the end of FY 1971.

Saturn V

	1969	1970	1971
Flight stages.....	$402,057,000	$357,116,000	$134,400,000
Vehicle support.....	133,653,000	127,323,000	96,600,000
Total.....	$535,710,000	$484,439,000	$231,000,000



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Developed as this country's most powerful launch vehicle, the Saturn V has flown seven times. Following the second of its two unmanned flight tests in April, 1968, the Saturn V was next used to launch the crew of Apollo 8 on their historic Christmas Eve journey around the moon. Each of the four manned missions performed by the United States during 1969 was launched on a Saturn V vehicle.

The Saturn V can launch payloads weighing 145 tons into low earth orbit and inject spacecraft weighing over 53 tons on voyages to the moon. It is seven to eight times as powerful as the Saturn IB and Titan III launch vehicles, neither of which is capable of a manned lunar mission. With a first stage sea level thrust of 7,750,000 pounds, and two high performance liquid oxygen/liquid hydrogen upper stages, it is the only vehicle comparable to the expected capability of the new launch vehicle reported being developed by the Soviet Union, whose predicted first stage thrust is 10 or more million pounds.

Fifteen Saturn V launch vehicles are being produced for the Apollo program. Of the eight vehicles that have not yet been flown, one is positioned on Pad A Launch Complex 39 at the Kennedy Space Center (KSC) being readied for the April launch of Apollo 13 to the moon, and the launch vehicle for Apollo 14 has been delivered to KSC. One is in storage. Five vehicles are in the concluding phases of production and testing. One of these has been assigned to the Apollo Applications program to launch the Saturn Workshop in 1972.

Further production of the Saturn V launch vehicle beyond the currently approved 15 vehicles has been suspended. Fiscal year 1970 and 1971 funding is primarily for completion of current production and activities in support of the flight schedule.

While the planned advent of the space shuttle during the last half of the decade will permit some heavy payloads to be carried to earth orbit by that system, a vehicle with the performance of a Saturn V will remain this nation's only launch vehicle capable of orbiting such diverse and essential payloads as space station modules, space tugs, nuclear propulsion stages, lunar orbit station modules, manned planetary mission modules and landing vehicles, and the systems required to establish a lunar surface base. The Apollo funding for Saturn V launch vehicle includes conserving the acquired skill techniques accumulated through eight years of Saturn V development and production. Videotapes and other graphic records of manufacturing techniques, test and checkout procedures, and other associated production tasks, will be made in an attempt to reduce the cost of reinitiating production. This effort will be supplemented by documenting the diverse production tasks and the efficient and economical methods developed for performing them. Funding will be used to preserve and store tooling, inventory and assess the future usefulness of equipment and materials, and performing any other necessary tasks related to concluding a production run while preparing for a future reinitiation.

Flight Stages

The first stage of the Saturn V, the S-IC, is produced by Boeing at the Michoud Assembly Facility near New Orleans, Louisiana. The S-II, or second stage, is manufactured by the North American Rockwell Corporation at Seal Beach, California. The McDonnell-Douglas Corporation builds the third stage, the S-IVB, at its Huntington Beach, California plant. The instrument unit, which controls the vehicle's flight, is built by the IBM Corporation at Huntsville, Alabama. The first and second stages are presently being test fired at the Mississippi Test Facility in Hancock County, Mississippi. The third stage was test fired at the Sacramento Test Facility in California. No further test firings of the third stage are planned. The F-1 and J-2 engines were developed and produced by the Rocketdyne Division of the North American Rockwell Corporation at Canoga Park, California.

During the remainder of FY 1970, one Saturn V launch vehicle will be delivered to the Kennedy Space Center. Three S-IC stages and two S-II stages will have completed static firing during the fiscal year and will be placed in storage. One S-IC stage is being refurbished to repair damage resulting from an F-1 engine malfunction that occurred during static firing. Two spare engines replaced those damaged by the accident. Assembly and systems installation on the last two S-IC and S-II stages will be completed. All S-IVB stages have completed fabrication. Static firing of S-IVB stages has been concluded. All undelivered S-IVB stages are in final assembly, checkout or storage. Three instrument units will be in assembly or checkout. Delivery of the last F-1 engine, this country's most powerful rocket engine, was made in October of 1969. Ninety-eight engines were produced in the Apollo program. Delivery of the last J-2 engine, this country's most powerful liquid hydrogen/liquid oxygen fueled engine was made in January 1970. For Apollo, 152 J-2 engines were built. These deliveries complete the present production of rocket engines for this country's manned space flight program.

In FY 1971, one Saturn V launch vehicle will be delivered to the Kennedy Space Center. All undelivered S-IC, S-II, and S-IVB stages will be in checkout or storage by the end of the fiscal year. Four instrument units will be in various phases of assembly and checkout during the fiscal year.

During FY 1971, funding for the flight stages, engines and instrument units of the Saturn V launch vehicle will be allocated toward completing production on those few remaining units on which work continues; test and checkout of completed stages; storage and maintenance of stages; analysis of flight data; and providing engineering and technical support for solving technical problems which may arise. The engineering and technical support by the prime contractors of the flight stages and engines is expected to form the major element of this and future year funding.

Vehicle Support

Funding in this area is for services and equipment that are common to more than one stage of a vehicle, and for the operation of the electrical and mechanical support equipment required to test and checkout the stages, instrument unit, and associated hardware. Saturn V checkout is based on the philosophy that improved vehicle reliability and minimum time at the launch site can be attained by using computer-controlled systems to verify component performance and systems operation.

Test operations at the Mississippi Test Facility, transportation of stages, operation of the Slidell Louisiana Computer Facility, range safety and tracking devices for vehicles, propellants, systems integration, computation services, engineering services, reliability, quality control and inspection, and flight evaluation programs are funded by this account.

Operations

	1969	1970	1971
Launch, flight and recovery...	$478,529,000	$369,998,000	$279,800,000
Technical.....	55,358,000	52,730,000	43,200,000
Total.....	$533,887,000	$422,728,000	$323,000,000

Operations funding provides for crew training, launch, flight, recovery and programwide technical and Department of Defense support required for manned space flights. Included in the Apollo portion of operations is funding for the basic capability to conduct all manned flight, regardless of program, together with activities necessary for specific Apollo missions. The associated operations project included in Space Flight Operations funds only those efforts unique to that specific program. Seven additional lunar missions are planned in the Apollo program; two in 1970, two in 1971, one in 1972, and two in 1974.

Launch, Flight and Recovery

The two principal centers for launch, flight control and recovery activities are the Kennedy Space Center (KSC), Florida and the Manned Spacecraft Center (MSC), Texas.

The Kennedy Space Center is responsible for checkout through system by system testing; analysis for possible hardware discrepancies during the preparation for launch of both the launch vehicle and spacecraft; maintenance and operation of the launch facilities; final integration and integrated checkout of the space vehicle and its payload; the operation and coordination of supporting facilities, ground support equipment and logistics support; and the conducting of the launch.

The major operational costs of the Kennedy Space Center are associated with the checkout of the spacecraft and the launch vehicles, and the launch support requirements.

Launch support is supplied by both NASA contractors and the Air Force Eastern Test Range (AFETR). The Department of Defense is reimbursed for AFETR costs incurred for NASA support. Included in launch support is the management and operations of launch complexes; systems engineering services; technical shop operations; propellant services and propellant systems laboratory operations; and ordnance storage. Also included are engineering design and fabrication services for the electrical and electronic systems that support the launch capability, the 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 pre-launch 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 to support 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

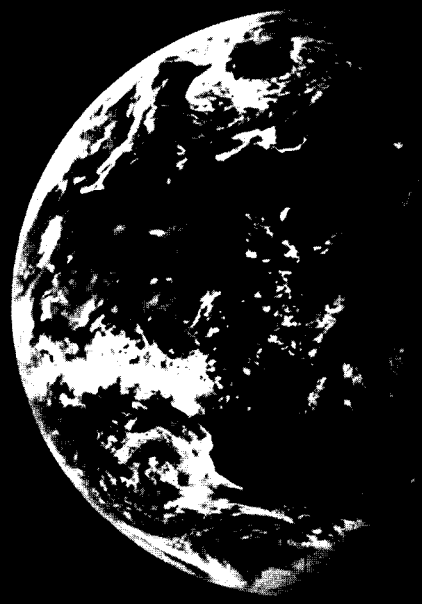
Technical operations provide for the systems engineering needed for the integrated technical support, review, and analysis of the entire Apollo program; supporting development; contractor administration, audit, and property administration services provided by the Department of Defense on a reimbursable basis; and for the nonrecurring maintenance and rehabilitation of government-owned industrial plants. In FY 1971 systems engineering services provide functional and performance standards for Apollo developed hardware; technical integration and evaluation; technical documentation; and overall trajectory analysis primarily through the principal systems engineering contractors - Bellcomm, Boeing and General Electric. Emphasis will continue to be placed on analysis of Apollo flight missions. Funding for supporting development will concentrate on engineering efforts to improve Manned Space Flight hardware. The nature of these efforts vary widely, extending from alternative subsystems to new material fabrication and testing. Effort in FY 1971 will continue to be devoted to those promising areas highlighted in previous work with new tasks focusing on applied systems development.

Saturn IB

	1969	1970	1971
Saturn IB.....	$42,276,000	---	---
Total.....	$42,276,000	---	---

Fiscal Year 1969 was the last year of Apollo funding for the Saturn IB launch vehicle. Seven unused Apollo Saturn IB launch vehicles have been transferred to Apollo Applications for use in that program. Production of the Saturn IB has been concluded.

EARTH AS SEEN BY APOLLO 11 CREW



OFFICE OF MANNED SPACE FLIGHT SPACE FLIGHT OPERATIONS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Space Flight Operations program is directed toward capitalizing on this nation's investment in trained manpower, facilities and the technology developed in the Gemini and Apollo programs for the launch, production and operation of manned space systems. The program incorporates and initiates some of the key elements of the recommendations of the President's Space Task Group in their September 1969 report. Provision is made for definition and design effort necessary for developing new systems and technology for space operations with emphasis upon the critical factors of (1) commonality, (2) reusability, and (3) economy. This program will be directed initially toward development of a new space transportation capability and space station modules which utilize this new capability and will provide an opportunity for broad international participation and cooperation.

Initial Space Flight Operations will be conducted in the Apollo Applications program building on the strong base of flight experience, ground facilities, and trained manpower developed in the Apollo program. Apollo Applications employs a Saturn Workshop, launched atop the first two stages of a Saturn V, an Apollo Telescope Mount for observing the sun, and the basic space vehicle hardware developed and procured in Apollo. This hardware is being modified to meet the unique requirements of the Apollo Applications missions and to accomplish a limited but carefully selected number of scientific, technological, medical and space application investigations.

Apollo Applications will determine and evaluate in a series of progressively longer missions, reaching up to 56 days, man's physiological responses and aptitudes in space under zero-gravity conditions, and equally important, his post-mission re-adaptation to the earth environment. The solar astronomy and other physical science experiments will greatly increase man's understanding of the sun and interplanetary space. Acquisition of earth resources data may accelerate international cooperation in understanding, improving, and controlling the management and use of earth resources of the entire world.

Great stress will be laid on investigating and evaluating the unique capabilities of man for judgment and discriminating observations, sensor operation, data selection and assessment, maintenance, repair, assembly and set-up, instantaneous and flexible reaction, manned flight control, and mobility while conducting experiments and operations. The Workshop mission will also develop and demonstrate techniques for increasing systems life and evaluate techniques for in-flight test and qualification of advanced subsystems.

The Apollo Applications missions are a prelude to the operation of a space station and space shuttle. This combination of a shuttle and a multi-purpose station or base will be a major step in realizing the potentialities of space science to make a visible contribution to the vitality and forward progress of both this country and the world.

The versatility of the space station and space shuttle to perform many varied tasks should lead to a productive and economical utilization of space. The long-term and multi-purpose nature of the station, and the space base which will develop from it, provides the means for consolidating many diversified efforts in space to obtain advantages of commonality. Scientific and applications experimentation will be strengthened with the initiation of new tasks previously not achievable. The station and base, with the logistics support of the space shuttle, will be a basic supportive system for much of the investigative activity to be conducted in earth orbit. The introduction of the reusable space shuttle will reduce the cost of this activity, simplify the operational procedures, and provide convenient and economical transportation.

SUMMARY OF RESOURCES REQUIREMENTS:

	1969	1970	1971
Apollo applications.....	$150,000,000	$300,052,000	$364,300,000
Operations.....	---	24,548,000	40,900,000
Space shuttle and station.....	(8,800,000)	18,500,000	110,000,000
Total	$150,000,000	$343,100,000	$515,200,000

Distribution of Program Amount by Installation:

John F. Kennedy Space Center, NASA.....	---	$9,600,000	$18,600,000
Manned Spacecraft Center...	$54,707,000	139,208,000	136,900,000
Marshall Space Flight Center.....	93,458,000	165,897,000	310,700,000
Jet Propulsion Laboratory..	---	150,000	---
Ames Research Center.....	145,000	3,407,000	1,870,000
Electronics Research Center	---	400,000	---
Langley Research Center....	125,000	638,000	930,000
NASA Headquarters.....	1,565,000	23,800,000	46,800,000

BASIS OF FUND REQUIREMENTS:

Apollo Applications

Apollo Applications will be directed toward near-earth missions emphasizing the utilization and application of space for man's benefit and knowledge. With flights commencing in late 1972, the program is structured about an

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earth orbiting workshop containing a solar observatory, laboratories, work areas, control stations and crew living quarters. Following the launch of the Workshop, three manned missions using Apollo Command and Service Modules will visit and use the Workshop during its planned eight month flight sequence.

The program will be a precursor of space station operations that will begin in the last half of the decade. While Apollo Applications will investigate new technological concepts, conduct experiments, and develop operational techniques applicable to the station, its greater importance will be to demonstrate during long duration manned flights the inter-association of man and his experiments.

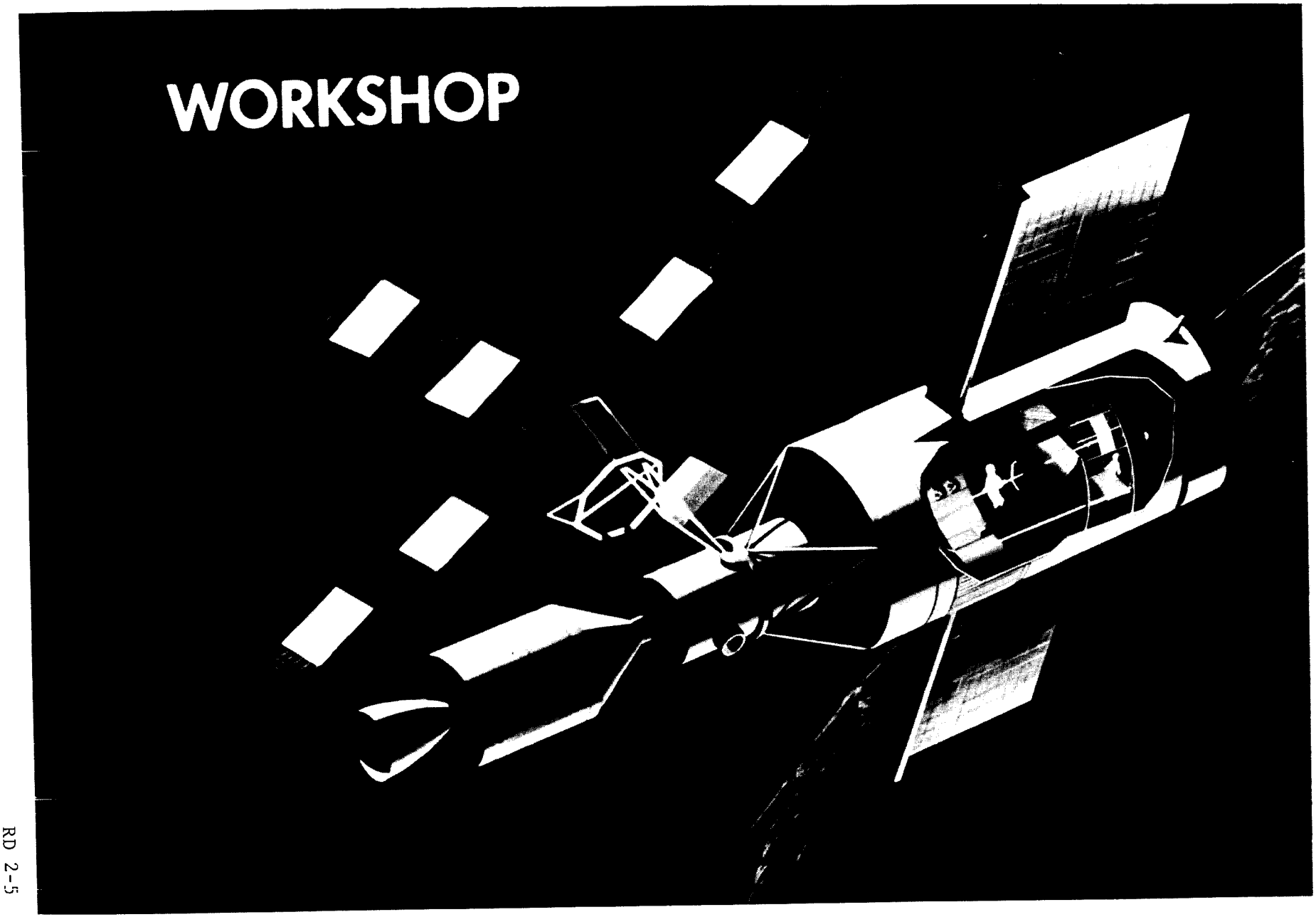
Medical Science

Man first journeyed into space nearly nine years ago, and has since progressed through longer and more distant flights. To date, he has successfully adapted to this new environment. The Gemini program demonstrated the ability of man to retain both his health and his capacity to perform physical and mental tasks for periods up to 14 days. Apollo has proved that he can readily acclimate himself to the 1/6th gravity force existing on the moon.

The first manned Apollo Applications flight will be a mission lasting up to 28 days, or twice the duration of existing experience, and will investigate the effects of prolonged weightlessness on man's health and behavior and on his ability to carry out his various duties. The second and third flights are planned for up to 56 days each, and will approach the regular crew cycles anticipated on the space station and space base.

The medical and behavioral studies of the flight crews during the Apollo Applications mission will focus on the effects of space flight on man, and the sequence through time of these effects. Man, to date, has seemingly been able to adjust to weightlessness and any physiological effects have apparently stabilized. Longer flight times could change these conditions. If undesirable effects are noted during the mission, the program will then evaluate means of mediating the effects, predicting their onset and severity, and determining the most effective method of prevention or correction. It is expected that a physician astronaut will be a member of one flight crew.

Included among the experiment studies that will assess the effects of weightlessness on man are: an evaluation of calcium and endocrine balance within the body; a determination of the occurrence and degree of bone demineralization; a survey of changes in the cardiovascular system and functions, including the electrical activity of the heart; an investigation of the frequency of chromosome aberrations in blood cells, and the changes in red cell mass, red cell survival and plasma volume; an examination of the effects of space on blood coagulation and cellular immunity; studies on the effects of a prolonged absence of gravity on the body's metabolic rate, and also on the functioning of the inner ear, which provides the body with its sense or orientation and balance.


WORKSHOP

These medical studies are expected to contribute to basic medical knowledge, not only on the effects of space on man, but by establishing reference points through the detailed and documented study of healthy human subjects, who are infrequently the object of medical research. As in the past, the experiments and their measurement systems may find applications here on earth in the diagnosis and treatment of the ill.

Bioscience

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 three 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. Potatoes, vinegar gnats, and mice will be studied for the effect of the space environment on these rhythms.

Space Physics and Astronomy

Knowledge of the sun with its tremendous range and combination of temperatures, pressures, and magnetic and radiative field strengths, provides the basis for new studies in various physical disciplines. Man is limited in his study of the sun because of the atmosphere that protects him from it. Our atmosphere shields terrestrial observation of the ultraviolet, extreme ultraviolet, X-ray, and most infrared radiation from the sun. The atmosphere, with its turbulence, blurs any optical images of the sun and clouds and atmospheric pollution also interrupt viewing. To overcome these problems and barriers, the Saturn Workshop will operate as a support base for a solar observatory - The Apollo Telescope Mount (ATM). The ATM contains 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.

The information received from the Apollo Telescope Mount will substantially increase man's knowledge of the sun and bring closer the day when he can understand the remarkable physical pehnomena evident there and the effect of these phenomena on man's existence on earth.

During the eight month flight of the Workshop, the crew will conduct other astronomical and space physics experiments. In one, nuclear emulsions will measure cosmic rays for return to the ground where physical and chemical characteristics can be observed. Cosmic radiation is the only particulate matter from outside the solar system that can be directly observed. Additionally, several sky surveys will be made by photographing selected areas of the sky in the ultraviolet wavelength, and examining it for possible X-ray sources. The brightness of light in the night sky will be measured in an evaluation of the phenomena known as Gegenschein and Zodiacal light. A study of the night and twilight earth horizon light and atmospheric airglow will be undertaken. Using a particle collection device, the distribution, composition, and morphology of micrometeoroids in near-earth space will be studied.

Earth Science

The Apollo Applications Workshop will orbit at an inclination of 50°, and at an altitude of 235 nautical miles. This is the highest inclination of any manned flight conducted by the United States. Inclinations of 50° are valuable for they permit earth resources survey coverage of the entire contiguous United States. Four earth resources experiments are proposed for the Apollo Applications program. The first would utilize multispectral photographic equipment and film for recording resources data. A second experiment is a proposed multispectral radiometric scanner. Another proposed experiment employs an infrared spectrometer and a fourth consists of a micro-wave radiometric experiment. The four instruments will be used to compare the relative value of data in the different spectral regions for their usefulness for application to agriculture, forestry, geology, geography, oceanography, water management, etc.

Manufacturing and Engineering Technology

The final set of Apollo Applications 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; the nature and speed of flame in zero gravity; and an assessment of the use of aerodynamic and electrostatic force fields instead of gravity for holding tools and parts in

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AND SIERRA NEVADA

place while working. An important experiment will be the evaluation of the feasibility of manufacturing selected materials in space utilizing the space vacuum and zero gravity conditions existing there. 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 Sequence

During the summer of 1969, the Apollo Applications mission sequence was considerably altered. The principal changes resulted from the decision to develop a ground-outfitted Orbital Workshop, with the first two stages of a Saturn V vehicle launching it into space. Previously, the Workshop was to be set up inside the empty tank of a spent S-IVB, after both that stage and the first stage of a Saturn IB vehicle had launched it into orbit. Formerly, the solar observatory, (the ATM), was to be launched by a Saturn IB as a separate mission and rendezvous and dock with the Workshop after reaching orbit. With the greatly increased performance capability of the Saturn V, the Workshop will be launched with all the principal hardware elements, such as the Airlock Multiple Docking Adapter, and solar observatory, integrated before launch. Further, it will be in a higher inclination orbit to provide improved coverage for the survey of earth resources. A final major change is that the Workshop will now provide its own electrical power, life support, and logistics supplies. In the previous mode of operation, the Workshop was to have relied on the Command and Service Module (CSM) for this support. Now the CSM while attached to the Workshop becomes the recipient rather than the provider.

After an unmanned launch from Launch Complex 39 at the Kennedy Space Center in late 1972, the Saturn Workshop will be positioned into a 235 nautical mile orbit with a 50° inclination. During the launch, the Multiple Docking Adapter, Airlock, and Apollo Telescope Mount will be protected by a payload shroud and will occupy the area taken by the Lunar Module and Command and Service Module during Apollo missions.

Following the orbiting of the Workshop, a Saturn IB with a modified Apollo Command and Service Module will be launched from Launch Complex 34 at the Kennedy Space Center sending the first flight crew toward a rendezvous and docking with the Workshop. The crew of this flight, as in each of the three manned missions, will consist of three astronauts.

The crew will dock the CSM with the Multiple Docking Adapter and transfer to the Workshop through the Command Module hatch and a hatch in the Adapter. They will then activate its systems and begin a mission planned to last up to 28 days. The Multiple Docking Adapter will provide access to both the Workshop and the Airlock. The Airlock will permit the crew to have access to

space where, wearing pressure suits, they can perform extravehicular activity. This first mission will emphasize medical experiments and initiating and verifying the operation of the ATM. Upon completing this first manned mission, the Workshop systems will be shifted to a standby condition, and readied for the next crew visit.

Approximately two months after the first crew has left the Workshop, a second flight crew will be launched to revisit and reuse the Workshop. The planned duration of their mission will be up to 56 days and it will focus on operating the solar observatory, and conducting the medical, earth resources, physics, biology, and technology experiments planned for the Workshop. Again, the Workshop will be placed in a standby condition upon the departure of the crew.

The third and last astronaut crew will revisit and reuse the Workshop in another mission that is also planned to last for as long as 56 days. Arriving about one month after the previous crew has returned to earth, they will continue making solar observations and performing the various scientific and technological experiments. With their departure, the Workshop will be deactivated approximately eight months after its launch.

Backup hardware, including a Workshop, Multiple Docking Adapter and Airlock, will be brought to the point of completion of manufacturing and systems installation, so that final checkout and delivery can be expeditiously accomplished. This hardware will also be available to conduct a second Workshop mission if such a future mission should be in the national interests.

Apollo Applications

	1969	1970	1971
Space vehicles.....	$52,645,000	$99,506,000	$89,600,000
Payloads and experiments.....	97,355,000	200,546,000	274,700,000
Space station.....	(8,800,000)	---	---
Total.....	$150,000,000	$300,052,000	$364,300,000

Space Vehicles

The Apollo Command and Service Module will be modified to support the long-duration missions its crew will be conducting in the Workshop. The CSM will operate in a quiescent mode while docked to the Workshop, with the Workshop supplying it with electrical power and an oxygen/nitrogen atmosphere. The principal modifications to the CSM include: providing an electrical power transfer umbilical and an atmosphere interchange duct with the Workshop; adding new descent battery packs for re-entry as the CSM fuel cells will not be operational by the time of re-entry; adding heaters and control wiring to

warm that portion of the spacecraft shadowed from the sun; installing additional Reaction Control System propellant tankage with a common manifold system, thus providing an alternate means for returning to earth in the event of a malfunction in the main engine of the Service Propulsion System; changing the spacecraft caution and warning system so that it can be monitored while the astronauts are not on board; allowing for communication and telemetry switching through the Workshop; making changes to the electrical power and propellant storage systems; and providing, within the Command Module, for the 900 to 1,000 pounds of supplies, equipment, and data that will be carried to and from the Workshop by each manned mission.

FY 1971 funding will continue the engineering and manufacturing effort begun in previous years for these program modifications to the Command and Service Module. Four spacecraft are being modified for this first Workshop, with one spacecraft held in reserve as a backup. All four spacecraft are presently in manufacturing assembly, and during FY 1971 the first of these spacecraft are scheduled to complete systems integration, and checkout of two spacecraft will begin during the fiscal year. FY 1970 and FY 1971 funding will also be used for testing and qualifying any modified or new components for these four spacecraft.

Saturn IB launch vehicles will be used in the Apollo Applications program to launch Command and Service Modules with its astronaut crews. All Saturn IB vehicles used in the program were transferred from the Apollo program.

Funding in previous years covered the storage and maintenance costs for the transferred vehicles, and for the production of the first stages of vehicles 213 and 214, (all further Saturn IB production was terminated last year) and for cadre efforts in the areas of engineering, operations, and logistics for the Saturn IB stage.

The FY 1971 funding request provides for continued storage and maintenance efforts, and for the costs of withdrawing four Saturn IB vehicles from storage, undertaking both modification and refurbishment of the first several vehicles, and checkout and delivery preparations of one vehicle in FY 1971.

Payloads and Experiments

Incorporated within the Orbital Workshop will be both the crew quarters and experiment stations and work areas. The Orbital Workshop supports the crew and missions by providing electrical power, communications and data acquisition, thermal control, attitude control, meteoroid shielding, and water storage. The Workshop consists of two levels with one level housing the crew quarters and medical experiments, and the second level being used as a work area with technology and additional medical experiments. The basic power for the Workshop will come from two massive solar cell arrays whose total area will be about 1,500 square feet.

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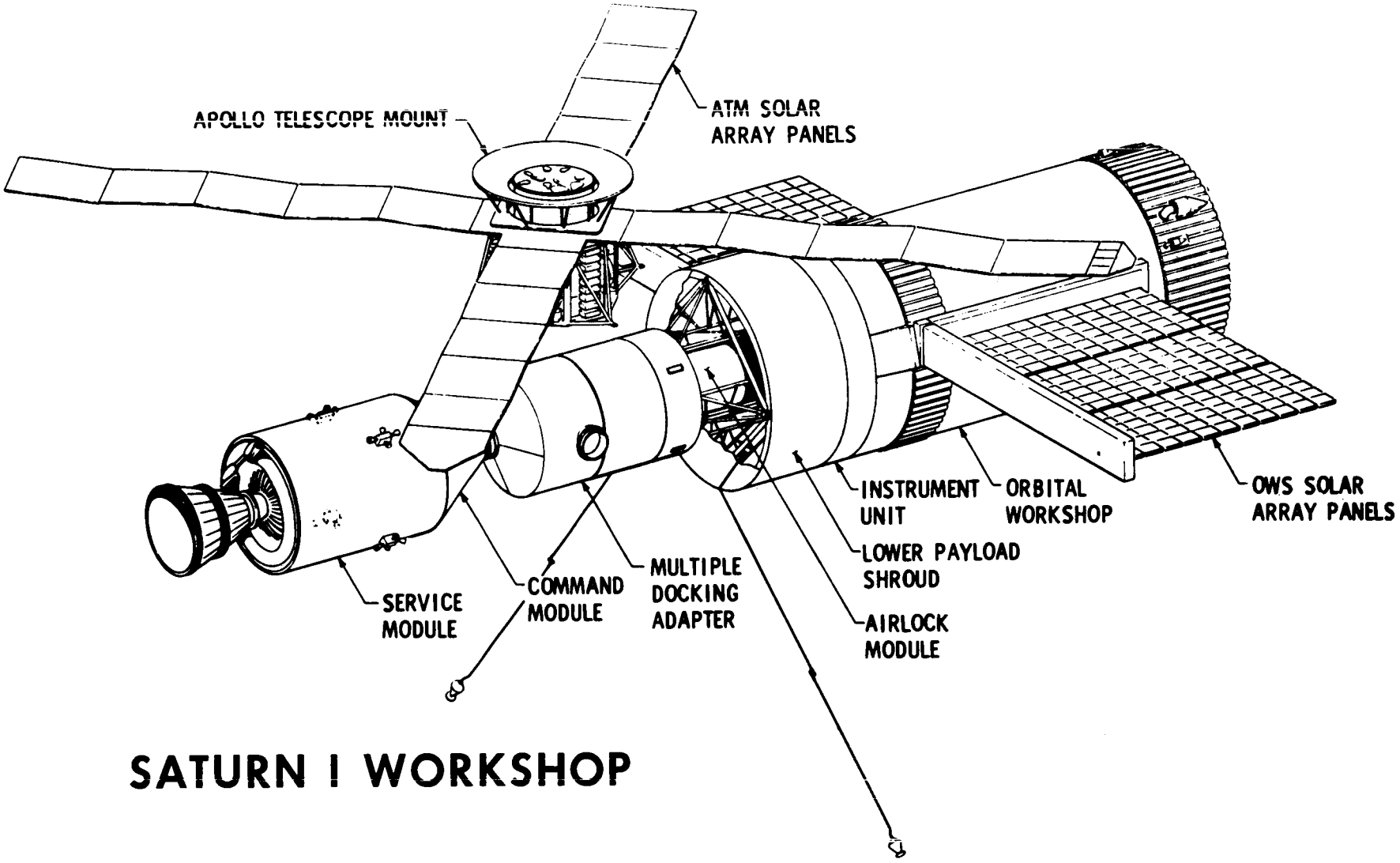


SATURN I WORKSHOP

The Workshop is being constructed by the McDonnell-Douglas Corporation using the basic structural frame of an S-IVB stage. The stage will have the engine and propellant piping removed and the tanks will be sectioned to provide floors and ceilings. A hatch with a window will be installed in the Workshop to allow access during pre-launch checkout and viewing during earth orbit.

Subsystem design, development, and fabrication began several years ago and will be completed in FY 1971. Systems installation began in FY 1970 and will continue in FY 1971, with the Workshop being checked out during the latter half of the year prior to delivery to the Kennedy Space Center. During FY 1970, thermal, dynamic and environment testing of the Workshop will be conducted.

Attached to the Workshop will be the Airlock Module, which provides systems for the Saturn Workshop in the areas of life support and thermal control, power conditioning and distribution, instrumentation, and controls and displays. The Airlock will contain an extravehicular activity hatch for access to space and the necessary EVA support systems. Around the Airlock, oxygen and nitrogen will be stored in pressurized vessels to provide the crew with a two gas atmosphere. The gases and tanks will weigh nearly 23,000 pounds.

The Airlock Module is also being developed by the McDonnell-Douglas Corporation. Subsystem design, manufacturing, and testing have been conducted for the past several years. The structural test article was delivered to MSFC for testing in May 1969. Fabrication and assembly of the flight unit was underway in 1969, and will be continued during both the current fiscal year and FY 1971. A series of systems tests in the operating mode of the Airlock Module and the Multiple Docking Adapter are scheduled in FY 1971.

The Multiple Docking Adapter, being developed by the Marshall Space Flight Center, includes: a docking part which connects the Command and Service Module with the Workshop, a crew access hatch to the Airlock, viewing windows, experiment work and storage areas, and the control and display unit for the solar observatory.

Fabrication, assembly, and checkout of vibration and structural test units were completed during FY 1969. Testing of these units will be conducted during FY 1970. Structural fabrication and assembly of the flight unit will begin in FY 1970, and will be continued in FY 1971, as will checkout and testing of the flight unit.

With the change to a Saturn V launched workshop, the Apollo Telescope Mount was modified from a free-flying module capable of automated rendezvous and docking with the Workshop, to an integrally attached experiment platform. This solar observatory weighs over 21,000 pounds and will be the heaviest

single scientific experiment unit yet flown in space by this country. (It utilizes three 415-pound control moment gyros and three axis control to give it precise pointing accuracy.) The Apollo Telescope Mount contains five major experiments for observing and recording solar activity. The film record of these observations will be returned to earth by the astronauts for analysis by scientists.

Fabrication of structural vibration and thermal test units of the ATM was underway in FY 1969, and testing of these units will be conducted during FY 1970 and 1971. Fabrication and assembly of the prototype unit will begin in FY 1970 and fabrication and assembly of the flight unit beginning in FY 1971, with delivery in FY 1972. Development and production of the ATM experiment began in 1967, and the tested flight units will be delivered to the Marshall Space Flight Center in early FY 1971.

Design, development, production, and testing of all other experiments for the Workshop have been underway for several years and will continue during FY 1970 and 1971. Most of these experiments will be delivered for incorporation into the Workshop, Airlock, or Multiple Docking Adapter by the end of FY 1971.

An essential element in achieving a successful mission is properly coordinating and locating the various experiments, so that each can function with minimal interference upon the operation of others, and is positioned so that it can obtain the maximum amount of data. To achieve this, efforts including payload analysis, systems engineering, and design and development work are undertaken.

Other tasks directed toward incorporating the experiments in the Saturn Workshop include supplying requirements data, program and planning specifications, payload interfacing, test and checkout plans and procedures, and ground and in-flight support equipment.

FY 1971 funding will continue this experiment integration effort and will also support the design, development, and fabrication of mission hardware, and associated studies and analyses of experiment alternatives and experiment performance. In addition, FY 1969 funding was applied to initiate Phase B studies for the Space Station. The continuing efforts in this area are discussed under the Space Shuttle/Space Station program.

Operations

	1969	1970	1971
Launch, flight and recovery.....	---	$18,198,000	$32,700,000
Technical.....	---	6,350,000	8,200,000
Total.....	---	$24,548,000	$40,900,000

Launch, Flight, and Recovery

This activity funds only the unique project requirements of missions to be conducted within Space Flight Operations. The basic support for manned space flight launch, flight, and recovery operations, is funded under Apollo.

Operations include efforts at the Kennedy Space Center and the Manned Spacecraft Center that are directly involved with prelaunch, launch, flight, crew, and recovery planning activities. Included are mission planning and analysis; procurement for an ATM simulator; trainer modifications to Apollo Application configurations; maintenance of Saturn IB launch capability; modification of launch checkout equipment to accommodate Apollo Applications unique hardware; test planning and procedures for checkout of previously deactivated equipment and systems as well as Apollo Applications unique hardware and planning for reactivation of launch complexes for Apollo Applications.

FY 1971 funds are required for mission planning, simulators and trainer modifications, crew training, initiation of reactivation of Saturn IB launch equipment and crews, including necessary equipment modifications to support the unique Apollo Applications missions; and test planning.

Technical

Technical operations provides for integrated technical support, review, and analysis of the Apollo Applications missions. These services include the development of functional and performance standards consistent with mission objectives and mission planning; technical integration and evaluation; formulation of test objectives and their subsequent integration; mission and systems specifications; trajectory analysis; checkout effectiveness; and technical documentation.

Space Shuttle and Station

During the last half of this decade, this country will commence a new epoch in manned space flight. In the short age of manned flight, man's journeys into space have been both brief and intermittent, focused on exploring this new region and testing his ability to survive. The space shuttle and space station will further transform this history.

To introduce this new epoch, when man will truly exploit the environment of space, this country must develop an economical system for ferrying men and materials to and from earth orbit. Without such a system, the performance of space tasks could become disproportionately expensive.

With the establishment of a space station and its continuous operation in near-earth orbit, and with the associated operation of the shuttle, the environment of space can be applied toward a tremendously quantitative and

qualitative expansion in human knowledge--to promote a better understanding of the earth, sun, solar system, and the universe beyond; of phenomena in the biological and physical sciences; and of the interrelationship and interaction of the many processes and phenomena that establish, control, and affect the environment of this planet. Many of these efforts will hopefully foster an improvement of human conditions.

The space shuttle, with its various capabilities, will be developed as a national vehicle and can be used by other government agencies and departments to assist them in meeting their responsibilities to the nation.

The space station can also be the basis for accelerating international cooperation in space. The station, possessing an environment where scientists, technicians, and observors, who are not astronauts, will perform tasks and conduct experiments; and permit citizens of many countries to participate in the exploration and application of space. It is expected that some countries may undertake the financing of from one to several experiments. It may contribute to greater cooperation among nations on earth as systematic studies and surveys of the earth demonstrate that environmental processes recognize no political boundaries.

Space Shuttle

The space shuttle is a reusable space vehicle system, which provides an economical method for meeting a variety of launch and orbital requirements, and represents the basic space transportation system for the remainder of this century.

Once operational, the shuttle could be the only vehicle used by the United States to transport men to and from earth orbit. As currently conceived, the shuttle will be able to carry at least 12 passengers to and from a space station or space base. With a cabin environment similar to that found in today's commercial airliners, and with gravitational forces of no more than 3G's being exerted during the launch and re-entry phases, passengers without special training can be carried to and from space safely and efficiently. This will permit men from many countries to travel in space and participate in the discoveries to be found, the experiences to be shared, and the knowledge to be applied.

The space shuttle is expected to have a payload capability of up to 50,000 pounds in low earth orbit (a capability presently exceeded only by the Saturn V) with a payload compartment 15 feet in diameter and 60 feet long and having a volume of 10,000 cubic feet. This capability can be utilized to meet a single requirement or distributed among several users.

As presently conceived, each space shuttle is composed of two stages - the booster and the orbiter. Both are reusable, and will be designed to perform 100 missions with a minimum of maintenance. It is expected that both stages will be manned, although the booster may have the capability of making an automated return and landing.

SPACE SHUTTLE LAUNCH

The shuttle has been assigned a preliminary design weight ceiling of 3.5 million pounds including propellant, or approximately 55% of the weight of a Saturn V. The projected height of the shuttle system is between 200 to 250 feet, considerably less than the 363 feet height of a Saturn V with the Apollo spacecraft.

The orbiter and booster will each use high-pressure liquid oxygen/liquid hydrogen fueled rocket engines for propulsion. Each engine will have a designed thrust of 400,000 pounds, or nearly twice the thrust of the J-2 liquid oxygen/liquid hydrogen engine used in upper stages of the Saturn V. It will be throttlable and capable of continued reuse and multiple restarts. In addition, both the orbiter and booster will use a set of jet engines similar to those used by aircraft, but which will be fueled by hydrogen. These engines will provide the power during the cruise return to the landing area.

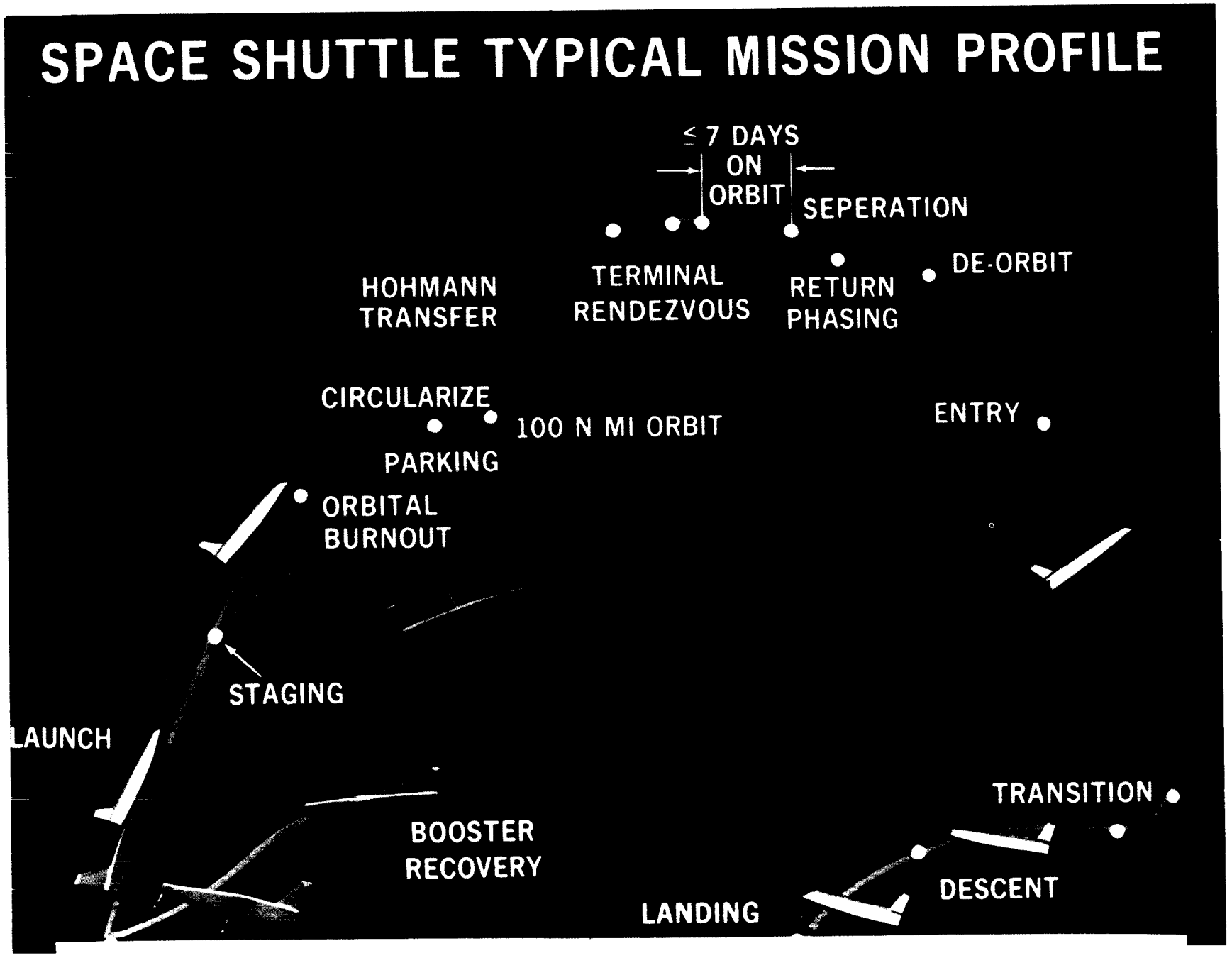
The operational sequence of the space shuttle begins at the launch area where the mission payload, contained in modularized cargo containers, will be loaded into the payload compartment of the orbiter. The shuttle is then moved to the launch complex for a vertical launch. The booster stage propels the shuttle to a suborbital altitude of 40 to 50 miles. The orbiter and booster then separate, and the booster maneuvers for a return to earth. An aerodynamic 'gliding' characterizes the initial phase of the return, but at an altitude of about 10 miles the jet engines are started to fly the booster subsonically back to the landing runway.

After booster separation, the orbiter engines ignite and burn until the stage gains the velocity needed for insertion into a low elliptical orbit. The engines are later restarted to circularize the orbit at 100 miles. Restarts can also be made to execute transfers to other desired orbits.

The life support and power systems of the orbiter are designed to provide it with the capability to be self-sustaining for up to seven days. At the conclusion of its mission, the engines are refired to brake the orbiter back into the atmosphere. Aerodynamic braking slows the orbiter until it reaches a speed where it is able to perform a transition to the cruise configuration of an airplane. Using the jet engines for power, it returns to the launch area for another mission. Both booster and orbiter stages will be designed to land on runways approximately 10,000 feet in length.

Having landed, the booster and orbiter will be checked out, provided with new payloads, refueled, and readied for another launch two or three weeks later. An important element in the design of the space shuttle will be the ability to achieve short turn-around times between flights and reduce the number of vehicles required for the planned missions.

Initially, the shuttle will be used in transporting flight crews, scientists, experiments and supplies to space stations and space bases in earth orbit. Later it will also be used for transporting supplies and


SPACE SHUTTLE TYPICAL MISSION PROFILE
≤ 7 DAYS
ON
ORBIT
SEPERATION
HOHMANN
TRANSFER
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PHASING
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BURNOUT
STAGING
LAUNCH
TRANSITION
BOOSTER
RECOVERY
DESCENT
LANDING

equipment into an earth parking orbit for transfer by a nuclear stage to such distant destinations as lunar and planetary bases. Some of the anticipated logistics requirements for the station and space bases are: food, water, ammonia, medical and hygiene supplies, and personnel supplies; propellant for the reaction control systems; gases and liquids that cool and pressurize; computer tape and microfilm; materials and experiment module fluids for the scientific and applications work being performed; and replacement and spare components and subsystems for repairs. The space shuttle will also have the capacity to launch experiment modules associated with the operation of the space station and space bases.

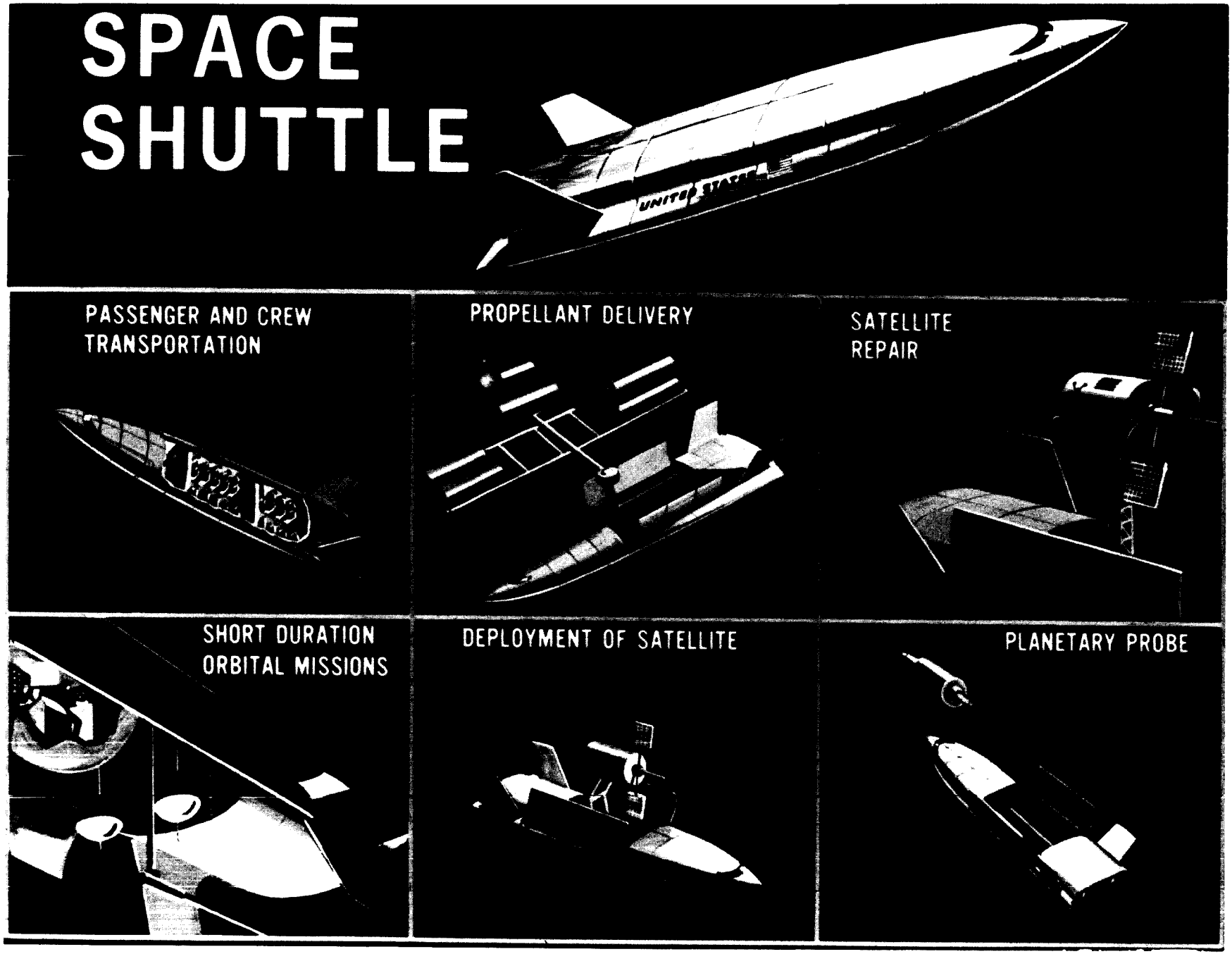
A shuttle, flying missions in a polar orbit, can complement the scientific and applications experiments conducted by investigators on the space station or base. The orbital inclination of the station or base is not planned to be greater than 55 degrees and will not encompass the polar and near polar region of the earth. A shuttle, launched into a polar orbit, will be able to cover every point on the earth.

This is especially important in the development of instruments pertaining to surveys of the earth's resources which are important to an understanding of the ecological and climatological process in the polar regions and their effect on the temperate and tropical areas. In the study of space physics, and particularly the environmental perturbations produced by radiation of various kinds and sources, the polar region is again important as the local of important phenomena in the atmosphere, ionosphere and magnetic field.

The space shuttle will be capable of carrying from one to several automated satellites and positioning them in their selected earth orbits. The shuttle can be used for satellite retrieval and maintenance. Satellites that have malfunctioned or indicate a degradation in performance can be returned to earth for failure analysis, repair, and future reuse. The shuttle can also be used to review satellite performance, monitoring their orientation, systems operation, and instrument development. Another application is its use in the developmental flight testing and calibration of various sensors and scientific experiments in space, thus demonstrating their performance before committing them to operation.

The space shuttle can serve as an orbital staging platform for automated planetary probes and spacecraft. It would launch the planetary spacecraft, and possibly its attached propulsion stage, into the orbit around the earth from which the spacecraft is inserted into a trans-planetary trajectory. When spacecraft size and weight permit, the propulsion stage would be integrally attached to the spacecraft on earth, and carried as a unit by the shuttle.

Future manned space exploration to the moon and to the neighboring planets will be made using nuclear propulsion stages. These stages, using liquid hydrogen fuel, will be reusable and capable of making ten round-trips between


SPACE
SHUTTLE
PASSENGER AND CREW
TRANSPORTATION
PROPELLANT DELIVERY
SATELLITE
REPAIR
SHORT DURATION
ORBITAL MISSIONS
DEPLOYMENT OF SATELLITE
PLANETARY PROBE

earth orbit and lunar orbit. For each trip, however, the stage must be refueled with approximately 250,000 pounds of liquid hydrogen. The space shuttle will be used to transport this liquid hydrogen to earth orbit.

Finally, the space shuttle will be designed so that it can be maintained in a state of launch readiness for lengthy periods, and yet be launched within two hours notice. In the event of an emergency in space, it could carry engineering or repair specialists to overcome the problem, or rescue an endangered crew.

The many expected uses for the space shuttle illustrate its versatility, and its unique ability to solve most of the logistics and transport problems associated with an effective utilization of the space environment. The expected high annual requirement, both in missions and in logistical weight, requires the development of a space transportation system that has a low operational cost. The space shuttle, through reuse, minimum post-mission maintenance and refurbishment, and aircraft type checkout operations, could reduce the cost per pound of payload in orbit by a factor of ten.

The NASA commenced detailed studies of the shuttle in 1969 with study contract awards to General Dynamics, Lockheed, North American-Rockwell, and McDonnell-Douglas. These contracts, which have been completed, were for preparing and analyzing conceptual designs for a reusable space logistics system that would reduce present payload launch costs by an order of magnitude. From the results of these contractor efforts and other NASA and Department of Defense studies, a preliminary space shuttle configuration has been established with the desired payload and performance characteristics, and a preliminary evaluation of various systems and technology requirements has begun.

During FY 1970, the NASA plans to award two sets of definition contracts for the space shuttle. One set of competitive contracts will be awarded for a study of the basic shuttle vehicle, including the aerodynamics, integrated thermal protection system and structure, avionics, and auxiliary propulsion. These studies will emphasize the reusability, maintainability, and low cost operational features of the shuttle and produce a proposed preliminary design of the space shuttle. Additionally, the contractors will assess the mass properties, performance and weight sensitivity, dynamics and control, and development risks inherent in the configuration. Finally, they will perform: system analyses, including safety, mission profiles, launch operations, and payload integration and logistics; design analyses, including structures and materials; and a cost and schedule assessment of the space shuttle program. A major element of the work in these contracts is expected to be the thousands of hours of wind tunnel testing undertaken to verify the soundness of the proposed preliminary designs.

A second set of competitive contracts will be for definition studies for the high performance liquid oxygen/liquid hydrogen engine to be used on the

shuttle. The contractors will undertake a design definition of the engine system and component configuration including the sequence of operation, performance limits, and design margins, and define the requirements for engine test stand facilities. The contractors will also identify and assess areas where economies can be achieved in the production and maintenance of the engines. In addition, they will conduct limited testing of critical components to demonstrate the capability of the components and subsystems to meet the requirements.

Presently, several contractors using other government and corporate funds are conducting test firings of smaller sized engines that contain some of the essential features of the shuttle engine; consequently, much of the technology required is under development.

Within the vehicle system, there are several important technology areas where additional work will be conducted to develop and apply technology for shuttle use. These include: analyzing the aerodynamic configuration of a vehicle that must engage in controlled flight through the orbital, hypersonic, supersonic, transonic, and subsonic flight regimes, and be landable on a contemporary runway; a thermal protection system using materials incorporating nonmetallic and metallic radiative heat shield concepts that can withstand temperatures that are expected to reach 2,000°F, and also provide reusability without refurbishment; dynamics and aerolasticity of the vehicle including dynamic loads and response, fuel slosh, shock loads at liftoff, staging, and landing; and within the flight dynamics and aerolastic environment the flutter, buffet, ground loads and divergence, coupled dynamics, POGO, winds, gusts, and control loads. Other important technology studies are: to produce efficient structural design employing materials with regard for vehicle weight, heat and dynamic loads, and reusability requirements; to improve materials such as: temperature bearings, lubricants and seals, and cryogenic insulation; and to explore methods for fabricating large quantities of high temperature metals. Much of the electronics technology is available but a major task will be to produce efficient integration of these systems.

This research is one part of a parallel effort. The results of this effort and of the information developed from the contractor design studies will be promptly coordinated between the various contractors to most effectively and efficiently progress toward the development of a technically and economically valid design of the space shuttle.

The NASA's Office of Advanced Research and Technology will undertake in FY 1970 and 1971 much of this supporting technology for the space shuttle. It is expected that much of the technology developed and demonstrated in the space shuttle will be used by military and commercial aircraft in future decades.

The FY 1971 funding for the space shuttle is for continuing definition efforts and for initiating a detailed design of elements of the shuttle,

especially the engine and the prototype development of selected critical components. Other funding may be applied to develop a necessary test capability through facilities modifications at selected sites where existing engine test stands are located. In addition, modifications in support of component and altitude testing may be required.

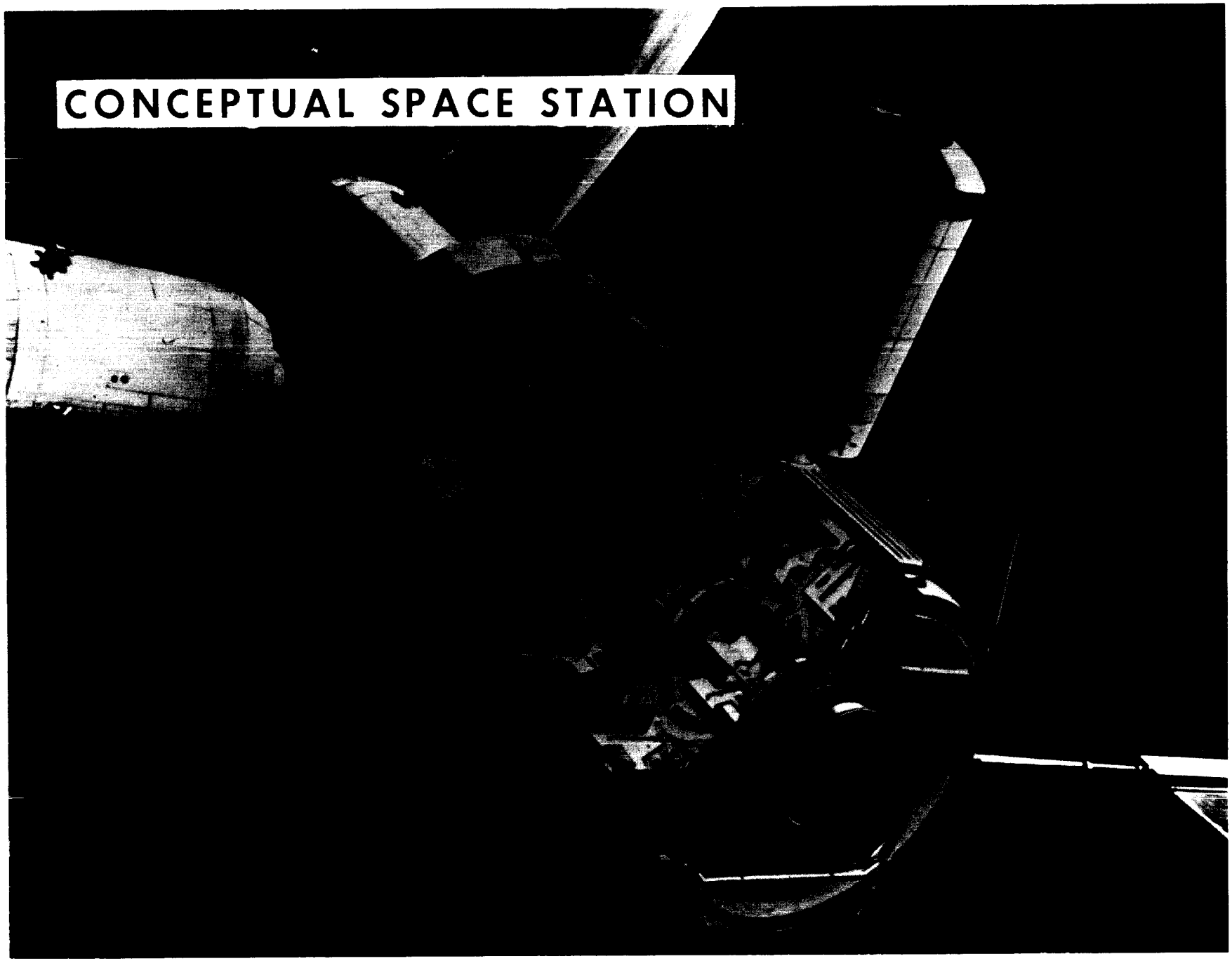
Space Station

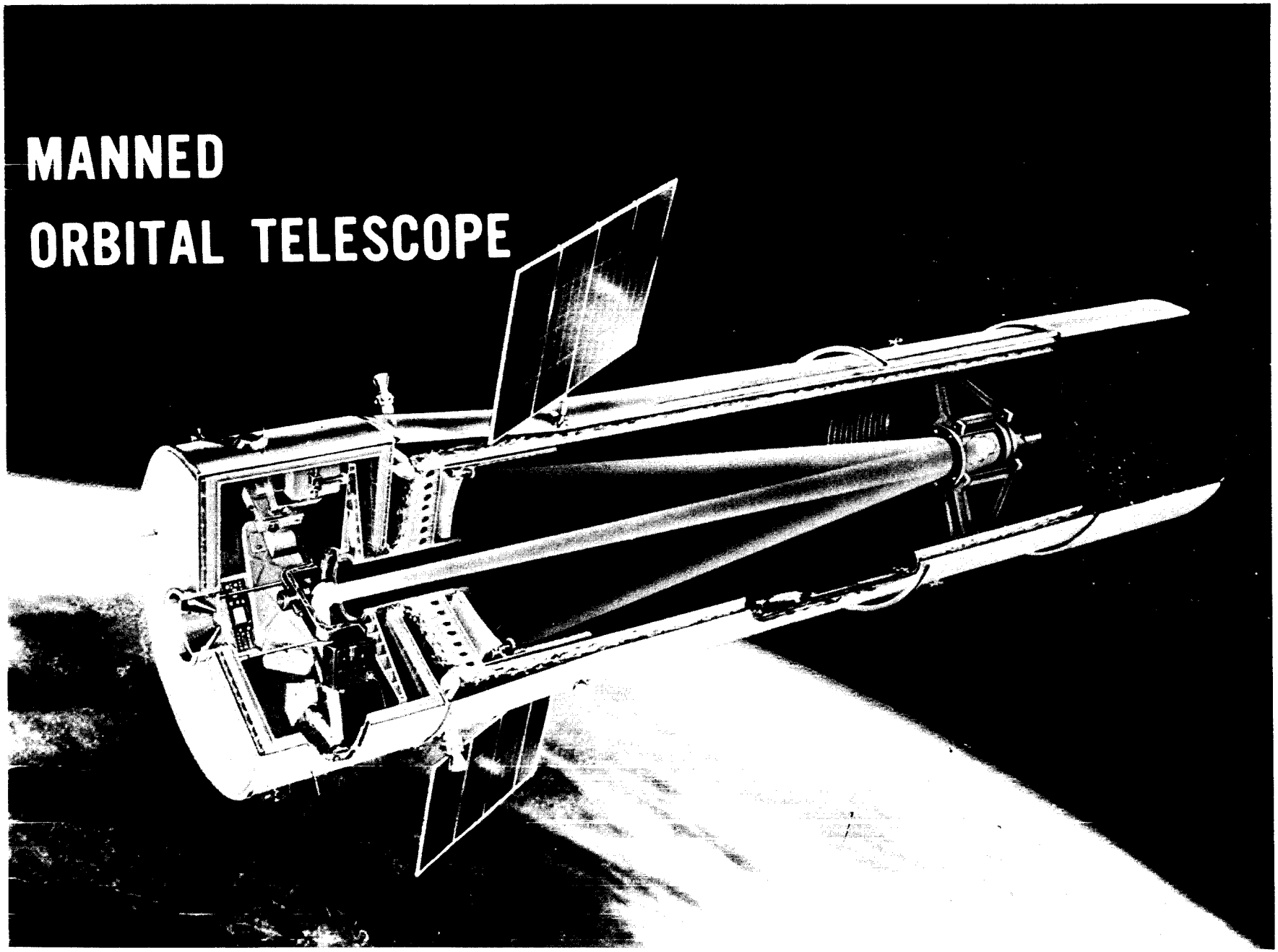
An essential element in the continued exploration and utilization of space in future decades is the space station. Without the station many of our endeavors in space will be restricted and their application to all men limited.

The space station and the space base which will develop from it will be the central carrier through which man can increasingly progress toward a fuller understanding of his world and the universe. The station and base will also provide the support for aggregating many of the necessary tasks to be undertaken in space, and for consolidating and inter-associating the many scientific and technological disciplines whose results provide the means for this progress in knowledge.

The space station will have an initial crew complement of 6 to 12 people. The subsequent base could be a multi-purpose facility in earth orbit housing a crew of 50 to 100 men. The station will primarily serve as the supporting platform for a very diversified group of scientific, applications, and technology experiments encompassing nearly all scientific disciplines. The experiments for the space station and space base will be conducted in various modes--some in modules attached to the station or base and with an environment of zero gravity or artificial gravity, and some free flying in varying orbits, inclinations, and altitudes.

The following principal experiment groupings, building on those done on the Workshop, are being considered for the space station and for possible later use in association with a space base. These manned experiments will complement and extend the information available from automated satellites observing specific phenomena. The X-ray telescope will examine X-ray sources in the sky, especially areas and objects where the X-ray radiation exceeds all other forms of radiation. The resolution power of the telescope in the stellar astronomy module will significantly increase our knowledge of astronomical objects and permit the observation of faint objects not observable from the ground. High resolution studies of the structure of the sun, and the various forms of solar activity will be conducted using a solar astronomy module. The ultraviolet stellar survey will map the entire sky for ultraviolet radiation which is not observable from the ground. A high energy stellar survey will locate gamma and X-ray sources in the sky and the infrared stellar survey will search the sky in wavelengths not recordable on the ground.


CONCEPTUAL SPACE STATION


MANNED
ORBITAL TELESCOPE

Within the science of physics, using scientific airlocks and subsatellites, data on the environment in the near-space regions of the earth will be obtained. Airglow, Gegenschein and Zodiacal light, the chemical composition of the atmosphere, and solar light scattering are among the phenomena that will be examined. From ionospheric studies and mapping, a greater understanding of plasma physics and environmental perturbations will be developed. A cosmic ray physics module will gather cosmic rays over large energy regions and determine their characteristics.

Bioscience experiments will include studies on the role of gravity on the physiology, biochemistry, and behavior of small vertebrates, invertebrates, and lower and higher order plants through their entire life cycle. In an allied group of experiments, biomedical and behavioral research on the effects of very long-duration flight on man will be conducted. Any psychological and behavioral changes will be monitored, and a detailed study of any physiological and functional changes will be performed.

In addition, earth surveys will be undertaken using the space station to test a variety of sensor devices for potential application to the operational systems of the future. The use of the space environment, with hard vacuum and zero gravity conditions, materials manufacturing and processing will be examined. Thin-film electronic devices, glass casting, precision spherical casting, crystal growth, high strength composite castings, and variable density castings such as foams are among the candidate areas for study. Demonstration of the utility of space for this purpose could result in use of the station or base for commercial production of specialized materials that cannot be duplicated on earth.

Flight crews using the station and base will be ferried to and from orbit by the space shuttle. The space shuttle will also provide the logistics support of the station and base and will be able to carry many of the experiment modules.

Conceptual studies underway on the experiment modules emphasize commonality so that four or five basic module types will be able to support the wide variety of experiments. Basic structural design and the systems for power, thermal control, attitude control, and life support are the principal elementa where commonality appears achievable.

The space station is being designed as a long life maintainable system for men working and living in space. Initially, it is expected to operate in a zero gravity condition. The station and base will be quite autonomous, having on-board command and control centers and life support systems that are capable of regenerating the environment, and operating for extended periods. The major source of power will be a nuclear reactor subsystem. A data relay satellite will provide continuous communications coverage with the ground. Living quarters will be attractive and comfortable, and housekeeping functions will be highly automated.

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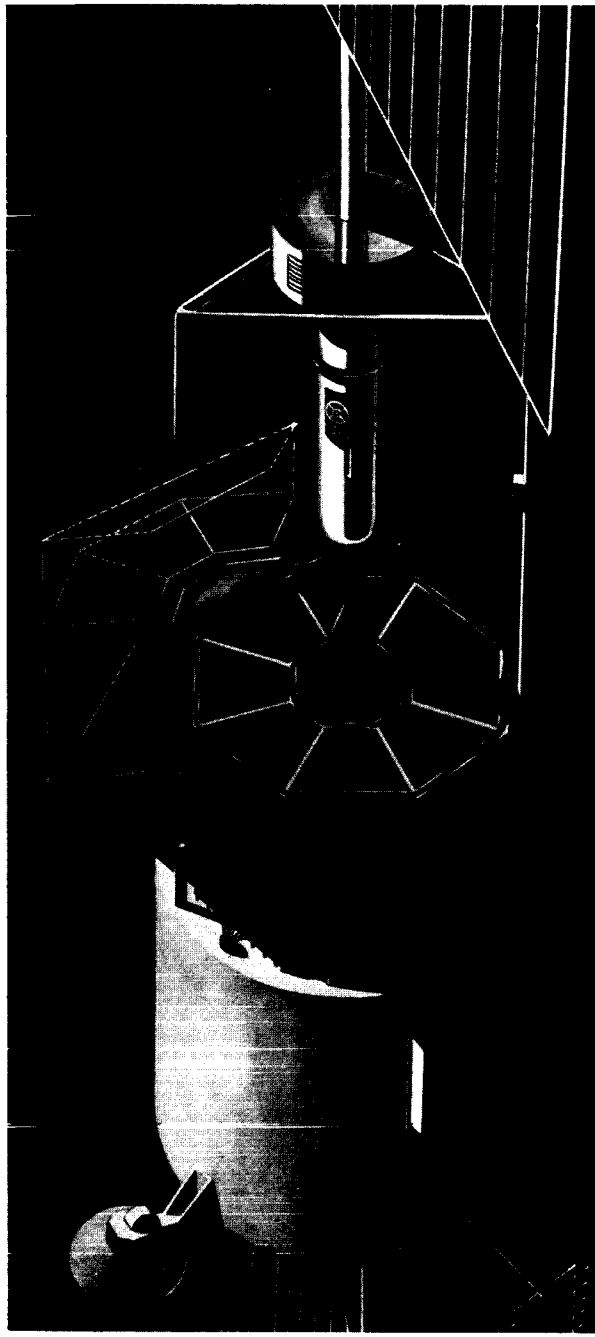
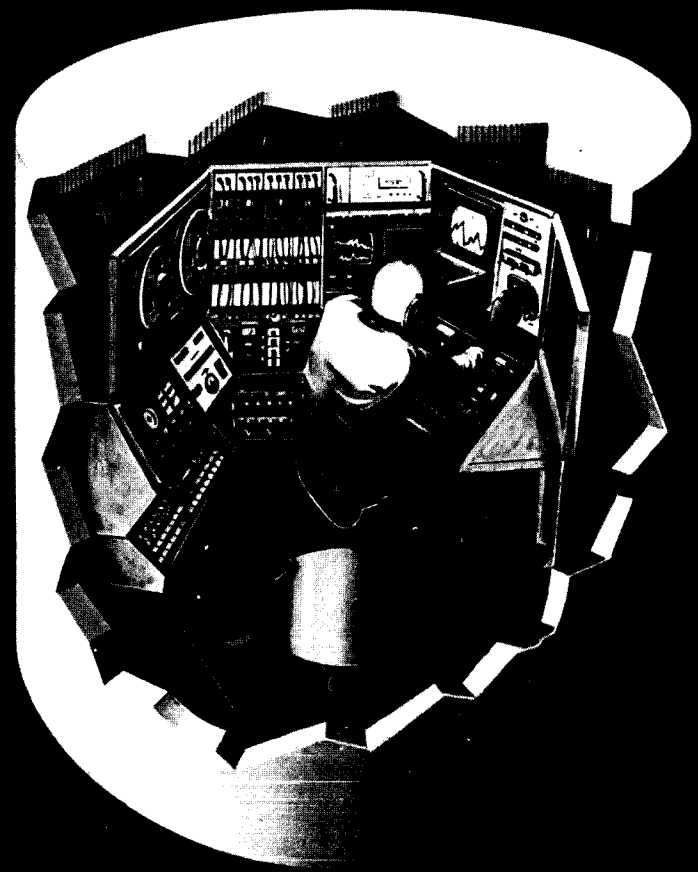
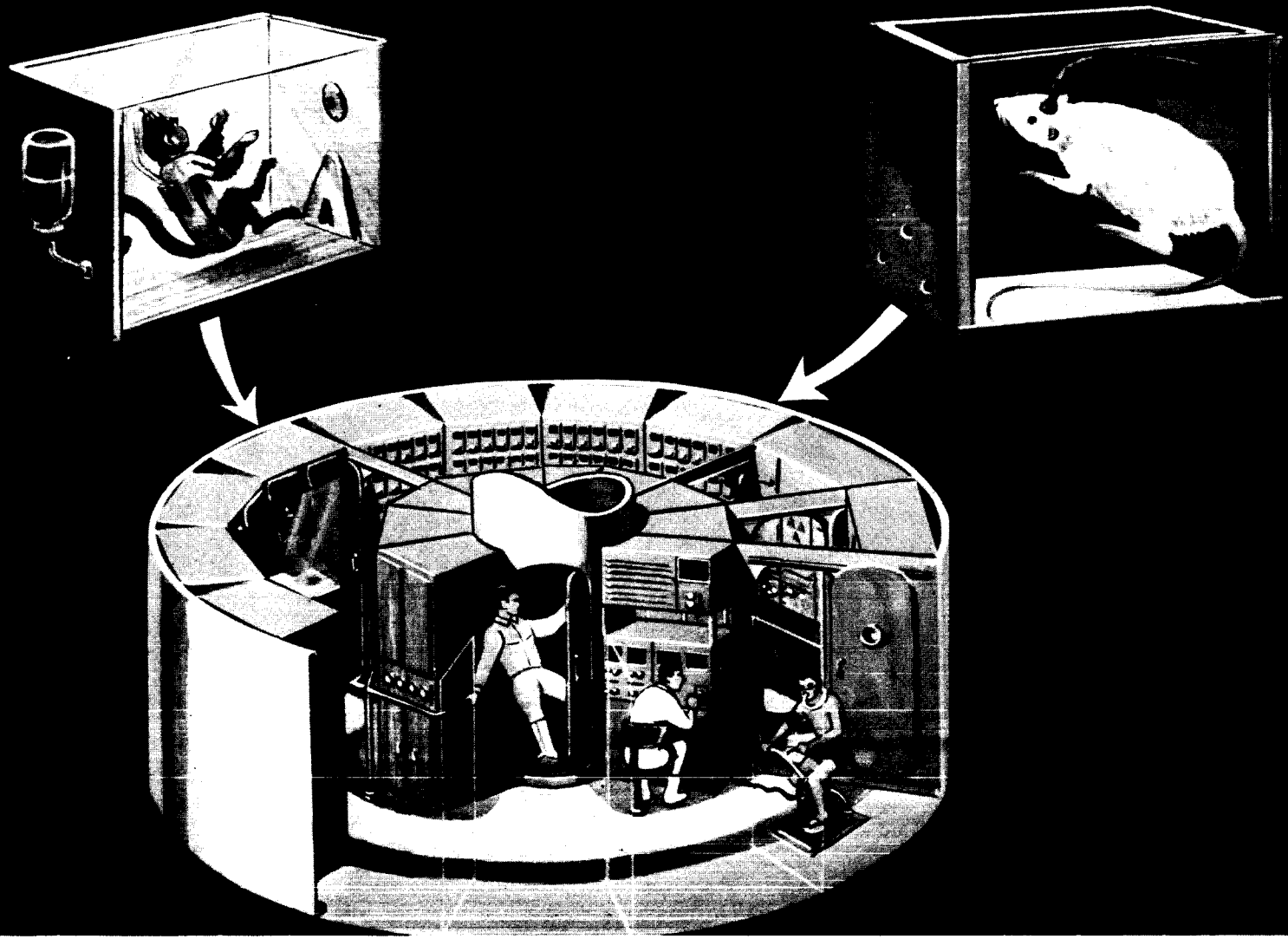
HIGH ENERGY PHYSICS AND COSMIC RAY MODULE

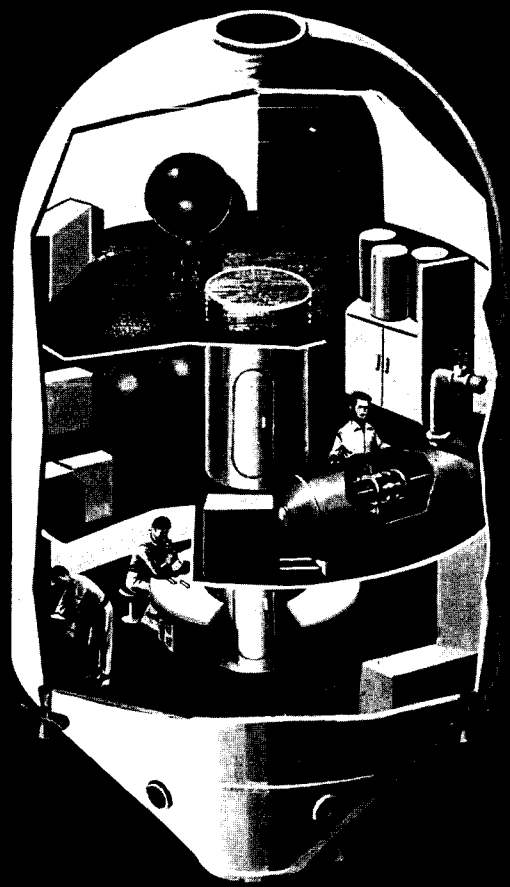


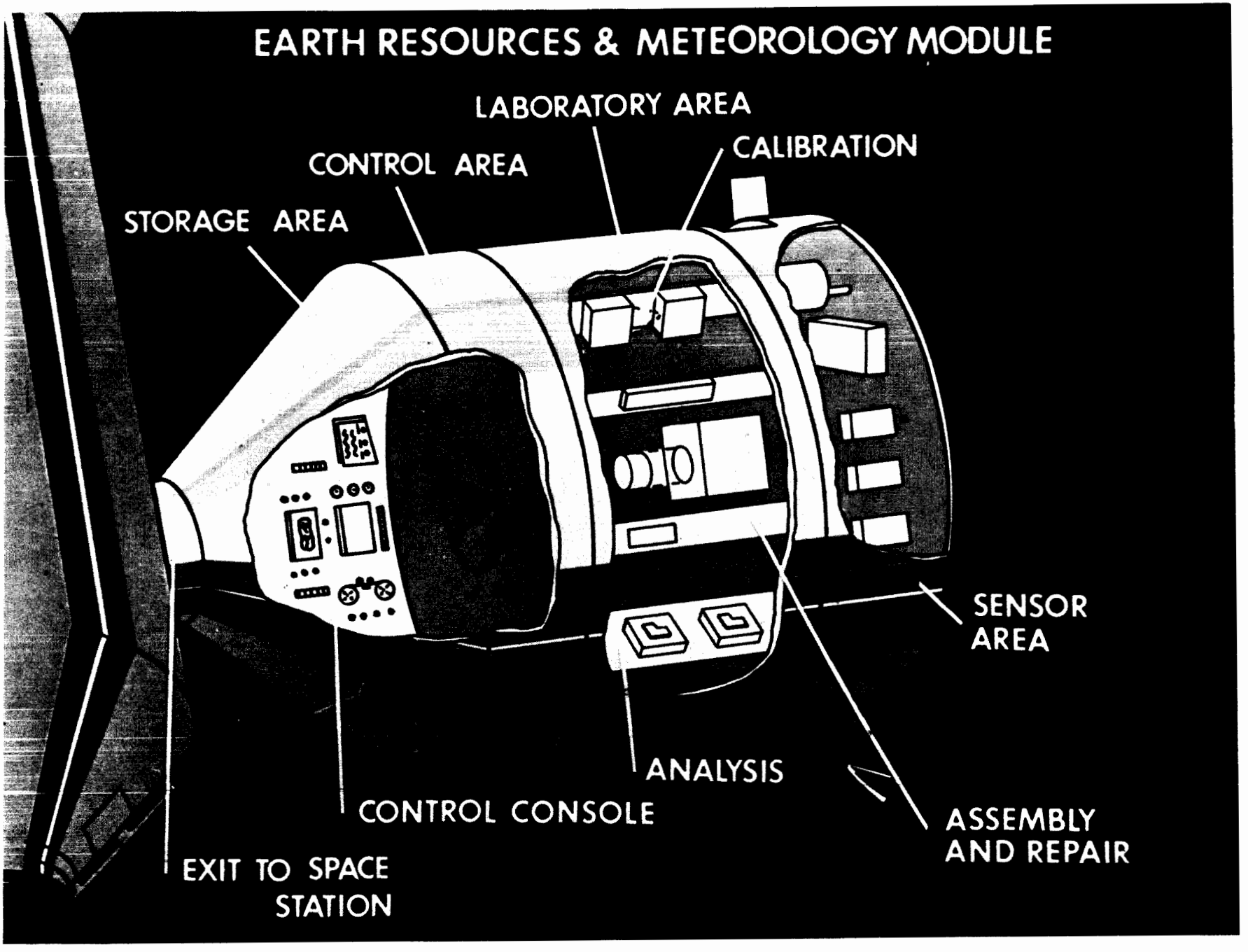


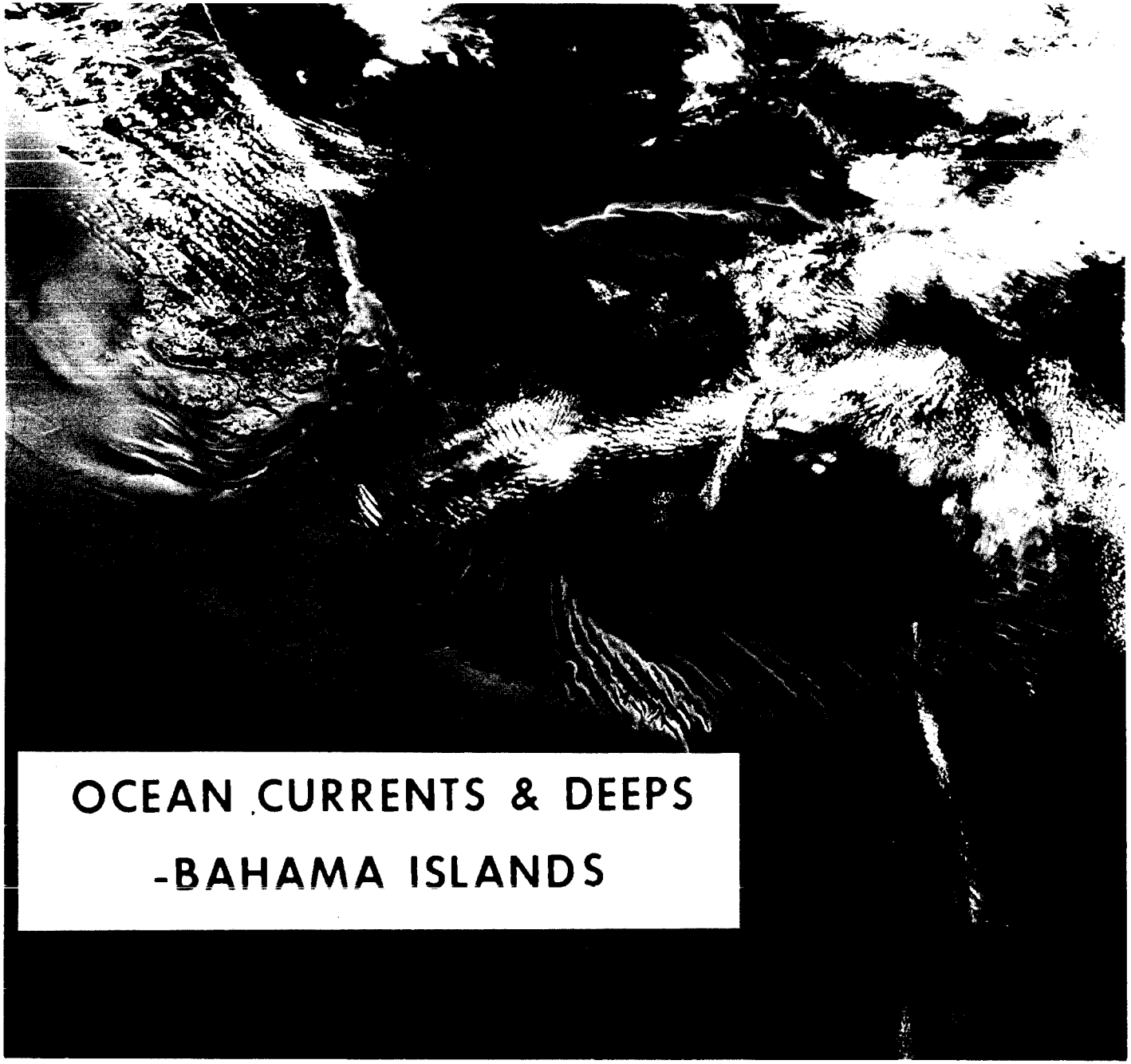
BIOLOGY LABORATORY

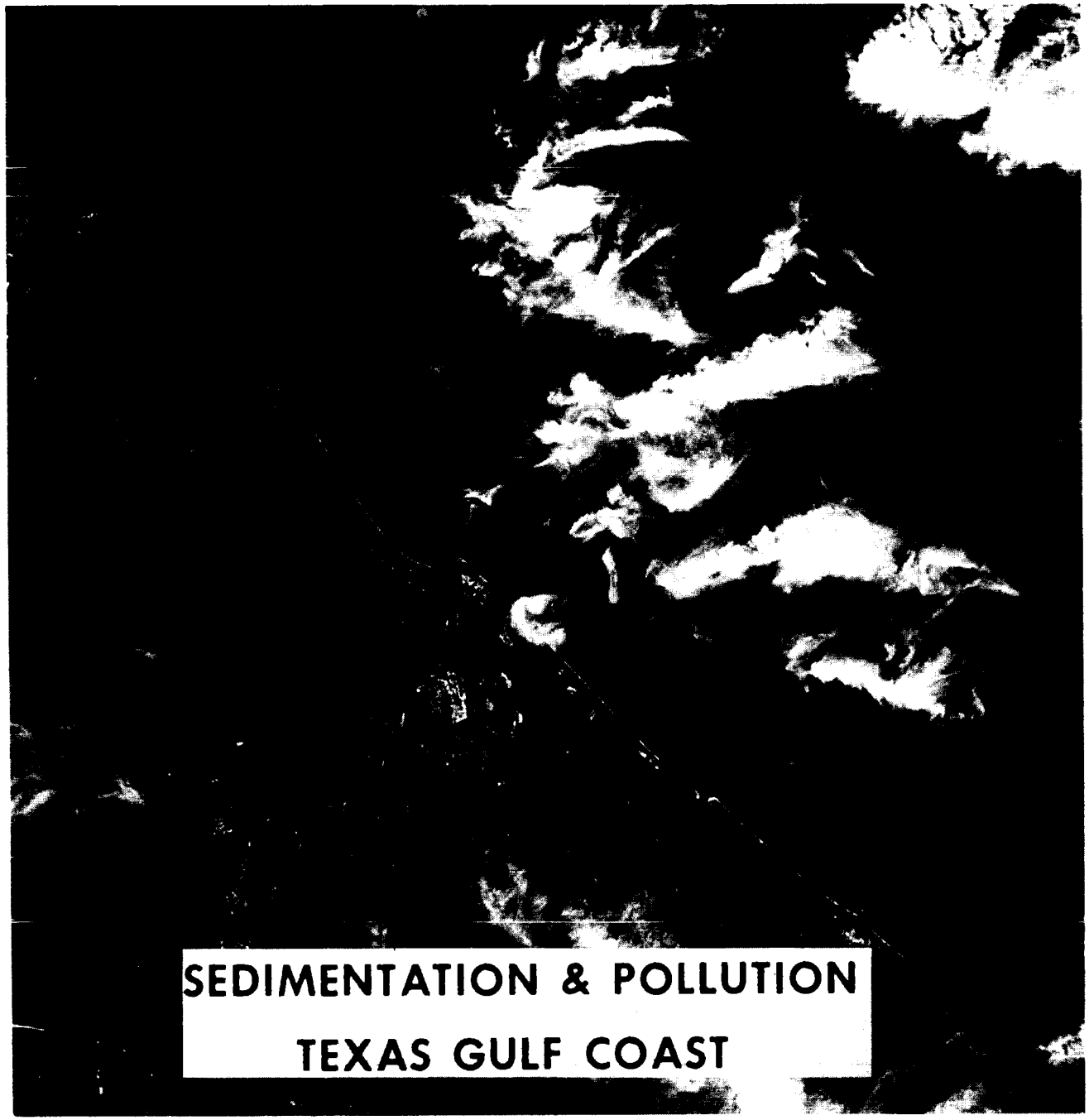


SPACE MANUFACTURING MODULE




EARTH RESOURCES & METEOROLOGY MODULE
LABORATORY AREA
CALIBRATION
CONTROL AREA
STORAGE AREA
SENSOR AREA
ANALYSIS
CONTROL CONSOLE
ASSEMBLY AND REPAIR
EXIT TO SPACE STATION


OCEAN CURRENTS & DEEPS
-BAHAMA ISLANDS


SEDIMENTATION & POLLUTION
TEXAS GULF COAST

The technology required to achieve these systems characteristics and features will significantly increase the capability of the country and much of this new technology can be applied by government and industry in developing or improving products and services on earth. An example of this is the life support system for the station and base. The space station and base will be a confined environmental system with limited resources which are delicately balanced. This is not dissimilar to how man is now viewing his earth. The atmospheric regeneration subsystem on the station must perform the following functions: atmospheric supply and pressure control, carbon dioxide removal and reduction, oxygen reclamation, and contaminant control. Another subsystem must provide for the generation of oxygen, hydrogen, and nitrogen. A third must supply water and provide for waste management including collection, transport, reclamation, sterilization and storage. The final subsystem is for temperature and humidity control. Some of the technology being developed for these subsystems may find application here on earth especially in the control of life critical resources and management of sources of severe pollution.

Space Shuttle and Station

	1969	1970	1971
Experiment definition.....	---	$6,000,000	$12,000,000
Shuttle engine definition and design.....	---	5,000,000	48,500,000
Shuttle airframe definition.....	---	7,500,000	22,500,000
Station definition.....	($8,800,000)	---	6,000,000
Shuttle/station preliminary design verification.....	---	---	21,000,000
Total.....	($8,800,000)	$18,500,000	$110,000,000

Experiment Definition

The early and accurate definition of the experiments and supporting systems in the Space Shuttle/Station program is vital to eventual mission success and the achievement of program objectives. The major portion of the space station operation will be the conduct of manned observations and experimentation. These will impose major requirements on the space station and experiment module design and operation, and dictate an early definition effort.

Before an experiment can be committed to a flight program, it must be determined as being feasible for missions planned in the program and be assessed for its specific contribution to the program objectives. Additionally, it must have well-defined funding and schedule projections and specifications for power, temperature, volume, and any other mission constraints. Assurance is needed not only on the experiment's appropriateness, but on its ability to be readily incorporated in the program and managed effectively. 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 for conduct by man in space to assure an effective use of the space station and the space environment.

In FY 1970 and 1971, funding will be primarily used to clarify and define candidate experiments and to determine the experiment groupings and their equipment that will most effectively use the space station. Efficient program planning dictates that this definition work begin, along with the preliminary design studies.

Shuttle Engine Definition and Design

Special engine studies conducted by NASA and DOD, both in-house and by contractors, together with the results of independent contractor efforts,

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indicate that the state-of-the-art in engine technology and engineering has advanced to the point where the definition of engines that could be used for the shuttle can be undertaken.

The FY 1970 and 1971 funding will provide for engine definition contracts. The contracts are of 11 months duration and are planned for award in the next few months. The studies will provide preliminary engine designs and specifications, define detailed engine requirements, and provide program plans for future development. The contractors will also conduct component testing that will support the preliminary design activities and they will coordinate their efforts with the airframe study efforts and identify the facilities required for the later project phases.

FY 1971 funding will also provide for the start of detailed design of the most promising engine candidates resulting from the engine definition studies. Design of the engines will begin in the last quarter of FY 1971. A need exists to agressively pursue engine design as an earlier phasing is required to provide the necessary information for integrating the engine systems into the airframe design. Design contracts are planned to obtain detailed engine design, manufacturing and test plans, detailed schedules, and the initiation of long lead time items required for component development.

Shuttle Airframe Definition

A series of special studies by NASA and DOD has produced several candidate shuttle configurations and permitted determination of systems characteristics. These results, together with other related studies, indicate that the technology required to proceed with the definition phase of the space shuttle airframe is available. As with the shuttle engine activities, the definition effort will be conducted through competitive contracts and will be of 11 months duration. Definition studies are scheduled to begin in the latter part of FY 1970.

FY 1971 funding supports continuation of the studies initiated in FY 1970. The definition studies will focus on specific point designs and supporting technology including: System analysis, (system safety analysis, mission analysis, system integration, launch operation analysis, system flight characteristics, payload integration, aborts); Design analysis; subsystem definition (propulsion, integrated avionics, mechanical landing, docking, etc.); configuration preliminary design; configuration preliminary verification (structural test program); and program management plan.

Station Definition

NASA is currently involved in the definition of a space station. The objective of this effort is to obtain the technical and program information needed for selecting a single design approach of a space station from the alternate approaches available.

The definition effort is being conducted in two parallel studies with industry--one managed by the Manned Spacecraft Center and the other by the Marshall Space Flight Center. The effort is focused on space station preliminary systems design and appropriate development and operation plans. Additional space station supporting activity includes a number of small competitive contracts for studies and technological investigations related to space station definition.

The first phase of the definition studies is scheduled for completion at the beginning of FY 1971. Funds are required in FY 1971 to exercise up to six one-month extensions of definition studies with each contractor. This will allow additional work which can be a beneficial extension of on-going definition efforts. This work will be based in part upon information derived from those contracts and will, within its general scope, include additional comparative analysis and detailed studies aimed at refining technical and program aspects.

At the present time, a number of in-house and contracted studies are underway in various disciplinary areas to ascertain how groupings of experiments, which form payload packages, can be integrated into the space station either in its initial flight configuration, or into separately launched experiment modules. In FY 1971, definition studies of candidate experiment modules which have long lead time requirements and whose operations will impact the station design and operating mode will be undertaken. Modules that can support such experiment packages as astronomical instruments, space physics equipment, materials analysis and manufacturing equipment, will be examined. This definition must take place early in the program cycle.

Shuttle/Station Preliminary Design Verification

The definition studies of the shuttle airframe and space station will identify systems, concepts and techniques critical to their final design. However, before final design criteria are established, additional trade-off analyses are required to verify contractor system selection. In addition, preliminary engineering designs will be initiated and advanced prototype testing conducted on selected long-lead systems to assure their timely availability. Although a considerable amount of research has been accomplished on critical systems such as power, environmental control and life support, design confirmation can be expedited by an early initiation of this prototype testing. This activity is a necessary bridge from the applied research effort of the Office of Advanced Research and Technology to the actual verification of specific technical approaches proposed by the definition contractors.

FY 1971 funding supports the above activities and as the studies progress, those other areas that will be identified as requiring additional verification prior to initiation of detailed design. Systems common to both the shuttle and station that are potential candidates for this effort are: integration

of the electronics systems, attitude control systems, and thermal protection systems. Wind tunnel tests of preferred shuttle designs will be performed. "Breadboard" fabrications representative of integrated electronics systems will be tested and dynamic simulations conducted to verify that the design concepts being produced will permit the initiation of detailed design. Similarly, testing of attitude control system components and systems/concepts will supply data on the use of liquid oxygen/liquid hydrogen propellents, thruster and system response, consistency of performance and thruster impulse capability.

Proof-of-concept testing of the thermal protection systems will be conducted on subsections to provide verification of materials selection, fabrication and installation techniques, characteristic weight, and inspection and refurbishment needs. It is planned that these tests will be conducted only with the more promising concepts.

These tests and studies will greatly increase the assurance that the later detailed design effort will be successful, and result in a more efficient and economical development program for the shuttle and station.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1971 ESTIMATES

OFFICE OF MANNED SPACE FLIGHT — ADVANCED MISSIONS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objectives of the Advanced Missions programs include examining 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:

	1969	1970	1971
Advanced missions studies.....	$2,500,000	$2,500,000	$2,500,000
Total.....	$2,500,000	$2,500,000	$2,500,000

Distribution of Program Amount by Installation:

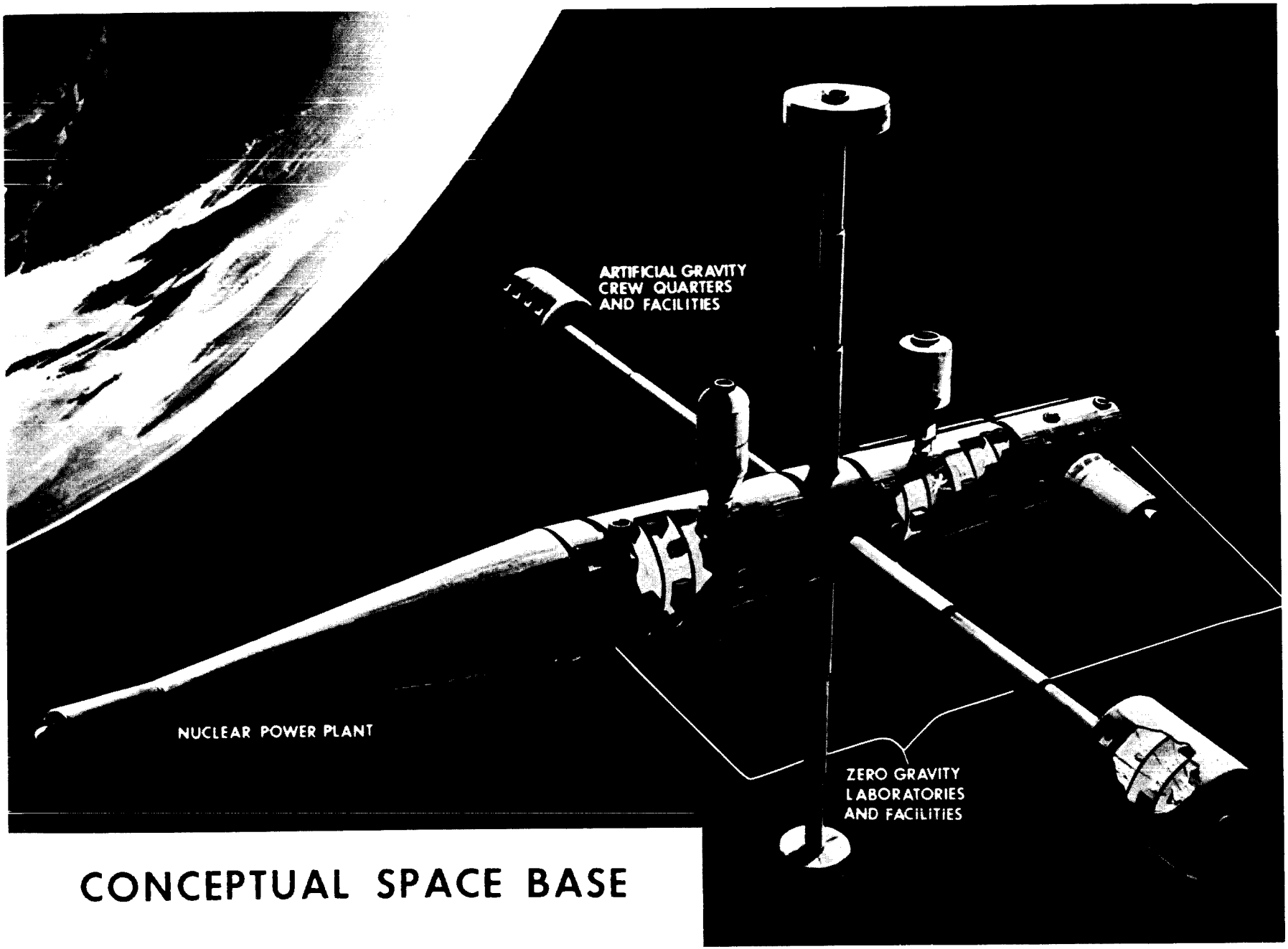
John F. Kennedy Space Center, NASA.....	---	---	$100,000
Manned Spacecraft Center.....	$465,000	$1,000,000	1,000,000
Marshall Space Flight Center....	810,000	800,000	1,000,000
Langley Research Center.....	125,000	---	---
NASA Headquarters.....	1,100,000	700,000	400,000

BASIS OF FUND REQUIREMENTS:

Advanced Missions Studies

Advanced studies.....	$2,500,000	$2,500,000	$2,500,000
Total.....	$2,500,000	$2,500,000	$2,500,000

Advanced studies enable this country to efficiently direct future manned space flight program planning. The studies use the capabilities of industry to perform conceptual designs and provide comparative technical data to supplement in-house activities. During FY 1970, emphasis is being reoriented to study the elements of the integrated program endorsed by the President's Space Task Group. Studies during this fiscal year include: requirements associated with future manned missions, focusing on applying hardware to be developed for the Space Station, Space Base, and future lunar missions; prescribing the desired characteristics of nuclear stages and chemical stages



CONCEPTUAL SPACE BASE

for use in transporting men and payloads to and from synchronous orbit, lunar orbit, the lunar surface, the planets, and between various low earth orbits; examining methods for conducting manned exploration of the moon after completion of Apollo; evaluating the effect of introducing various degrees of self-support in conducting future manned space flight missions; and reviewing critical aspects of proposed future missions, to promote their operational safety.

Funding in FY 1971 will continue to concentrate on the future activities included in the integrated program:

(a) Escape and rescue systems studies will be conducted to establish the best methods and techniques for performing escape and rescue missions from low earth and synchronous orbit space stations and bases, from lunar orbit, and from the lunar surface.

(b) Integrated mission management and operations planning studies will be performed to develop a concept that supports all missions, and develop its evolution through the next decade.

(c) Space base studies will be directed toward the support requirements for major space operations, including the erection of large structures in earth orbit, geosynchronous missions, lunar missions and possible planetary missions. Also to be investigated is the practicality of using the space base for support of a refueling station, as a personnel and cargo staging platform, and as a hardware assembly area. Examination of the performance and operational characteristics of a reuseable vehicle, such as a space tug for manuevering men, equipment and modules in space will be conducted.

(d) Advanced lunar studies will be undertaken to determine the characteristics of a lunar orbit station and a lunar surface base as the integral part of an advanced lunar exploration and exploitation program. An assessment of the compatability of the proposed mission mode with the objectives of this future lunar program will include: personnel and equipment transfer mechanisms between the lunar surface, lunar orbit, and earth orbit; crew sizings for orbital operations; the commonality of a lunar orbit station with earth orbit space station modules; the modification of space station systems for use in a lunar surface base; and the design and operational characteristics of a reuseable lunar landing vehicle.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1971 ESTIMATES

RESEARCH AND DEVELOPMENT BUDGET PLAN FOR

SPACE SCIENCE AND APPLICATIONS PROGRAMS

Program	Fiscal Year 1969	Fiscal Year 1970	Fiscal Year 1971
Physics and astronomy.....	$128,850,000	$111,835,000	$116,000,000
Lunar and planetary exploration.....	87,923,000	151,013,000	144,900,000
Bioscience.....	37,900,000	19,670,000	12,900,000
Space applications.....	98,665,000	128,400,000	167,000,000
Launch vehicle procurement.....	99,900,000	108,800,000	124,900,000
Total.....	$453,238,000	$519,718,000	$565,700,000

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1971 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS — PHYSICS AND ASTRONOMY PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Physics and Astronomy program, when viewed in the framework of broad scientific and technological efforts, has the following objectives: to understand the origin and continuing evolution of the earth, our solar system, the stars, galaxies, and the universe. 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.

To attain this goal, a variety of techniques are used to gather information. These include theoretical and laboratory research; aircraft, balloon and sounding rocket flights; as well as observations using small and large automated spacecraft and manned systems. The latter category covers manned earth orbital flights (AAP) as well as observations conducted from the lunar surface under the Apollo program. 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.

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:

	1969	1970	1971
Supporting research and technology/ advanced studies	$22,497,000	$17,500,000	$17,500,000
Airborne research	1,000,000	1,600,000	3,000,000
Data analysis	3,412,000	3,000,000	3,000,000
Sounding rockets	19,234,000	18,500,000	18,500,000
Solar observatories	13,812,000	14,700,000	16,100,000
Astronomical observatories	36,392,000	31,600,000	27,100,000
Geophysical observatories	13,072,000	6,000,000	5,200,000
Explorers	19,431,000	18,935,000	25,600,000
Total	$128,850,000	$111,835,000	$116,000,000

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Distribution of Program Amount by Installation:

	1969	1970	1971
Kennedy Space Center.....	$60,000	---	---
Manned Spacecraft Center.....	666,000	$490,000	$450,000
Marshall Space Flight Center....	777,000	1,214,000	1,500,000
Goddard Space Flight Center.....	99,422,000	83,700,000	86,800,000
Jet Propulsion Laboratory.....	537,000	920,000	650,000
Wallops Station.....	838,000	734,000	860,000
Ames Research Center.....	2,017,000	3,094,000	4,910,000
Electronics Research Center.....	47,000	40,000	---
Langley Research Center.....	886,000	773,000	740,000
NASA Headquarters.....	23,600,000	20,870,000	20,090,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology/Advanced Studies

Space physics.....	$10,300,000	$7,300,000	$7,300,000
Astronomy.....	12,197,000	10,200,000	10,200,000
Total.....	$22,497,000	$17,500,000	$17,500,000

The Supporting Research and Technology/Advanced Studies programs enhance the overall scientific and technological return from NASA flight projects and help 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 a full supplement of simultaneous ground-based and balloon 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.

These funds provide partial support for the Goddard Institute for Space Studies, the Space Science Board, and the Research Associate Program. About 250 research tasks are carried out by universities, nonprofit and industrial research institutions, NASA centers, and other Government agencies. The following specific areas of research are being supported:

Space Physics

The work is largely devoted to support of research related to 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. In general, these tasks may be categorized in the traditional disciplines of particles and fields, ionospheres, and interplanetary dust.

Particles and fields tasks include research in magnetodynamics and plasma physics, studies of the solar wind and magnetosphere, and magnetometer and plasma detector development. Research in cosmic rays and the radiation belt are carried out under this area. Special efforts are being made to develop detectors for the study of ultrahigh energy cosmic rays. Advanced studies are being performed of combined satellite V systems and of a spacecraft to assess conditions in interplanetary space.

Tasks included in the ionospheres area cover ionospheric theory, plasma physics, radio propagation, electromagnetic waves, ionospheric electron content, electron density and electron temperature, ion mass spectrometers, plasma and langmuir probe observations, antenna impedance, solar terrestrial relations, and ionospheric and magnetic storms and disturbances.

Under the category of interplanetary dust are included the study of meteorites and micrometeorites, micrometeorite simulation, development of instrumentation, theoretical studies, interplanetary gas and dust, noctilucent clouds, cometary physics, and physical and chemical analyses of dust particles. Also included in this area are problems relating to chemical releases, Zero-G physical phenomena, airglow, and zodiacal light observations.

Astronomy

Research supported in this area involves the study of the sun and other stars and objects outside the solar system. Research tasks include studies of the sun and 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. Also included are solar radio and radar astronomy.

Research tasks related to objects outside of the solar system include observation by ground-based and balloon-borne telescopes, radar and radio astronomy, and instrument development. Theoretical studies of stars, galaxies, interstellar and intergalactic matter, and advanced development work on experimental tests of the validity of Einstein's Theory of Relativity are also supported in this area.

Advanced studies are being performed of systems that will lead to the development of large space astronomy facilities, such as, a 120 inch optical telescope, large X-ray and gamma ray observatories, and low frequency radio astronomy antennas.

Airborne Research

	1969	1970	1971
Airborne research.....	$1,000,000	$1,600,000	$3,000,000
Total.....	$1,000,000	$1,600,000	$3,000,000

Research with instrumented aircraft has been an integral part of the NASA program since 1965. This Airborne program has helped bridge the gap between ground-based experiments and those which require the higher costs and complexities of rockets and space vehicles. In the past, this program has supported auroral and airglow research, observations of the solar corona during total eclipses, and infrared astronomy.

Funding includes that planned for the acquisition of a C-141 airplane and for the continuation of the development of a 36 inch infrared telescope. The C-141 airplane and 36 inch telescope will provide us with a unique and cost effective airborne astronomical observatory. It will be used to explore an essentially unobserved part of our universe in that portion of the infrared spectrum that is blocked from our view due to water vapor in the lower atmosphere.

Data Analysis

	1969	1970	1971
Space physics.....	$3,162,000	$2,650,000	$2,600,000
Astronomy.....	250,000	350,000	400,000
Total.....	$3,412,000	$3,000,000	$3,000,000

The operation of the National Space Science Data Center (NSSDC) and correlative studies utilizing space data are supported under this project. Following the successful launch of a spacecraft, the investigators are funded to perform the primary analysis of the data. As soon as definitive reduced data tapes have been produced, the investigators make them available to other interested scientists by placing reduced data records in the NSSDC.

The NSSDC, located at the Goddard Space Flight Center, was established to serve as a central repository 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.

In general, flight projects support the primary analysis of data by principal investigators. If required, further support of primary analysis of data acquired from major long-lived experiments has been provided by this project. The primary purpose of the Data Analysis project is to support correlative studies from several separate investigations, as well as new approaches to the analysis of available data. All proposals for research are competitively evaluated and support is provided for those efforts that are expected to contribute most to the total advancement of knowledge.

Sounding Rockets

	1969	1970	1971
Space physics.....	$9,200,000	$8,200,000	$8,000,000
Astronomy.....	10,034,000	10,300,000	10,500,000
Total.....	$19,234,000	$18,500,000	$18,500,000

Sounding rockets provide 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 and relatively low cost flight opportunities for: (1) conducting test flights of instrumentation being developed for spacecraft; (2) providing unique opportunities to study scientific phenomena; and (3) cooperative projects with scientific groups in foreign countries.

Sounding rockets are currently being utilized to conduct measurements of the wide variety of constituents in the earth's upper atmosphere, their variation with altitude, longitude, latitude, time-of-year, etc., and their reaction to incoming radiation and energetic particles. The nature and behavior of the earth's electric and magnetic fields is being studied by a variety of instruments and ionizing chemical clouds released at high altitudes.

Recoverable rocket payloads continue to provide the unique means of collecting samples of micrometeorites, interplanetary dust, noctilucent cloud particles, and upper atmosphere trace gases for study and analysis. The study of cosmic radiation and energetic particle influx and their relationship to such phenomena as aurora and airglow are being continued at a reduced level due to budget constraints. Our knowledge and understanding of the nature, characteristics, and dynamics of heterogeneous layers of the ionosphere is being 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, active areas of the sun and its corona, and the atmospheric constituents 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 program has made major contributions through test flights of instruments being developed for the Orbiting Solar Observatory and the Apollo Telescope Mount (ATM), as well as providing the in-flight calibration of instruments in orbit on board the Orbiting Observatories and Explorer spacecraft. Special note should be made that a series of approximately 30 rockets will be launched from Wallops Island during a total solar eclipse on March 7, 1970 carrying scientific instruments designed to conduct complementary experiments to study the sun, its radiation, and its effect on the earth's ionosphere and atmosphere during the eclipse.

Responsibility for flight support activities has been assigned to the Goddard Space Flight Center, which also has resident experimental scientific groups in all disciplines. NASA Headquarters has responsibility for experiments developed by scientists at universities, in industry, at other agencies, and in other countries. The Ames Research Center has responsibility for high accuracy solar pointing control systems. Responsibility for flight support activities for certain special projects is assigned to Wallops Station.

Over 80 Physics and Astronomy sounding rockets, primarily of the Nike Cajun/Apache/Tomahawk, Aerobee, and Javelin types were launched during Calendar Year 1969 from sites in the United States Canada Brazil, India, Sweden, and Norway.

NASA plans to continue the sounding rocket flight program in FY 1971 at the current level. Forty to fifty scientific teams will be supported by this program effort.

Solar Observatories

	1969	1970	1971
Orbiting Solar Observatory (OSO):			
Spacecraft.....	$6,815,000	$8,570,000	$8,220,000
Experiments.....	6,997,000	6,130,000	7,880,000
Subtotal OSO.....	$13,812,000	$14,700,000	$16,100,000
Delta (Launch Vehicle Procurement Program).....	($2,400,000)	($1,300,000)	(---)
Total (including Launch Vehicles).....	($16,212,000)	($16,000,000)	($16,100,000)

The Orbiting Solar Observatory (OSO) program is an observational and scientific program designed to obtain new knowledge of the sun, the earth's atmosphere, and the stars over a broad range of electromagnetic spectrum not available to ground-based observatories. OSO obtains scientific information of changes on the sun which may be very slow, with periods of the order of 11 or 22 years, the periods of the solar cycle, or changes on the order of a month and of changes on the order of seconds, as in the case of short-lived,

unpredictable activities, such as solar flares. Operational OSO's have provided a new observational model of solar flares, with precursive activity in the ultraviolet and X-ray spectral regions. Also, the concept of a "quiet" sun is losing validity, as the OSO data shows.

The OSO is a specialized spin-stabilized space observing platform. The spacecraft consists of a sail, upon which is mounted solar pointing and scanning experiment instruments and which, during the daylight portion of the orbit, points continuously at the sun, and a rotating wheel which houses solar terrestrial and celestial scanning experiment instruments.

Six OSO's have been launched and operated successfully between 1962 and 1969. Two of these, OSO-V and OSO-VI, are continuing to operate and perform valuable observations in support of our solar physics research objectives. Four additional approved missions are scheduled for launch through the mid-1970's to provide the increased spectral, temporal, and spatial resolution necessary to further advance our understanding of the sun. A flight payload of seven experiments was recently selected for one of these missions from a total of 30 proposals submitted by three foreign countries, eight universities, two U.S. Government agencies, and three commercial institutions.

The FY 1971 funds will provide for: (1) the continued operation of OSO-V and VI and for analysis and publication of associated data; (2) the development, testing, launch, and initial operation of the OSO-H mission; and (3) the OSO-I, J, and K scientific instrument and spacecraft development and test to be continued. The next four OSO missions will provide major contributions to the understanding of the physics of particular regions of the sun. OSO-H will concentrate on the solar corona and OSO-I will emphasize the interface between the corona and the chromosphere.

Astronomical Observatories

	1969	1970	1971
Orbiting Astronomical Observatory (OAO):			
Spacecraft.....	$28,027,000	$21,280,000	$19,710,000
Experiments.....	8,365,000	10,320,000	7,390,000
Subtotal OAO.....	$36,392,000	$31,600,000	$27,100,000
Centaur (Launch Vehicle Procurement Program).....	($8,800,000)	($5,600,000)	($1,500,000)
Total (including Launch Vehicles).....	($45,192,000)	($37,200,000)	($28,600,000)

The Orbiting Astronomical Observatory-II (OAO-II) is now providing detailed information required by astronomers in their search for understanding of the universe. Only by establishing an observatory for investigating the ultra-

violet region of the spectrum outside the earth's atmosphere are scientists able to study these emissions for extended periods of time. As in any exploration, OAO is now accomplishing a sky-mapping operation as a first objective. At the same time, spectral energy distribution data on selected celestial objects in the ultraviolet range are being gathered.

During the first year's observations, the Smithsonian Celescope has taken almost 6,000 ultraviolet pictures of the celestial sphere. Important results of these observations are: (1) many giant stars are fainter in the ultraviolet than predicted, (2) the earth's hydrogen corona is more extensive than appreciated and (3) the Orion nebulosity was observed in detail. The Wisconsin experiment has made observations of 762 celestial objects and obtained data that indicate: (1) young stars are hotter than estimated, (2) most nearby galaxies are generally brighter in the ultraviolet than previously theorized, (3) dark nebulae are bright in the ultraviolet apparently due to the characteristics of the interstellar particles for which OAO has obtained a great deal of fascinating data and (4) preliminary determination of abundance of ozone in the Martian atmosphere.

The next two OAO missions will build on the OAO-II results by providing moderate resolution spectrometer data of stars down to the tenth magnitude and carry out high resolution ultraviolet spectral analysis of fainter celestial objects, respectively.

The successful OAO-II mission has demonstrated a major advance in the state of the art essential to realizing the potential of space astronomy. The OAO project required the development of spaceborne hardware and operational capability which meet the most advanced scientific and technical requirements of the space program. The OAO spacecraft is designed to point in any direction with an accuracy of one-tenth second of arc, and to hold that attitude for extended periods of time. With this operational capability, astronomers can obtain observations of celestial objects and phenomena in those regions of the electromagnetic spectrum that are inaccessible to ground-based instrumentation.

The third OAO (OAO-B), to be launched in 1970, will carry the Goddard Space Flight Center (GSFC) 36-inch telescope to obtain absolute spectrophotometry data on stars, nebulae, and the brighter galaxies. This mission will be the first to include the Inertial Reference Unit (IRU) developed by the Massachusetts Institute of Technology (MIT).

The fourth OAO (OAO-C), scheduled for launch in 1971, will carry a major experiment for Princeton University and a small piggyback experiment for the University College London. The Princeton Experiment Package (PEP) is a 36-inch Cassegrainian reflecting telescope with a concave grating spectrometer. Studies will be made of spectra of interstellar gas and of composition and physical characteristics of interstellar gas and dust, as well as stars. The London experiment consists of three telescopes with paraboloidal reflectors, photon detectors, and gas counters to study X-ray emissions and to search for interstellar absorption.

Although the OAO observatory is, to a large extent, automated, the successful operation of the mission requires closely integrated support from ground facilities to meet the objectives of the scientific investigators.

Extensive ground facilities in the United States and in four other countries (Ecuador, Chile, Australia, and Malagasy) are provided for control of the mission in orbit, and to receive telemetry for transmission to the OAO Control Center at GSFC.

Development of the OAO spacecraft was initiated in 1960. Funding prior to FY 1970 provided for the complete design, fabrication, integration, and test of the observatory for the OAO-I and II missions, and for the prelaunch, launch, and post-launch support of these missions. During this period, an IRU was developed at MIT to augment the star trackers in the stabilization and control subsystem of OAO-B and OAO-C. In addition, the OAO-B spacecraft was fabricated and delivered to GSFC for acceptance test.

Major requirements for FY 1970 funds include: OAO-II operation and data processing; integration of equipment and test of the OAO-B spacecraft; acceptance test and calibration of the Goddard Experiment Package; prelaunch support of the OAO-B mission; and equipment development and qualification for the OAO-C mission, including the PEP.

In FY 1971, the funding will provide for continued analysis and publication of data from OAO-II; launch support, operation, and data processing for the OAO-B mission; completion of subsystems integration and test for the OAO-C spacecraft; acceptance test and calibration of the OAO-C experiment instruments; and assembly and test of the OAO-C observatory system in preparation for a late 1971 launch.

Geophysical Observatories

	1969	1970	1971
Orbiting Geophysical Observatory (OGO):			
Spacecraft.....	$6,411,000	$730,000	$100,000
Experiments.....	6,661,000	5,270,000	5,100,000
Subtotal OGO.....	$13,072,000	$6,000,000	$5,200,000
Thor-Agena (Launch Vehicle Procurement Program).....	($233,000)	(---)	(---)
Total (including Launch Vehicles).....	($13,305,000)	($6,000,000)	($5,200,000)

The Orbiting Geophysical Observatory (OGO) project has as a primary objective the accomplishment of a series of coordinated scientific studies of the earth's environment and the effect of solar activity on that environment.

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Six OGO missions, each including 20 or more experiments, have been launched at the rate of one each year starting in 1964. The last mission in this project (OGO-VI) was launched in June 1969 and has successfully accomplished its initial objectives. These six missions have alternated between high altitude, low-inclination orbits for magnetospheric and interplanetary studies, and low altitude, nearly polar orbits for global studies of atmospheric and related phenomena, and have provided good coverage from solar minimum through solar maximum.

The scientific accomplishments of the OGO project have had a significant impact on our understanding of the earth's space environment. In particular, the results disseminated in over 300 papers and published reports have indicated the complex, dynamic nature of this environment. The knowledge obtained provides a firm basis for the next phase of earth environment studies: that of specific research leading to an understanding of the physics of observed phenomenalistic processes.

The development of a large, complex laboratory system like OGO for space studies and the proven long life of these systems under strenuous conditions, is a major technical and engineering achievement. This experience has benefited other space programs and has provided a technology base for the development of advanced space laboratory concepts.

In November 1969, routine data acquisition for OGO-I and III was discontinued and these observatories were placed in a standby mode. Operation of OGO-II and IV was terminated in November 1967 and October 1969, respectively.

The OGO-V and VI missions continue to perform well and are providing, from a stabilized platform, data for approximately 40 investigations. In 1969, through a series of special operations, experiment instrumentation aboard OGO-V was used successfully to obtain, for the first time, a virtually complete sky survey of hydrogen Lyman-alpha radiation emitted by our galaxy. Also, as part of the 1969 Airborne Auroral Expedition, OGO-VI data acquisition in the northern polar regions was coordinated with flights of the CV-990 airplane and with the geostationary satellite, Applications Technology Satellite-V. We plan to continue to exploit the national investment in OGO flight systems and the data bank acquired through extended operations. This will be accomplished through selective investigations which make use of instrumentation in orbit or available data.

Management of the OGO project is the responsibility of GSFC. Development of the spacecraft system and fabrication and testing of flight observatories was accomplished under contract to TRW Systems, California.

Funds in FY 1971 will provide for operational support of OGO-V and VI, special operation of earlier OGO's as appropriate, and continuation of data analysis.

Explorers

	1969	1970	1971
Space physics	$12,018,000	$10,715,000	$12,820,000
Astronomy	7,413,000	8,220,000	12,780,000
Subtotal Explorers	$19,431,000	$18,935,000	$25,600,000
Scout (Launch Vehicle Procurement Program)	($2,300,000)	($4,400,000)	($3,900,000)
Delta (Launch Vehicle Procurement Program)	($2,700,000)	($6,400,000)	($6,200,000)
Total (including Launch Vehicles)	($24,431,000)	($29,735,000)	($35,700,000)

The Explorer program utilizes classes of relatively small spacecraft consistent with Scout and Delta launch vehicle capabilities for coordinated research on the environment of the earth, earth-sun relationships, the nature of the interplanetary medium, and astronomical observations. These spacecraft are designed and configured especially for the requirements of the particular mission. The program also provides for cooperative satellite projects with other Government agencies and with foreign governments.

During 1969 three Explorer missions were launched, including two cooperative satellites. The International Satellite for Ionospheric Studies-I (ISIS-I), the fourth cooperative mission with Canada, launched in January 1969, continues the ionospheric studies begun in 1962 with Alouette I. The seventh Interplanetary Monitoring Platform (Explorer 41) was launched in June 1969. This spacecraft supported the Apollo 12 mission by monitoring emergetic particle radiations from the sun, and is expected to perform a similar service during manned missions in 1970. The first German satellite, AZUR, was successfully launched in November 1969, for studies of trapped radiations, aurorae, and solar particles.

Fiscal Year 1971 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-I) discovered a variety of phenomena. It observed extraterrestrial sources and thousands of solar radio bursts in the 0.2 to 10 MHz frequency range, and measured both steady and sporadic radio emissions from the earth's radiation belts. RAE-B is being prepared to continue the observation of extraterrestrial sources.

It will be placed into a far earth or lunar orbit to minimize the interference from the radio background of the earth.

X-ray astronomy constitutes one of the most promising areas of science. With a limited Sounding Rocket program we have discovered numerous sources, proved that the intensity of these sources varies with time, and that the X-ray emission from at least one pulsar is modulated just like the radio and optical signals. Two Small Astronomy Satellites (SAS-A and C) are being prepared to follow up on these discoveries. In addition, NASA plans a cooperative program with the United Kingdom (UK) and the Netherlands in this area. Other astronomy Explorer missions include a gamma ray satellite, SAS-B, and a solar ultraviolet monitor (Solrad-C) that will be launched under a cooperative agreement by the Naval Research Laboratory.

Investigations of the upper atmosphere and ionosphere continue to be most fruitful. A theoretical model has been developed that explains the spatial distribution of electrons and various ions in a gravitational and magnetic field. One consequence is a helium bulge near the equator where the ions are magnetically confined, and an escape of hydrogen and helium from the polar ionosphere where the magnetic field is open. The international cooperative program continues to play a major role in this research. The third Italian satellite, San Marco-C, is planned for the study of atmospheric density variations. The fourth UK satellite (UK-4) and ISIS-B will study the properties of the upper ionosphere, and a second German satellite is just being started for both ionospheric and atmospheric studies.

Because atmospheric drag causes rapid decay of satellite orbits, an altitude regime of the greatest interest has not been explored on a global basis. Investigations with sounding rockets have shown that most of the incoming solar radiation is absorbed below 150 miles; this region controls, therefore, the behavior of much of the upper atmosphere and ionosphere. Atmospheric Explorer spacecraft will be built with on-board propulsion to overcome the atmospheric drag. Detailed design studies and initial development of the spacecraft and scientific payload are underway. The scientific payload assigned to these missions will help us gain an understanding of the global processes in the thermosphere that control parameters in the upper atmosphere.

The radiations present in the outer magnetosphere have been identified. Of particular interest, are low energy protons (less than 50 keV) that are found in the outer radiation belt during geomagnetic storms. The Small Scientific Satellite-A (SSS-A) constitutes our primary attempt to understand the behavior of the low energy protons and to find the mechanism that produces them. These observations will be supplemented with data to be taken in a different part of the magnetosphere under our cooperative program with the Air Force Cambridge Research Laboratories (AFCRL-A). Electric fields in the outer radiation belts will be studied with a release of barium ions to be performed as part of our cooperative program with Germany.

The Interplanetary Monitoring Platform (IMP-H, I, and J) missions will continue, during the declining part of the solar cycle, the investigations of the magnetospheric boundary, the geomagnetic tail, and interplanetary space. Studies will be conducted with more diverse and greatly improved instruments. The latter of these missions also will provide the near earth reference data that will be required to interpret many of the measurements to be performed with Pioneers F and G. In addition, the IMP satellites will continue to provide radiation monitoring in support of manned missions.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1971 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS

LUNAR AND PLANETARY EXPLORATION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objective of the Lunar and Planetary Exploration program is the scientific exploration of our solar system utilizing manned and automated spacecraft, supported by earth based observations and laboratory research. Its achievement 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 has two major thrusts: the further manned exploration of the moon, and automated investigation of the planets and interplanetary medium.

Earlier unmanned programs have already considerably 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 and 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, instruments measured the lunar surface bearing strength, and rudimentary chemical analysis was performed on lunar surface materials.

Manned exploration began with the Apollo program. 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, the real payoff of each mission.

The planetary and interplanetary programs have experienced a high degree of success beginning with the Mariner II flyby of Venus in 1962 and continuing with the most recent successful launchings of Mariner VI and VII this past summer. The Mariner II mission provided new data on the magnetic and atmospheric characteristics of Venus. Mariner IV, in 1965, provided the first closeup pictures of Mar's cratered surface and showed that its atmospheric density was very low compared to the earth. Mariner V, launched in June 1967, made more precise measurements of Venus' ionosphere, magnetosphere and atmosphere. Pioneer IX in November of 1968 marked the last in the preliminary series of missions to measure the interplanetary medium. These

early flights provided much insight into understanding how solar disturbances are propagated through space, the effect of these disturbances on terrestrial phenomena, and the relationship between solar activity and solar and cosmic rays.

SUMMARY OF RESOURCES REQUIREMENTS:

	1969	1970	1971
Supporting research and technology/ advanced studies	$18,571,000	$17,980,000	$17,400,000
Planetary astronomy	3,700,000	3,800,000	4,800,000
Data analysis	2,337,000	2,600,000	3,900,000
Pioneer	4,700,000	20,800,000	32,900,000
Mariner Mars 1969	26,130,000	4,491,000	200,000
Mariner Mars 1971	20,058,000	60,342,000	29,600,000
Mariner Mercury 1973	---	1,000,000	21,100,000
Viking	12,427,000	40,000,000	35,000,000
Total	$87,923,000	$151,013,000	$144,900,000

Distribution of Program Amount by Installation:

Kennedy Space Center	$3,000	---	$100,000
Manned Spacecraft Center	246,000	$1,096,000	680,000
Marshall Space Flight Center	615,000	115,000	250,000
Goddard Space Flight Center	3,554,000	4,632,000	3,550,000
Jet Propulsion Laboratory	56,412,000	86,221,000	69,475,000
Ames Research Center	5,158,000	19,774,000	29,320,000
Electronics Research Center	25,000	25,000	---
Langley Research Center	10,487,000	22,343,000	25,100,000
NASA Headquarters	11,423,000	16,807,000	16,425,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology/Advanced Studies

Lunar science	$5,602,000	$6,580,000	$6,000,000
Planetary science	5,269,000	4,200,000	4,200,000
Planetary advanced technical development	6,000,000	6,000,000	6,000,000
Planetary advanced studies	1,700,000	1,200,000	1,200,000
Total	$18,571,000	$17,980,000	$17,400,000

Supporting Research and Technology and Advanced Studies programs 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, and by, drawing on basic data derived from ground based research and Ranger, Surveyor, and Orbiter missions, and previous 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. Success to date is just a beginning, as 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 1971 lunar science effort will include: continued production of geologic maps of landing sites; plotting traverse routes; selection of future landing sites; and the investigation of instrument concepts for remote physical and chemical analysis. FY 1971 will also see the Lunar Science Institute fully operational at the Manned Spacecraft Center in Houston, Texas.

The Planetary Atmospheres program funds research in atmospheric phenomena including that of the earth and the planets, and the gaseous phenomena associated with comets. In FY 1971, research will be conducted into the design of experiments, and the 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.

A third area financed under Planetary Supporting Research and Technology is the Planetology program which supports research in the increasingly important field of planetary geology. As the planetary program progresses from earth based observational data to flyby and orbiter data, and in 1975 to data from landers, planetology research will play a more important role in determining the nature and properties of the planets. In FY 1969 and 1970 research toward the development of scientific instruments for project Viking was one of the major goals of the Planetology program. In FY 1971 the emphasis will be on the development of instrumentation for geochemical and geophysical studies of Mars to be used on future lander missions.

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) extend the nominal lifetime of the systems for long duration missions such as a Jupiter flyby, with approximately 1 1/2 years of spacecraft transit, and the Grand Tour missions which may be up to 12 years in duration; (2) develop power sources which use nuclear energy and allow a spacecraft to operate for extended periods without dependence on solar

energy; (3) develop instruments and subsystems which will survive in hostile environments; (4) develop the ability to communicate up to three billion miles; and (5) perfect the techniques and subsystems for swingby trajectories which require great precision in spacecraft control and tracking. In FY 1971, research in the ATD program will continue work in these areas, with somewhat more emphasis on the critical technologies for Venus probes and buoyant Venus stations and advanced Mars exploration.

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. Alternate mission approaches, including the utilization of existing systems are evaluated, resource requirements determined, and advanced technology requirements examined. In FY 1969 and 1970, studies were continued on: (1) multiple planet Grand Tour and other outer planet flybys; (2) surface sample return from Mars; (3) buoyant stations and atmospheric probes of Venus; (4) Jupiter orbiters; (5) comet flybys; and (6) asteroid belt surveys. In FY 1971 it is planned to continue the investigation of the more promising missions and to initiate additional studies such as: (1) orbiters of Saturn and other outer planets; (2) atmospheric probes of Jupiter; (3) comet rendezvous; and (4) Mars rovers.

Planetary Astronomy

	1969	1970	1971
Planetary astronomy.....	$3,700,000	$3,800,000	$4,800,000
Total.....	$3,700,000	$3,800,000	$4,800,000

One approach to the scientific exploration of the solar system is to observe the planets and associated bodies from the vicinity of the earth. Although astronomers have studied the planets for well over 100 years, a very large amount of information can still be obtained from observations made from the vicinity of the earth. New instrumentation and observing techniques combined with the use of airplanes, balloons, rockets, and earth orbiting satellites as observing platforms in addition to ground based observatories have increased the possibilities of astronomical observations far beyond those considered feasible a few years ago.

The application of radar observations in planetary studies illustrates the great potential value of using new observation techniques. Radar observations of the planets have, within the last eight years, resulted in the determination of accurate rotation periods for the planets Venus and Mercury. They have also determined precise distance values for the nearer planets as well as giving information on the size of Mars and Venus. Topographic variations on the surface of Mars have also been obtained for limited regions of that planet. With improvements to one or more of the largest existing radar systems, it will be possible to map the entire cloud covered surface of Venus

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at sufficient resolutions to observe in detail features such as mountains, craters, etc. And it is important to realize that almost all of the information determined thus far from radar observations could not be determined from any of the presently planned planetary spacecraft.

In the case of radar observations and many other types of observations, the data obtainable from the vicinity of the earth complements the scientific return from the presently planned planetary flight program. In fact, a combination of the two methods is required to achieve 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.

To assist with the interpretation and analysis of the observations, simultaneous programs in laboratory and theoretical studies are also supported. Existing instrumentation such as telescopes, radio and radar systems, spectrographs, etc., 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 also supported through this program. The increase of one million dollars in funding in FY 1971 is to start on the construction of one much needed major instrument.

Data Analysis

	1969	1970	1971
Lunar data analysis.....	$1,887,000	$2,000,000	$2,000,000
Planetary data analysis.....	450,000	600,000	1,900,000
Total.....	$2,337,000	$2,600,000	$3,900,000

The primary purpose of lunar and interplanetary missions is to conduct experimental investigations which will advance our knowledge and understanding. Data are obtained by scientific instruments aboard the spacecraft and are transmitted to earth for analysis by the scientists conducting the experiments. The initial data reduction and analysis is funded by the flight project as a part of is project responsibilities. Usually, the time required to reduce and thoroughly analyze the data extracting the full scientific value and then publish the results is longer than the period of support provided by the project. The Data Analysis project will provide for reduction of data from the Mariner V, VI and VII planetary missions, the Pioneer missions to interplanetary space and missions pertinent to scientific exploration of the earth's upper atmosphere.

In addition, analysis of lunar data from several flight programs continues, with attention centering on Surveyor (nearing completion), Orbiter, and now the Apollo program. Initial emphasis has been given to photo analysis of Orbiter data bearing on selection of safe Apollo landing sites, and orbit

analysis (gravity anomalies) bearing on Apollo landing trajectories. Attention will continue to be given to these analyses but the major effort will be directed to scientific problems in these and other areas of the moon. For these studies the Orbiter data are supplemented by a wealth of new high resolution Apollo photography, much of it in color, of selected parts of the lunar equatorial zone. This information will then 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 1971 Data Analysis program.

Pioneer

	1969	1970	1971
Spacecraft and support	$2,860,000	$13,287,000	$25,266,000
Experiments	1,840,000	7,513,000	7,634,000
Subtotal, Pioneer	$4,700,000	$20,800,000	$32,900,000
Delta (Launch Vehicle Procurement Program)	($1,152,000)	(---)	(---)
Centaur (Launch Vehicle Procurement Program)	(1,265,000)	($4,600,000)	($15,900,000)
Subtotal, launch vehicles	($2,417,000)	($4,600,000)	($15,900,000)
Total (including launch vehicles)	($7,117,000)	($25,400,000)	($48,800,000)

The objectives of the Pioneer project are: to obtain scientific information at widely separated points in interplanetary space; to supply interplanetary environmental data on a continuing basis; and to conduct, during the 1972 and 1973 Jovian opportunities, exploratory investigations of the interplanetary medium, the nature of the asteroid belt and the environmental and atmospheric characteristics of the planet Jupiter.

The project is responsible for three series of missions, Pioneers VI-IX, Pioneers F and G and Helios A and B. The first series of spacecraft weighed about 140 pounds each and were launched in 1965, 1966, 1967 and 1968, by the Thrust-Augmented Improved Delta. A fifth spacecraft, Pioneer E, was lost during launch in 1969 when the launch vehicle failed. The four Pioneers now in solar orbit are all functioning and Pioneer VI has operated longer in interplanetary space than any other spacecraft. These interplanetary outposts are essential elements of our network of deep space "weather stations." The instruments on these Pioneers are designed to measure the solar wind flow, magnetic fields, the electron density in space, and to observe the energy spectra, fluxes, and direction of solar and galactic cosmic rays. The opportunity to obtain such measurements at widely separated positions in deep space is providing unique and valuable scientific information about the sun and its

influence on the solar system. The combination of these measurements from the four widely separated stations enables us to detect and estimate the paths of solar storms. Such information helps forecasters to provide advance warning of radiation dangers to spacecraft and of variations in the protective magnetic envelope of the earth which affects the long range radio communication of the world.

The development of Pioneers F and G was initiated in FY 1969. These spacecraft are to be launched into trajectories permitting the exploration of interplanetary space between one and five Astronomical Units (AU) from the sun including the asteroid belt and Jupiter. (One AU is equal to the mean Earth-to-Sun distance, 92,000,000 miles.) With this trajectory, we should be able to study the possibly hazardous region of the asteroid belt, to measure the gradient of the sun's influence on interplanetary space and the penetration of galactic cosmic radiation into the solar system. While the spacecraft passes in the vicinity of Jupiter, instruments will measure the properties of charged particles, magnetic fields, and electromagnetic emissions associated with the planet. Data from these measurements will be used to study the composition and dynamics of the atmosphere surrounding the planet and its interaction with the interplanetary medium. It will also be used to analyze the thermal balance of Jupiter and the source of energy which the planet seems to have. These missions will require new features on the Pioneer spacecraft to compensate for the lessening of solar radiation as a power source and the more demanding communications and thermal conditions. For example, Radioisotope Thermoelectric Generators (RTG's), rather than the more conventional solar cells, will be utilized to provide electrical power to the spacecraft. New experiment instrumentation will also be required to make measurements in the asteroid belt and near Jupiter.

In FY 1969, NASA also initiated its largest international cooperative project as part of the Pioneer program. The objective of this project, called Helios, is to investigate the properties of and processes in interplanetary space in the direction of and close to the sun (about 0.3 AU) by developing, launching, and operating an automated spacecraft. The spacecraft will be developed in West Germany with about one-third of the scientific experiments supplied by NASA.

FY 1971 funds will be used for design and development work on the Pioneer F and G spacecraft and its selected experiments. Operational support for the four active Pioneer spacecraft and for data analysis will continue. Development of U.S. experiments for Helios will continue.

Mariner

	1969	1970	1971
Mariner Mars 1969.....	$26,130,000	$4,491,000	$200,000
Mariner Mars 1971.....	20,058,000	60,342,000	29,600,000
Mariner Mercury 1973.....	---	1,000,000	21,100,000
Total Spacecraft and Support.....	$46,188,000	$65,833,000	$50,900,000
Atlas Centaur (Launch Vehicles Procurement Program).....	($11,039,000)	($9,800,000)	($4,300,000)
Total (including launch vehicles).....	($57,227,000)	($75,633,000)	($55,200,000)

Over the past six years, the Mariner spacecraft has evolved from the 450 pound Mariner II used for man's first successful mission to another planet to the 2,200 pound (including 900 pounds of propellant) Mariner 1971 to be used for our first orbiting mission of another planet. The Mariner spacecraft represents a major tool in the planetary program for remote observations, from an attitude controlled spacecraft, of the other planets in the solar system.

The Mariner II, flyby of Venus in 1962, provided the first direct temperature and magnetic field measurements from near the planet. This was followed by the Mariner IV flight past Mars on July 14, 1965 which conducted initial closeup scientific observations of Mars and its environment. Pictures of the planet showed a cratered surface similar to that of the moon. Valuable information on the planet's atmosphere and ionosphere was also acquired. On October 19, 1967, Mariner V flew past Venus some 2,600 miles from the planet's surface and made measurements to determine the properties of the Venusian atmosphere and the interaction between the planet and interplanetary medium, improving and significantly augmenting the data acquired five years earlier by Mariner II. Scientists are still analyzing data telemetered back by Mariner V. According to Mariner V, Venus is a hot planet with a thick lower atmosphere--mostly carbon dioxide. The heavy atmosphere is surrounded by a sphere of hydrogen analogous to that of earth.

On July 31 and August 5, 1969, Mariner VI and VII passed within 2,000 miles of the Martian surface completing the most ambitious and successful planetary reconnaissance ever attempted. The scientific data returned 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 VII, 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 VII provided interesting and likely regions for future missions to concentrate their efforts in pursuit of this question.

The scientific investigation of Mars using orbiting spacecraft will begin in 1971. The Mars 1971 spacecraft, which will use many of the proven subsystems of the Mariner IV and Mariner 1969 exploratory flyby missions, will begin detailed studies of the atmosphere and environment of the planet and provide a closeup look at large areas of the surface. This 1971 mission will provide broad topographic and thermal coverage, record seasonal variations in the atmosphere and on the surface, and major other long term dynamic observations.

Although some of the scientific instruments for the Mariner-Mars 1971 missions will be improved versions of those carried on the earlier Mariner-Mars 1969 flyby, the scientific data return will be increased significantly. This increase in data return results from the spacecraft being in orbit about the planet allowing multiple measurements and observations over a period of several months. From orbit, it will observe approximately 70% of the planet's surface including the wave of darkening, cloud movements and any other dynamic and seasonal changes in the planet atmosphere and on the planet's surface. In addition, the low point of the orbit will be about 1,200 miles as compared with the nominal 1,800 mile closest approach distance of the Mariner-Mars 1969 flyby. This closer distance to the surface will allow higher resolution measurements from all instruments, and will increase the value of the occultation and celestial mechanics experiments.

The Mariner-Mars 1971 orbiter design is based on existing Mariner technology which resulted in successful planetary investigations of Venus during 1962 and 1967, and of Mars during 1965, and was used to develop the spacecraft which will be launched to Mars in early 1969. The actual hardware to be used for the 1971 orbital missions will make extensive use of spare hardware and test equipment from the Mariner-Mars 1969 project.

A single modified Mariner spacecraft will be used to study both Venus and Mercury in 1973. Although the similarities between 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 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 an 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.

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, which will perform the systems integration function of the prime contractor for the Mariners under development; subcontracting will be for complete subsystems. The Lewis Research Center is responsible for the launch vehicles.

The funds requested for FY 1971 will support post launch operations for the Mariner Mars 1969 spacecraft and continued analysis of scientific and engineering data. FY 1971 funds requested for Mariner Mars 1971 will be used for spacecraft systems testing, launch operations and the initial portion of mission operations. FY 1971 funds will also be used to prepare functional specifications for the Mariner Mercury 1973 spacecraft in order to permit initial flight hardware procurement activities. A systems contractor will be selected during the year.

Viking

	1969	1970	1971
Orbiter - spacecraft and experiments	$2,300,000	$17,000,000	$10,000,000
Lander - spacecraft and experiments	10,127,000	23,000,000	25,000,000
Total	$12,427,000	$40,000,000	$35,000,000

The exploration of Mars initiated in 1965 by the Mariner series of spacecraft will be extended to surface exploration with a Viking landing in 1975, rescheduled from the previously planned 1973 opportunity. While these prior missions were to study the planet from orbital or flyby distances, the 1975 mission will be the first opportunity to obtain data from direct measurements in the Mars atmosphere and on its surface.

The objectives established for the Viking project 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 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, at some time in the past, or the possibility of life existing at a future date.

The lander to be used for this mission will be a soft lander similar to those used in the Surveyor program. Technology developed for Surveyor and the Apollo Lunar Module will be directly applicable to the Viking lander. This lander will be mated with a modified Mariner 1971 orbiter, which will have the capability to insert the lander into orbit prior to landing. This will permit orbital entry for the lander which has the advantage of smaller surface dispersions, lower entry velocities, and better control of entry angles. The launch vehicle to be used will be a Titan/Centaur.

The Office of Space Science and Applications, NASA Headquarters, is responsible for overall management of the Viking project. The responsibility for project management is assigned to the Langley Research Center (LaRC). LaRC will also be responsible for the lander system. The Jet Propulsion Laboratory, which has had responsibility for all Mariner projects, will be responsible for the Mariner class orbiter. FY 1970 funds are being used to initiate preliminary design activities on the orbiter and lander subsystems.

In FY 1971 funds will be used to continue the development of critical long lead items, such as the landing radar system, the landing propulsion system and many of the science instruments. Design effort will continue. Funds will further provide for scientific investigation support.

OFFICE OF SPACE SCIENCE AND APPLICATIONS — BIOSCIENCE PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Bioscience program has three principal objectives: (1) the attainment of a thorough understanding of the effects of the space flight environment on terrestrial organisms; (2) the search for extraterrestrial life and life related molecules, with the primary emphasis directed initially to the moon and nearest planets; and (3) prevention of the unintentional transfer of terrestrial organisms to the planets, so that studies of extraterrestrial life will not be complicated or voided.

The first objective has three areas of effort: (a) to study the effects of space environmental factors on living earth organisms, especially, weightlessness and effective dissociation from factors related to the earth's rotation; (b) to exploit the unique space environment to analyze organism-environment relationships, especially the role environment plays in establishing and maintaining normal organization in living systems; and (c) to study the physiological, behavioral, and genetic responses and adaptations of living organisms to the space environment.

The biological effects of the space flight environment are being studied in the Biosatellite project. During flights of Biosatellite I and II the engineering design and integrated operation of the spacecraft systems were thoroughly checked out. The Biosatellite II experiment results showed that there was an interaction between radiation and weightlessness and other factors encountered in space flight. This interaction varied between greatly increasing the effects of radiation-induced damage, to decreasing the effect significantly depending upon the type of organism studied. The plant experiments studying the biological effects of weightlessness showed a close correspondence to results obtained by rotation on the horizontal clinostat. Post-flight laboratory control studies, in addition to those performed before and during flight, have been conducted to clarify questionable results such as the contribution of vibration. The contributing biologic mechanisms are still being studied.

The Biosatellite III mission had a 14 pound pig-tailed monkey as an experiment subject. During the mission, the effects of weightlessness upon the central nervous system, the cardiovascular system, and the metabolic function were studied. Particularly significant data were recorded from all instrumentation channels during the 8-1/2 days of flight. Much of the data still remain to be analyzed, but the findings to date reveal many of the physiological effects of weightlessness, and indicate the great value of carefully designed animal experiments in collection of biomedical data relevant to space flight.

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The specific aims of the second objective - the search for extraterrestrial life include: (a) physical and chemical evaluation of planetary surfaces as a possible environment for life; (b) determination of whether or not life exists, or has existed; (c) if life in some form exists, determination of its characteristics; and (d) if no life exists, investigation of the pattern of chemical evolution in order to evaluate the probability of its future occurrence either spontaneously or by contamination, and the reason for its present nonexistence.

The development of prototype instrumentation for exobiological studies on the Martian surface is needed as a precursor to flight instrument development for future Mars landers. The life detection and organic analytical techniques developed in various laboratories must now be converted into flight instruments which in turn must be tested and integrated into the payload required to achieve the scientific objectives of the exobiology program. The development of this instrumentation is one of the most important items in the Bioscience Supporting Research and Technology (SR&T) project and is extremely critical to the pursuit of planetary exploration.

The third objective of the Bioscience program (Planetary Quarantine) is shown as a separate line item because of its direct relationship to the planetary flight program. Continuing efforts are being made, before initiation of space flights destined to land on the planets, to assure adequate technology development in the solution of the complex problems related to the planetary quarantine constraints. This item is in direct support of all future planetary missions intended to probe the atmospheres or land on the planets.

SUMMARY OF RESOURCES REQUIREMENTS:

	1969	1970	1971
Supporting research and technology/ advanced studies.....	$8,900,000	$11,170,000	$9,400,000
Planetary quarantine.....	1,300,000	2,500,000	2,000,000
Biosatellite.....	27,700,000	6,000,000	1,500,000
Total.....	$37,900,000	$19,670,000	$12,900,000

Distribution of Program Amount by Installation:

Manned Spacecraft Center.....	---	$300,000	$400,000
Marshall Space Flight Center.....	$135,000	372,000	400,000
Goddard Space Flight Center.....	86,000	50,000	100,000
Jet Propulsion Laboratory.....	2,003,000	1,614,000	1,100,000
Wallops Station.....	80,000	30,000	25,000
Ames Research Center.....	27,129,000	8,450,000	3,330,000
Langley Research Center.....	190,000	127,000	100,000
NASA Headquarters.....	8,277,000	8,727,000	7,445,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology/Advanced Studies

	1969	1970	1971
Advanced programs and technology...	$322,000	$2,400,000	$2,000,000
Exobiology.....	3,000,000	3,500,000	3,000,000
Environmental biology.....	1,890,000	1,500,000	1,400,000
Behavioral biology.....	1,241,000	1,450,000	1,400,000
Physical biology.....	1,696,000	1,570,000	1,200,000
Bio-communications.....	751,000	750,000	400,000
Total.....	$8,900,000	$11,170,000	$9,400,000

Advanced Programs and Technology

Emphasis in the area of Advanced Programs and Technology is heavily oriented toward defining the scientific requirements for future biological space flight investigations. This activity, of necessity, begins with determining the scientific character of the experiments to be flown and the space flight situation under which the investigations will be conducted. Among these situations are the options between manned and unmanned flight; automated or man-tended experiments; and earth orbital, lunar orbital or heliocentric flight. Time periods of experimentation vary from a few days in earth orbit in Bioexplorer type spacecraft, to several weeks or months in earth and heliocentric orbits in Bioexplorers and Biopioneers. For manned missions the time ranges from 28 days in the initial mission of the Apollo Applications program (AAP) through several years (possibly including successive generations of animals) in a space station.

The classes of biological specimens under consideration fall into the following broad categories: primates; microorganisms; cells and tissue cultures; semi-microscopic animals and plants; small vertebrate animals; plants; and invertebrate animals. Since several years are required to bring an investigator's hypothesis to flight in the space environment, it is necessary to establish experiment feasibility early to assure readiness to meet the various launch opportunities.

For manned flight systems it is currently considered desirable to maintain a clean separation between the life support systems for man-inhabited portions of the spacecraft and the bioscience experiments. In certain experiments it is also necessary to keep the experimental specimens physically isolated from contact with man. Therefore, a modular approach for environment control and maintenance is required. In efficient utilization of man in a space station laboratory, it is also necessary to define and develop new equipment and techniques which are workable in this environment. Logistics requirements for transporting test specimens, expendable supplies, and experiment rotation as well as the return of specimens to earth must be worked out. These studies and developments require close coordination with

space station design and operation planning to ensure compatibility. Studies are now being initiated on such areas as optimum groupings of experiments, and spacecraft interface requirements. These will be continuing efforts until a satisfactorily operating manned space laboratory has been achieved.

Future automated spacecraft missions are required to satisfy requirements of short term experiments with simple measurement requirements and for those experiments to be flown in heliocentric orbit or other deep space trajectory. The Bioexplorer and Biopioneer systems would satisfy these requirements. Studies have been completed which indicate the feasibility of satisfying many of the needs for automated systems with the Scout launch capability. Additional study and preliminary design activities for such systems are included in the FY 1970 and FY 1971 Bioscience Advanced Mission Study category.

Exobiology

An integral and perhaps inevitable event in the origin and evolution of the universe was the origin of life. An understanding of the controlling factors in the origin of life and determination of the uniqueness of life on the earth are the primary objectives of the Exobiology project. The research areas considered basic to the project area are:

(1) Chemical Evolution - study of the chemical events on the primitive earth or on any primitive planet with a similar history which preceded and led to the origin of life. There are two approaches to chemical evolution: (a) by the application of energy (electrical discharge, ultra violet radiation, heat, etc.) to the simple components (methane, ammonia, water) of the primitive atmosphere, and (b) organic geochemistry which includes analysis of ancient rocks and sediments of the earth, moon and other planets, for fossils (both chemical and biological), providing a record of the events taking place at the time of the origin of life. Extraterrestrial analysis can be done *in situ* or on returned samples.

(2) Biological Adaptation - a study of the response of terrestrial organisms (primarily microorganisms) to extremes of environment (temperature, radiation, pressure, atmospheric composition, water availability, etc.) likely to be characteristic of extraterrestrial environments. Two basic problems are being explored - survival and growth. Are terrestrial organisms accidently landed on an extraterrestrial surface likely to survive and be detected inadvertently by our life detection experiments and are terrestrial organisms likely to grow and destroy indigenous life forms? What are the limits of environmental extremes which carbon-based life can tolerate, so that we may estimate the likelihood of life on any given planet? Are there other chemistries which could produce a "living" system capable of tolerating quite different environments than we ordinarily consider?

(3) Life Detection - the development of techniques which will allow us to determine the presence or absence of past, present, or potential life elsewhere in the universe. The emphasis is on automated systems performing

relevant environmental measurements and chemical analyses early in the program. These evolve to more complex payloads making more integrated and sophisticated measurements and ultimately to unmanned and even manned laboratories. The most likely techniques seek the more basic attributes of terrestrial life - organic chemical, metabolic, and growth analyses, as well as imaging systems for visual detection and morphology. Ultimately, data on all of these basic attributes will be acquired hopefully on a single sample. The development of prototype instrumentation for the above studies, is included here.

(4) Flight Experiments and Return Sample Analyses - lunar samples are available for analyses in FY 1970 and FY 1971. They are being studied for evidence of biologically significant organic matter and for evidence of all living or fossil biota. Preliminary studies of Apollo 11 samples are suggestive of the presence of organic matter, but the data from contaminated samples are difficult to interpret.

Environmental Biology

Living organisms, from microbial forms to man, are extremely responsive to their environment. Life forms have successfully adapted their life forms and life cycles to an inconceivable variety of biologic environments. The space environment provides still another variety of unique environmental factors to which living earth systems are being exposed.

Earth-based studies deal with the known space flight factors that may exert effects in biological systems. Information is being accumulated on the effects of acceleration, vibration, magnetism, radiation and simulated weightlessness, individually and in combination. Emphasis is placed on a thorough investigation of genetic, cellular, biochemical and physiologic components of life.

Experience to date, in plants and animals (Biosatellites) and humans, indicates that space flight induces a variety of changes in life processes. The specific causes of these transient or permanent alterations, and the mechanisms by which they are brought about are unknown and must be verified experimentally. We must recognize and understand factors which directly or indirectly influence cellular function, either at the molecular level of interaction, or in the process of some more integrated function such as cell development.

Many effects of a physiologic nature were observed when plant species were exposed to lunar materials. Most of these were beneficial as shown by more vigorous growth and quality in plants exposed to lunar material. Thus, a new area of biologic research is being developed to determine what factors in the lunar material are compatible with life and how it is affected.

Earth life with which we are familiar generally requires sufficient quantities of water, warmth, atmosphere, mineral and organic nutrient, and energy. Looking beyond our familiar habitat and into the world of extremes

takes us into an area of biologic exceptions. This minority of living systems that exists under extreme ranges of the physical and chemical environments permitting growth, reproduction and other physiologic processes of earth organisms is under study to determine absolute limitations of life by the environment and the mechanisms by which normal levels of metabolic function are maintained within these limits.

Behavioral Biology

The role of behavioral biology in space bioscience is twofold: (1) to explore the ways in which the extreme conditions of space flight affect the behavior of organisms, and (2) to use the unique features of the space environment to advance the analysis of behavior. In addition to weightlessness, which represents the principal unique factor in space, important effects upon behavior include drastic reductions in familiar modes of sensory stimulation, the removal or alteration of ordinary day-night cycles and, particularly for higher forms, a rather severe kind of social isolation.

A major area of endeavor is the border region between perception and control of movement. The origin and maintenance of eye-hand coordination is an extremely promising topic for current research in behavioral biology. The various feed-back and feed-forward mechanisms involved in manipulatory behavior have become susceptible to laboratory experimentation. If there is any deterioration in the performance of high level motor skills it is important to learn about this from the standpoints of astronaut safety and a deeper understanding of mechanisms in sensorimotor coordination.

Orientation in space is engaging the attention of investigators interested in understanding and controlling those functions which are essential to extravehicular activity and those other maneuvers in space which require complex behavior. Both ground based and in-flight studies on the sensation of gravity, such as the determination of thresholds for angular and linear acceleration and responsiveness of the otoliths, semicircular canals, and other gravi-receptors to both transient and prolonged stimulation will contribute to this understanding.

Absence of the day-night cycle and other periodic aspects of the earth environment make space an ideal laboratory for learning about the origin and nature of circadian rhythms. Interest in this subject extends to a concern for behavioral and other biological events, observed by man, with a periodicity of approximately twenty-four hours, exemplified by the cycle of sleep and wakefulness. Studies of various stages of sleep, particularly those dealing with neurophysiological and biochemical changes during that stage associated with rapid eye movement promises new knowledge equally relevant to man in space and his normal environment. The relationships between the requirements for sleep, the process of fatigue, and the effects of gravity remain almost totally unexplored.

Physical Biology

Broad experimental and theoretical research provides a strong background of knowledge for planning and development of experiments for space flight. This includes comparative physiology, bioinstrumentation and biophysics, and molecular biology, including theoretical biology.

Biorhythmicity and oscillatory phenomena in physiological activity has long been recognized.

All living organisms demonstrate some degree of biological periodicity. These persistent rhythms can be accounted for by either the hypothesis that they are timed by an autonomous, endogenous oscillator system, or the hypothesis that these are dependent for their timing on an exogenous rhythmic input. The ultimate goals for studying these phenomena are the understanding of basic life processes and the monitoring and evaluating the physical condition and well-being of animal and man during space flight missions.

Crucial to conducting successful biological experiments in space is the need for advanced instrumentation and methods for measuring and analyzing behavioral and physiological reactions. Recent advances in solid state technology and theory have created a unique opportunity to develop new and especially miniaturized methods for obtaining biological information. Accordingly, basic research and preliminary development of experiments are sponsored for the acquisition of devices and techniques unique for the special problems arising out of space flight activities. These devices and methods are sought on the basis of their potential and/or immediate use to the Bioscience program.

Coincident with biological experimentation in space environments and with the search for extraterrestrial life is the need for an understanding of the form and function of cells, their relationship to one another, and of their constituents. This also includes an understanding of the evolutionary relationship of cells and their parts, and of cellular phenomena. Both experimental and theoretical studies are supported in order to develop an insight into the kind of response living organisms will have during space flight and also for the kind of life and/or life-related chemistry and physiology that might be found and should be sought on other planets.

Earth orbital satellites with space monitoring and position locating systems present a unique opportunity to study and monitor the earth's ecology and especially the earth's wildlife. Studies are being initiated to determine the feasibility of using or developing various systems for monitoring the behavior and physiology of wildlife and the interrelationship of the total bioecology of earth. Crucial to these studies are ground-based research efforts in optical bio-telemetric and physiological instrumentation and in microminiaturization of bio-instrumentation as well as in animal behavior in migration, navigation and orientation of living forms, in sensory systems; and in the development of theoretical models and concepts to interpret and use data as they are generated.

Bio-Communications

The Bio-Communications project was established to improve communication and understanding among scientists engaged in activities related to space biology. As the body of scientific knowledge expands in size as well as scope, it becomes increasingly difficult for a scientist to keep abreast of knowledge in his own field, and pertinent advances outside his field. The goal is to make the scientist more aware of advances in his own specialty, and open the door for a greater exchange of ideas and dissemination of information between and among scientific disciplines.

The Bio-Communications project provides:

(1) Partial support of the Space Science Board of the National Academy of Sciences and its subcommittees,

(2) Training of scientists through research associates and summer institutes,

(3) Consultation to administrative program scientists,

(4) Cross-disciplinary communication between physical and biological sciences,

(5) Research literature, report analyses, current status reports, and

(6) Conferences, symposia, and informal meetings.

Planetary Quarantine

	1969	1970	1971
Planetary quarantine.....	$1,300,000	$2,500,000	$2,000,000
Total.....	$1,300,000	$2,500,000	$2,000,000

The absolute prerequisite in the search for extraterrestrial life is that all possible measures be taken to prevent the transfer of any biological or organic earth forms to the planets and to maintain them free of such terrestrial contamination until the question of existence of planetary life is answered. The knowledge of environmental factors gained by both Venus flybys in 1967 has permitted a reassessment of the possibility of contaminating that planet. Flybys of Mars are assisting in the design of more effective planetary quarantine measures. Missions preliminary to later landing probes to date have neither confirmed nor denied the possibility of the existence of life in the outer atmosphere of Venus and on Mars.

Major launching nations subscribed to the objective that there must not be more than one chance in a thousand of contaminating a planet during the

period of biological exploration. This level of safety has required new technology development of decontaminating procedures during manufacture and sterilization of space vehicles by dry heat and other methods before launch and the protection of the sterile vehicle from recontamination during and after launch. These requirements impact the design of the spacecraft as well as procedures for trajectory control, assembly, testing and checkout during the preflight period. Research results now assure that we can obtain reliable mission hardware performance together with positive sterilization. Investigations in FY 1971 are directed toward further simplifying the sterilization requirements and implementing effective operational procedures.

In the operational area all lunar flights have been monitored to provide an inventory of the microorganisms landed on the moon. These operations have been extended to Apollo in order that any life detection results on the returned lunar samples may be more quickly interpreted to prevent prolonged unnecessary quarantine of returned astronauts and investigators making later life detection analyses of the lunar samples.

Biosatellite

	1969	1970	1971
Spacecraft	$21,166,000	$4,700,000	$1,200,000
Experiments	6,334,000	1,100,000	300,000
Operations	200,000	200,000	---
Total Spacecraft Operations	$27,700,000	$6,000,000	$1,500,000
Thor-Delta (Launch Vehicle Procurement program)	($1,200,000)	(---)	(---)
Total (including launch vehicles)	($28,900,000)	($6,000,000)	($1,500,000)

The Biosatellite has been the only automated spacecraft devoted to biological research. Management responsiblity for the Biosatellite project has been assigned to the Ames Research Center. Spacecraft development and fabrication is under contract to the General Electric Company, Re-enty and Environmental Systems Division, located at Philadelphia, Pennsylvania.

Thirteen experiments were orbited on Biosatellite II for two days using specially selected plant cells, animals and simple forms of life to study the effects of the space environment upon biochemical processes in cells, their development and growth, the transmission of hereditary characteristics and the structure of living tissues. Positive effects of the space environment (weightlessness and/or radiation) were observed on cell division and differentiation, growth and development, chromosome aberrations and mechanics, mutations, biochemical processes and population dynamics. A definite interaction between weightlessness and radiation was noticed; in some cases this resulted in an enhancement of development, in some cases there was an

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impairment. The greatest effects of this environment of space were observed in: (1) young and actively dividing cells and tissues; (2) rapidly dividing cells with a high metabolic rate; cells such as sperm and egg after meiosis. Mature cells were least affected. The detailed results have been presented at national and international scientific meetings and in a number of scientific journals.

On June 28, 1969, the first of the two planned primate missions, Biosatellite III, was flown. The second of these two missions, Biosatellite F, was cancelled on July 11, 1969, as a result of an amendment to the FY 1970 Budget which reduced Biosatellite funds that year by $12.0 million.

The specific goals of the Biosatellite III flight were to study cycles of sleep and wakefulness; states of attention, including levels of alertness accompanying the performance of two tasks; continuous measurement of blood pressure; pre- and post-flight studies of whole body metabolism to reveal changes in fluid distribution in body tissues and blood; to estimate urinary excretion of calcium, creatine, and creatinine; to evaluate changes in bone density attributable to calcium loss; and to study effects of prolonged weightlessness on the reproductive system.

From a preliminary examination of the data from the Biosatellite III flight, it is apparent that there was a disturbance in the normal 24 hour sleep-wakefulness cycle. Also, for the first time, the occurrence of rapid eye movement sleep (associated with dreaming in man's normal sleep on earth) was confirmed. There was a pronounced loss of body fluid, which in the opinion of the experimenters was a consequence of weightlessness. The detailed analysis of nervous and cardiovascular system data will continue for several months. Data on the animal's metabolism is still undergoing analysis; however, initial estimates by the experimenter point to a considerable loss of calcium from the bones of the monkey.

Funding for FY 1970 provides for the orbital operations and recovery of Biosatellite III, the reduction and analysis of data by the spacecraft contractor and the experimenters, and the submission of their written reports.

Also it will provide for spacecraft contract termination activities (inventory location, identification and disposition), subcontract claims, scrap disposition, reports and administrative processes.

Funding for FY 1971 will provide for the continued analysis of Biosatellite III data by the experimenters and any claim resulting from the spacecraft contract close-out and termination that could not be settled in FY 1970.

No funds will be required for Biosatellite subsequent to FY 1971.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1971 ESTIMATES

OFFICE OF SPACE SCIENCE AND APPLICATIONS SPACE APPLICATIONS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The objectives of the Space Applications programs are to: (1) expand the knowledge of 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 Environmental Science Services Administration (ESSA), 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; and (7) 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 Communications the endeavors are to: (1) study the factors which affect efficient space use of the frequency spectrum, such as extension of use into the millimeter wave region and ultimately to optical wavelengths; (2) 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; (3) develop and test improved technology for accurate stabilization and pointing of the large space erectable antennas which will be required on spacecraft; (4) develop efficient satellite techniques for collecting data from many remote, unattended platforms; (5) 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; and (6) cooperate with Alaska and India on their potential TV experimentation by utilizing ATS-I and ATS-F satellites.

In the area of Earth Resources Survey from space three goals have been established: (1) to establish the relative roles of aircraft and spacecraft for operational remote sensing of the earth's resources; (2) to provide systematically and simultaneously acquired data from a number of sensors on a single experimental spacecraft which will permit the user scientists to determine the utility of earth resources data obtained from space; and (3) to develop efficient techniques for data processing, analysis, storage, and dissemination.

In Geodesy the aim is to contribute to the National Geodetic Satellite Program in: (1) the accurate determination of the shape of the earth and anomalies in its gravitational field; (2) exploring the utility of geodetic satellite technology and techniques to the solid earth sciences and oceanography; and (3) determining and understanding the wobble of the earth's axis of rotation.

In Meteorology the goals are: (1) to use infrared and microwave sounding techniques for global measurement of the vertical structure of the atmosphere via satellites, and (2) to develop, based on our successful experimentation with the Applications Technology Satellites (ATS), a first generation prototype operational Synchronous Meteorological Satellite (SMS) to permit continuous viewing of the global atmosphere and weather conditions. Achievement of the first goal will start to provide the three-dimensional meteorological data which are needed for the fuller understanding of meteorological processes which can ultimately lead to long-term forecasting based on atmospheric models simulated numerically by computers. Achievement of the second goal will permit the continuous monitoring of cloud patterns associated with short-term severe atmospheric disturbances such as thunderstorms and tornadoes; monitoring the tropics to detect hurricane development; and estimation of wind velocities by short-term tracking of small scale clouds.

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.

SUMMARY OF RESOURCES REQUIREMENTS:

	1969	1970	1971
Supporting research and technology/advanced studies...	$19,600,000	$24,900,000	$25,900,000
TIROS/TOS improvements.....	5,800,000	3,700,000	3,200,000
Nimbus.....	31,800,000	27,300,000	28,000,000
Synchronous meteorological satellite.....	---	2,700,000	15,600,000
Meteorological soundings.....	3,000,000	3,000,000	3,100,000
Cooperative applications satellite.....	100,000	100,000	100,000
Global atmospheric research program (studies).....	---	---	1,000,000

	1969	1970	1971
Applications technology satellites	$24,700,000	$39,000,000	$31,100,000
Geodetic satellites	2,465,000	1,700,000	3,500,000
Navigation/traffic control satellites studies	---	---	3,000,000
Earth resources survey	(11,200,000)	(26,000,000)	(52,500,000)
Aircraft program	8,900,000	11,000,000	11,000,000
Earth resources technology satellite	2,300,000	15,000,000	41,500,000
Total	$98,665,000	$128,400,000	$167,000,000

Distribution of Program Amount by Installation:

Kennedy Space Center	$58,000	---	---
Manned Spacecraft Center	9,949,000	$12,530,000	$12,500,000
Marshall Space Flight Center	447,000	150,000	200,000
Goddard Space Flight Center	72,193,000	91,622,000	131,400,000
Jet Propulsion Laboratory	2,029,000	1,858,000	1,500,000
Wallops Station	529,000	644,000	200,000
Ames Research Center	100,000	175,000	200,000
Electronics Research Center	2,124,000	1,825,000	---
Langley Research Center	980,000	4,170,000	4,300,000
Lewis Research Center	1,125,000	1,095,000	1,700,000
NASA Headquarters	9,131,000	14,331,000	15,000,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology/Advanced Studies

Applications technology	$974,000	$925,000	$950,000
Communications	3,113,000	2,985,000	3,950,000
Earth resources	7,060,000	9,022,000	9,000,000
Geodesy	1,530,000	1,230,000	1,250,000
Meteorology	4,800,000	5,412,000	5,400,000
Navigation	1,173,000	1,285,000	1,300,000
Interdisciplinary applications	950,000	4,041,000	4,050,000
Total	$19,600,000	$24,900,000	$25,900,000

Nearly every technique and space system in Space Applications must be preceded by Supporting Research and Technology (SR&T) effort. This effort includes supporting activities in all disciplines (Applications Technology, Communications, Earth Resources, Geodesy, Meteorology, and Navigation/Traffic Control), and a number of interdisciplinary activities. The SR&T emphasizes activity in four major areas: (1) theoretical and

applied research, (2) sensor and instrumentation development, (3) spacecraft technology, and (4) data processing and management.

The largest area is theoretical and applied research. Here, the main activity is in examining the feasibility of applications of space, through studies such as investigations of ERS signatures and development of inversion techniques of radiation measurements in meteorology. In sensors and instrumentation development, effort is on potential future spacecraft remote sensors, such as microwave radiometer and multispectral scanners. In spacecraft technology, work continues on subsystems for support functions, such as advanced tape recorders and phased array antennas. In data processing and management, effort continues in improving techniques for processing and analyzing space acquired data and their integration with data obtained from other sources. Such efforts include studies in multispectral correlation of images and indexing and storage of sensors and associated data.

The plan is to continue these efforts in each of the discipline areas as listed below:

In Applications Technology, effort continues in control systems directed at stabilization of spacecraft into orbit; spacecraft equipment developments to improve amplification and antenna system capabilities; and increasing the reliability and useful lifetime of satellite components.

In Communications, effort consists of system comparison and trade-off studies to determine the merits of advanced concepts; techniques applicable to small, terminal multiple access communications; evaluation and development of components and subsystems required for high power communications; propagation studies and component development in the frequency region 10 to 100 GHz where frequencies are more available for space communications; studies in the data relay satellite systems area and in antenna beam widths; and frequency analysis and prediction methods needed for developing sharing criteria. In FY 1971 additional emphasis will be put on the study of radio interference and propagation. This involves the investigation of methods for improving use of the radio spectrum and studying frequency sharing criteria as related to greater density of satellites and earth terminals, and to explore the use of frequency bands at higher regions of the spectrum. Efforts on information networks will be also receive additional emphasis.

The Earth Resources program is unique both in the wide variety of potential users interested in the information that will be the outcome of the spacecraft program and in the vast quantities of data to be handled, even during the experimental phases of the program. The study, research, and technology development program for FY 1971 will be more specifically focused on preparing for the advent of spacecraft dedicated to the Earth Resources objectives. Theoretical, laboratory, ground and aircraft studies

and field investigations will be extended in cooperation with the user agencies such as the Departments of Agriculture, Interior, Commerce and Navy, to further define the requirements of the users for spacecraft data collection, processing and distribution and the capability of spacecraft sensors to meet these requirements. Spatial, spectral and time-varying characteristics of the data must be considered. The current experience in the discipline fields of agriculture, forestry, geography, cartography, geology, hydrology, and oceanography is planned to be extended to include transportation, census, earthquake monitoring, and pollution control. An important aspect of the program is the mutually supporting roles of aircraft and spacecraft as remote sensing platforms. Studies will be directed at qualitative and quantitative analyses of the capabilities of the several methods available for remote sensing of the environment, supported by experience in the ERS aircraft flight program, to assist in planning the relative roles of these methods in programs of the future. Studies, software development and data management systems development will be directed toward meeting the difficult problems of structuring spacecraft data into that most useful for experimental analysis and eventual application to national problems. The experimental analysis and investigation program, to which the ERS aircraft flight program provides essential support, will be extended in the direction of development of broader sensor instrumentation capability and an integrated aircraft and spacecraft data management system and facility. A program for developing centers with special competences in processing and analyzing data automatically both analog and digital techniques will be extended. In addition, advanced studies will be continued to improve the understanding of total Earth Resources Survey systems and the benefits which can be anticipated therefrom.

In Geodesy, emphasis is placed on conducting: (1) conceptual studies, feasibility analysis and configuration definition of geodetic spacecraft, (2) analysis of geodetic requirements by various disciplines in terms of spacecraft mission, (3) analysis of feasibility and effectiveness of geodetically optimized ground based spacecraft observation systems, and (4) research into geodetic effectiveness and feasibility of advanced observations systems and techniques, to provide more precise and densified measurement of geodetic data, and to calibrate geodetic observation methods intended for extraterrestrial use.

In Meteorology, effort is concentrated on: (1) the development and evaluation of components for potential meteorological satellite system application; (2) investigation of scientific techniques and tools for the systematic observation, analysis and subsequent interpretation of meteorological atmospheric phenomena; and (3) optimization system analysis.

In Navigation/Traffic Control, studies and experiment development will be conducted on data and voice transmission and position determination techniques via satellite to ships, aircraft, and other mobile platforms;

future navigation and traffic control satellite concepts; search and rescue and collision prevention techniques; and the collection and retrieval of data from fixed and moving platforms such as balloons, buoys, and animals.

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 Sciences. Also included within this program is the conduct of selected advanced missions studies which will define the requirements of future space applications flight missions.

TIROS/TOS Improvements

	1969	1970	1971
TIROS-M spacecraft.....	$4,300,000	$1,900,000	$700,000
TOS improvements.....	1,500,000	1,800,000	2,500,000
Total Spacecraft and Support	$5,800,000	$3,700,000	$3,200,000
Delta (Launch Vehicle Procurement Program).....	($1,400,000)	($200,000)	(---)
Total (including launch vehicles).....	($7,200,000)	($3,900,000)	($3,200,000)

The objectives of this project are to: (1) provide research and development toward advanced operational meteorological satellite systems, particularly in support of the TOS program and future satellite systems of the National Operational Meteorological Satellite System (NOMSS), (2) provide maximum interim operational data for use in weather analysis and forecasting, (3) measure emitted infrared and reflected solar radiation in selected spectral regions, (4) observe cloud patterns and cloud cover, (5) measure the earth-atmosphere heat balance, and (6) develop system concepts and basic configurations which will maximize success and minimize costs when subsequently used in operational systems.

Ten TIROS research and development spacecraft, of which nine were funded by NASA and one, TIROS-X, by 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, which is the operational prototype of the second-generation operational satellite series, the Improved TIROS Operational Satellite (ITOS), is scheduled for launch from the Western Test Range during January 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, realtime weather analyses. The mission will use a three-axis stabilized, earth-oriented satellite in a circular. near-polar, sun-synchronous orbit to obtain meteorological observations of the earth's cloud cover. Complete global coverage will be provided on a daily basis. Daytime coverage will be 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 will provide the direct readout capability by which about 500 worldwide receiving stations will be able to obtain local cloud cover information. The AVCS sensors will provide the stored data capability whereby the ESSA Command and Data Acquisition (CDA) stations at Goose Creek, Alaska, and Wallops Island, Virginia, will acquire global cloud cover data for central analysis at the National Environmental Satellite Center, Suitland, Maryland. Also carried by the ITOS-series spacecraft as part of the primary sensor complement are two infrared scanning radiometer (SR) subsystems, which will 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 (SPM) and a flat plate radiometer (FPR).

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 will be continued. Continuation of this work is necessary in FY 1971 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.

FY 1970 funds are being 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.

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FY 1971 funds are required for TIROS-M's post-launch support and data acquisition and handling efforts, for continued sensor and subsystems development for TOS Improvements, and for in-depth studies for future operational satellite systems.

Nimbus

	1969	1970	1971
Spacecraft	$22,826,000	$17,100,000	$15,500,000
Experiments	7,489,000	7,900,000	11,300,000
Ground operations and support	1,485,000	2,300,000	1,200,000
Total	$31,800,000	$27,300,000	$28,000,000
TAT - Agena and Delta (Launch Vehicle Procurement Program)	($5,743,000)	($2,801,000)	($1,500,000)
Total (including launch vehicles)	($37,543,000)	($30,101,000)	($29,500,000)

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.

This project includes development, launch, and operation of a series of meteorological 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 accomodate a number of sensors.

The first two spacecraft in the planned series of seven Nimbus satellites were Nimbus I, launched on August 28, 1964, and Nimbus II, 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 III. 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. Nimbus III successfully flight tested experiments to determine the vertical temperature structure of the atmosphere, remote sensors to measure radiation reflected and emitted by the earth and its atmosphere, an improved cloud cover imaging system, and a worldwide data collection system. The successful measurement from satellite of temperatures in the atmosphere has been termed "as significant to the advancement of meteorology as the launching of the first satellite." In addition, Nimbus D is scheduled to be launched in Calendar Year 1970, Nimbus E in 1972, and Nimbus F in 1973. Nimbus D, using the same basic spacecraft design as Nimbus III, will test an advanced control system, advanced experiments for determining the vertical temperature structure, and additional experiments such as a temperature/humidity infrared radiometer, a monitor of the water content of the atmosphere, and a more refined worldwide data collection system that will include the first meaningful spacecraft wind measurement experiment. Nimbus E and F will test advanced infrared radiometric and spectrometric and microwave experiments designed to allow penetration of cloud layers for the global determination of the vertical structure of 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.

FY 1970 funds are being used for continued acquisition and analyses of data from Nimbus III, for completion of the development, test, and launch of Nimbus D, and for continued development of the Nimbus E and F spacecraft and selected experiments. These funds will also be used for acquisition and analysis of data from Nimbus D subsequent to its launch this fiscal year.

FY 1971 funds are required for continued acquisition and analysis of the data from the Nimbus D spacecraft in orbit and to further continue the development of the Nimbus E and F spacecraft and selected experiments.

Synchronous Meteorological Satellite

	1969	1970	1971
Spacecraft.....	---	$2,000,000	$10,200,000
Experiments.....	---	700,000	2,200,000
Ground operations.....	---	---	3,200,000
Total.....	---	$2,700,000	$15,600,000
Delta (Launch Vehicle Procurement Program).....	---	($1,100,000)	($2,600,000)
Total (including launch vehicles).....	---	($3,800,000)	($18,200,000)

The objectives of the Synchronous Meteorological Satellite (SMS) are to demonstrate a prototype operational system which will meet the requirements of the ESSA 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.

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.

FY 1970 funds were used for initiating the design and development of the two SMS spacecraft and sensors. FY 1971 funds will be used to initiate procurement of SMS A and B.

Meteorological Soundings

	1969	1970	1971
Large research sounding rockets.....	$2,050,000	$2,050,000	$2,150,000
Small sounding rocket systems.	730,000	730,000	730,000
Field experiment support.....	220,000	220,000	220,000
Total.....	$3,000,000	$3,000,000	$3,100,000

The objectives of this project are to determine the structure and characteristics of the atmosphere in the 30 to about 100 km region through the use of research and development sounding rockets and to develop a meteorological sounding rocket system amenable to research, range support, and routine operational requirements.

Three areas of effort are involved:

(a) Large research sounding rockets to explore the characteristics and phenomena of the atmosphere between 30 and about 100 km. This region is important to meteorological science, and cannot be reached except by sounding rocket. Nike Apache and occasionally Tomahawk class rockets are used to explore the relations and mechanisms operating between and within the various regions of the atmosphere, and the effects of solar energy and its variations upon the structure and circulation in the atmosphere.

(b) Small sounding rocket systems are utilized to obtain measurements in the region of approximately 30 to 60 kilometers above the earth. Included in this effort is the development of an inexpensive operational meteorological sounding rocket system capable of reliable launches amenable to the requirements for range support, research and network operations.

(c) The sounding rocket field experiment support, which through cooperation with other countries, provides 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 research rockets is assigned to Goddard Space Flight Center, for small sounding rocket system development to Langley Research Center, and for field experiment support to Goddard Space Flight Center and Wallops Station.

FY 1970 and prior years funds were utilized to launch large research and small developmental sounding 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. FY 1971 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.

Cooperative Applications Satellite

	1969	1970	1971
Spacecraft and support.....	$100,000	$100,000	$100,000
Scout (Launch Vehicle Procurement Program).....	(---)	(---)	(1,100,000)
Total (including launch vehicles).....	($100,000)	($100,000)	($1,200,000)

This project is being carried out jointly by NASA and France. The effort consists of developing instrumented 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 1970 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 data analysis along with France of the reduced data.

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

This project was initiated in FY 1967. FY 1969 and prior year funding were used for preparation of computer program models, for U. S. scientific investigations and analysis of balloon and spacecraft antennas, and for electronics for general project support. Fiscal year 1970 funds are being used to continue U. S. scientific and technical support. Fiscal year 1971 funds are required to continue technical support and provide launch and post-launch support.

Global Atmospheric Research Program (GARP) Study

	1969	1970	1971
GARP study.....	---	---	$1,000,000
Total.....	---	---	$1,000,000

The Global Atmospheric Research program (GARP) is an international cooperative program directed toward obtaining data for increasing understanding of the general circulation of the atmosphere and for laying 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 the world scientific community through the International Council of Scientific Unions; national and international organizations have been established to plan and execute the program. The major event, a global exercise planned for 1975, is expected to require seven (7) meteorological satellites operating simultaneously for about a year. International commitments to provide these satellites have not been made.

Long term weather forecasting cannot be achieved without first achieving the GARP goals. In FY 1970, NASA initiated studies to determine the nature of its possible support to the GARP experiment. The study planned for FY 1971 will involve detailed study, comparative analysis, and preliminary system design directed toward facilitating the choice of a single project approach for NASA support to GARP. The study will also identify facilities, logistics operations, additional advanced technology, and advanced development tasks required to furnish spacecraft, ground support, and related data management for the global experiment.

Applications Technology Satellites

	1969	1970	1971
Spacecraft.....	$14,293,000	$14,700,000	$15,600,000
Experiments.....	9,824,000	19,800,000	14,200,000
Operational support.....	583,000	4,500,000	1,300,000
Total.....	$24,700,000	$39,000,000	$31,100,000
Atlas centaur and Titan IIIC (Launch Vehicle Procurement Program).....	($3,596,000)	($3,700,000)	($4,700,000)
Total (including launch vehicles).....	($28,296,000)	($42,700,000)	($35,800,000)

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. Because of launch vehicle anomalies, the desired orbits for ATS-II, launched April 6, 1967, and for ATS-IV, launched August 10, 1968, were not achieved, thus limiting the experimental value of these spacecraft. ATS-V, launched August 12, 1969, experienced problems with the active stabilization system prior to planned despinning of the satellite and the deployment of the gravity gradient system. However, many objectives from seven of the twelve experiments flight tested on the mission will be achieved. ATS-I, launched December 7, 1966, and ATS-III, launched November 5, 1967, into synchronous orbits have performed successfully and continue to operate. Two spacecraft, ATS-F and -G, are scheduled for launch in Calendar Years 1973 and 1974, 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) and demonstrate the high pointing accuracy it requires, and, in addition, will flight test a number of scientific and technology experiments.

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 major contracts for ATS-I through ATS-V missions were with Hughes Aircraft Company for spacecraft development; General Electric Company for gravity gradient stabilization; and Westinghouse Corporation for integration. The spacecraft development contractor for ATS-F and -G, which will either be the Fairchild-Hiller Corporation or the General Electric Company, will be selected early in 1970.

Fiscal year 1970 funds were used for ATS-V final development, experiments, launch and post-launch support; and for continued procurement of ATS-F and -G long lead time items and will be used for commencement of spacecraft development. Fiscal year 1971 funds will be used for continuation of ATS-F and -G development and experiments and for continued development of promising advanced applications experiments which have been defined but have not been assigned to a specific flight mission.

Geodetic Satellites

	1969	1970	1971
Spacecraft and support.....	$2,465,000	$1,700,000	$3,500,000
Delta (Launch Vehicle Procurement Program).....	(---)	(2,600,000)	(---)
Total (including launch vehicles).....	($2,465,000)	($4,300,000)	($3,500,000)

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-I in June 1966; GEOS-I on November 6, 1965; and GEOS-II on January 11, 1968. GEOS-I and -II contained similar instrumentation, namely, optical beacons, geometric and gravimetric instrumentation, range and range rate transponders, laser retro-reflectors, and doppler beacons. GEOS-II also carried two C-band transponders, a radar passive reflector, and a laser detector. Data obtained were utilized for Pageos-I, GEOS-I, and GEOS-II.

The Office of Space Science and Applications is responsible for the overall program. Project management of GEOS-C, previously at Headquarters, will be assigned to Goddard Space Flight Center.

Fiscal year 1970 funds are being used for continued analysis of GEOS-II data and to initiate effort on GEOS-C, which will obtain the additional data required to complete the gravimetric objective of the National Geodetic Satellite program and to demonstrate the feasibility of employing a geodetic satellite radar altimeter to measure the mean sea level of the ocean. Fiscal year 1971 funds will be used to continue the development of GEOS-C spacecraft and experiments.

Navigation/Traffic Control Satellite Studies

	1969	1970	1971
Spacecraft and support.....	---	---	$3,000,000
Total.....	---	---	$3,000,000

The objectives of this project are to study and design spacecraft capable of providing the communication, navigation, and traffic control technology required to demonstrate its application for: (1) improving air traffic control services in the over-ocean areas; (2) providing communication and navigation services to ships and aircraft; and (3) providing the aids in search and rescue operations and collision prevention system operations for marine and aviation vehicles.

Fiscal year 1971 funds are required for detailed design studies.

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

Earth Resources Survey

	1969	1970	1971
Earth resources technology satellites			
Spacecraft.....	$1,375,000	$3,900,000	$13,000,000
Experiments.....	800,000	10,600,000	20,700,000
Ground operations.....	125,000	500,000	7,800,000
Subtotal.....	$2,300,000	$15,000,000	$41,500,000
Delta (Launch Vehicle Procurement Program).....	(---)	(---)	(3,900,000)
Subtotal (including launch vehicles).....	($2,300,000)	($15,000,000)	($45,400,000)

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	1969	1970	1971
Earth resources survey/aircraft			
Operations.....	$1,300,000	$1,700,000	$2,100,000
Data processing.....	1,400,000	2,300,000	2,800,000
Sensors.....	6,200,000	7,000,000	6,100,000
Subtotal.....	$8,900,000	$11,000,000	$11,000,000
Total, Earth Resources Survey (including launch vehicles).....	($11,200,000)	($26,000,000)	($56,400,000)

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 two activities in earth resources: (1) a comprehensive program to design, launch, and evaluate experiments on Earth Resources Technology Satellites, and (2) 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 above 50,000 feet.

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 cultural 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 FY 1970 through the performance of two parallel detailed system design studies that encompass both the first two spacecraft and the related ground data handling system. A selection of the more promising system will be made very early in FY 1971 so that the system can enter into the detailed engineering and fabrication stage in FY 1971. The two satellites, which are planned for sun-synchronous orbit, are designated Earth Resources Technology Satellite (ERTS) A and B and are to be launched successively early in CY 1972 and CY 1973. 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 Earth Resources Survey aircraft supporting project objective is to conduct tests and experiments with instruments analagous 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.

In FY 1971 two substantial additions to the aircraft instrumentation capability will be 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. Together with the RB57 high altitude aircraft, assigned to NASA by the Air Force, a much improved capability for experimentation will be available. 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 1969 funds were utilized for operation of three aircraft, for sensor procurement, and data handling systems. Fiscal year 1970 funds are being utilized to continue this effort, procure additional sensors, and continue the modification of a high altitude aircraft to obtain a better understanding of atmospheric effects on remote sensing capability.

The Office of Space Science and Applications is responsible for the overall management of this project. Responsibility for execution of the Earth Resources Survey/Aircraft project is assigned to Manned Spacecraft Center. Responsibility for management of the ERTS A&B project is assigned to Goddard Space Flight Center. Effort in the Earth Resources Survey is coordinated with other user agencies through the Earth Resources Survey Program Review Committee 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.

Fiscal year 1971 funds are being requested to continue aircraft operations, sensor procurement, and data processing to conduct about 30 flights over 60 test sites, and to initiate spacecraft and sensor hardware procurement for the first two ERTS spacecraft.

OFFICE OF SPACE SCIENCE AND APPLICATIONS LAUNCH VEHICLE PROCUREMENT PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Launch Vehicle Procurement program objective is to provide launch vehicle and launch services to support mission requirements. Major activities include the procurement of vehicle hardware, launch operational services, engineering and maintenance support, and necessary product improvements to flight vehicles and support equipment. The program includes Supporting Research and Technology/Advanced Studies efforts for necessary vehicle improvements. The vehicles being procured are: Scout, Delta, Thor Agena, Atlas Centaur, Titan III Centaur, and the Titan IIIC. They comprise a balanced family of vehicles which is planned to satisfy present and future automated spacecraft requirements in the most efficient and economical manner.

The Launch Vehicle Procurement program is subdivided into three major categories: (1) vehicle hardware, (2) supporting activities, and (3) product improvement. This subdivision, as presented during FY 1970, permits vehicle hardware to be readily identified with specific missions. This vehicle hardware is shown parenthetically in the budget requests of the various spacecraft missions in addition to being presented in the Launch Vehicle Procurement request in total. Funding requirements for supporting activities and product improvement are not included in the parenthetical notations shown with spacecraft projects since these efforts are not directly associated with specific missions.

The supporting activities category includes funds to cover recurring costs, which are continuing in nature, such as launch operations services, guidance services, engineering support, and launch complex maintenance. These costs, unlike the cost of hardware, are based on the establishment of a capability, rather than a quantity of units produced.

In the product improvement category, the major work is dedicated to enhancing reliability and performance in support of spacecraft requirements.

SUMMARY OF RESOURCES REQUIREMENTS:

	1969	1970	1971
Supporting research and technology/advanced studies	$4,400,000	$4,000,000	$3,000,000
Scout	12,600,000	13,700,000	15,100,000
Delta	24,300,000	32,100,000	34,000,000
Agena	11,300,000	5,300,000	---
Centaur	44,200,000	50,000,000	68,100,000
Titan IIIC	3,100,000	3,700,000	4,700,000
Total	$99,900,000	$108,800,000	$124,900,000

Distribution of Program Amount by Installation:

John F. Kennedy Space Center	$3,329,000	$1,717,000	$2,968,000
Marshall Space Flight Center	202,000	---	---
Goddard Space Flight Center	26,734,000	35,199,000	33,975,000
Jet Propulsion Laboratory	265,000	490,000	510,000
Electronics Research Center	1,282,000	1,257,000	---
Langley Research Center	12,905,000	13,582,000	15,130,000
Lewis Research Center	50,455,000	50,963,000	65,573,000
Headquarters	4,728,000	5,592,000	6,744,000

The overall plan for launches during this period is:

Vehicle	Calendar Year 1969	Calendar Year 1970	Calendar Year 1971
Scout	1	7	5
Delta	6	2	2
Agena	2	2	-
Centaur	3	1	3
Titan	-	-	-
Total	12	12	10

The above table includes Advanced Research and Technology missions but excludes reimbursable launches and vehicles procured for other agencies, which average approximately six per year.

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology/Advanced Studies

	1969	1970	1971
Advanced studies.....	$750,000	$1,025,000	$1,030,000
Propulsion and energy conversion	740,000	730,000	500,000
Guidance, control and navigation.....	1,480,000	1,675,000	1,260,000
Instrumentation and electronics.	225,000	60,000	60,000
Structures and materials.....	405,000	510,000	150,000
Vehicle engineering.....	800,000	---	---
Total.....	$4,400,000	$4,000,000	$3,000,000

The objective of the Supporting Research and Technology/Advanced Studies project is to provide data for management decisions concerning launch vehicles and stages required for future automated missions by conducting a systematic program of studies and research.

In FY 1970, three launch vehicle advanced studies were initiated. One was directed at design of a versatile upper stage concept for high energy missions. The second study involves the design of a minimum cost launch vehicle as a replacement for one or all vehicles of the current automated launch vehicle family. The third study includes an analysis of growth versions of the Titan III (including 7 segment solids) for possible use with Centaur for planetary missions. Supporting Research and Technology effort was initiated on the effects of long term space vacuum on solid propellant motors and to determine long term space mission requirements for solid propulsion systems. Extensive effort was directed at testing and evaluating the modular strapdown guidance system presently under development. In the area of instrumentation, studies were continued in developing nondestructive test techniques for electro-explosive devices.

In FY 1971, advanced studies of spacecraft thermionic and magneto-hydrodynamic nuclear-electric propulsion systems are planned. The advantage of hybrid rocket motors for combined launch vehicle and spacecraft applications will also be studied. Effort will be directed at upper stage propulsion and astrionics problems and their interaction with spacecraft systems.

Additional study emphasis will be placed on the application of non-chemical propulsion systems to launch vehicle upper stages. Minimum cost launch vehicle system design studies, least cost vehicle family studies, and high energy upper stage studies will be continued to help provide direction to future automated launch vehicle developments in order to maintain an economical and reliable transportation system.

Scout

	1969	1970	1971
Hardware procurement.....	$3,900,000	$4,700,000	$7,100,000
Supporting activities.....	7,300,000	8,000,000	7,000,000
Product improvement.....	1,400,000	1,000,000	1,000,000
Total.....	$12,600,000	$13,700,000	$15,100,000

Scout is a four stage all solid propellant launch vehicle. It is the smallest in the NASA vehicle family and is used for small scientific satellites, space probes and high speed re-entry experiments. The Scout project has been in existence for ten years and over this period, 67 launches have been conducted of which 54 have been successful. The vehicle has been used to support missions for the DOD, AEC, foreign countries and international organizations.

The technical management of the Scout project is at the Langley Research Center. The prime contractor for the production, checkout and launch of this vehicle is Ling-Temco-Vought (LTV), Dallas, Texas. Launch operations of the Scout vehicles are conducted from the Western Test Range, California, Wallops Island, Virginia, and from the Italian San Marco platform in the Indian Ocean off the Coast of Africa.

In FY 1970, funds are being utilized to complete vehicle hardware production contracts and systems management and engineering contracts started in fiscal years 1968 and 1969. In addition, the Scout first stage motor is being improved. This improvement will increase the performance capabilities of the vehicle by approximately 30 percent.

In FY 1971, funds requested will be utilized to initiate new hardware procurements, to sustain the Scout launch capability at two launch sites and continue efforts related to the Scout first stage motor development in addition to completing a new "S" band telemetry destruct system development.

Delta

	1969	1970	1971
Hardware procurement.....	$8,852,000	$12,800,000	$14,200,000
Supporting activities.....	11,593,000	14,000,000	17,600,000
Product improvement.....	3,855,000	5,300,000	2,200,000
Total.....	$24,300,000	$32,100,000	$34,000,000

Delta is the workhorse vehicle in the NASA launch vehicle family. Through 1969, it has performed successfully 68 times in 74 attempts. Delta is a three stage vehicle consisting of the first stage Thor booster, the Delta second stage and a solid propellant motor third stage. This vehicle is capable of lifting a wide variety of payloads into orbit. It has been used to launch communication, meteorological, scientific, and biological satellites.

Technical management for the Delta project is assigned to the Goddard Space Flight Center. The prime contractor for the Delta vehicle is the McDonnell-Douglas Astronautics Company, Santa Monica, California. NASA procures the first stage Thor boosters through the U. S. Air Force, which has management responsibility for the production of this vehicle stage. Launch operations of the Delta vehicles are conducted from the Eastern Test Range, Cape Kennedy, Florida, and the Western Test Range, California.

Fiscal year 1970 funds are being used to initiate new hardware contracts for Thor boosters, Delta second stages and solid motor third stages along with the necessary launch operations services and other supporting services necessary to sustain the Delta launch capability during this period. In addition, major product improvements being accomplished during FY 1970 are: the design, test and qualification of a larger version of the TE-364 solid motor; completion of the adaptation of the Thor booster to use six solid motors for thrust augmentation; and the incorporation of an inertial guidance system into the Delta vehicle.

Fiscal year 1971 funds will be utilized to continue funding of hardware contracts initiated in FY 1970, and for continued support of launch operations and maintenance of ground support equipment. In addition, the major product improvement efforts on the TE-364 and the inertial guidance system for Delta started in FY 1970 will be completed with FY 1971 funds.

Agena

	1969	1970	1971
Hardware procurement.....	$6,770,000	$1,751,000	---
Supporting activities.....	4,530,000	3,549,000	---
Total.....	$11,300,000	$5,300,000	---

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 is used by NASA for polar orbital missions launched from the Western Test Range in California.

The technical management of the Agena project is assigned to the Lewis Research Center and to the Goddard Space Flight Center. Lockheed Missiles

and Space Corporation, Sunnyvale, California is the prime contractor for the Agena stage. McDonnell-Douglas Astronautics Company, Santa Monica, California is the prime contractor for the Thor booster. The Agena and booster stages are purchased from these contractors through the U. S. Air Force.

No FY 1971 funds are required since there are no NASA missions currently planned for this vehicle system after the launching of the SERT IIA and Nimbus-D missions during the first half of 1970.

Centaur

	1969	1970	1971
Hardware procurement.....	$21,700,000	$20,000,000	$21,700,000
Supporting activities.....	21,600,000	14,400,000	20,800,000
Product improvement.....	900,000	15,600,000	25,600,000
Total.....	$44,200,000	$50,000,000	$68,100,000

Centaur is a high energy upper stage vehicle using liquid hydrogen and liquid oxygen propellants. This stage has been used with the Atlas booster in successfully supporting NASA's Surveyor, Mariner, Orbiting Astronomical Observatory and Applications Technology Satellite missions.

A new Centaur configuration - the Titan Centaur - is currently being developed. It is based on integration of an improved Centaur stage with the Titan III booster. This configuration involves four stages: one stage consisting of two strap-on, five segment solid motors, the second and third composed of the two stage Titan core and the fourth, the Centaur upper stage. This vehicle configuration will become operational in 1974.

The Lewis Research Center has technical management responsibility for the Centaur project. General Dynamics/Convair is the prime contractor for the Atlas Booster and the Centaur stage. Associate contractors are Honeywell, Inc. for the Centaur Guidance System 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 Titan III are manufactured by the United Technology Corporation and the propulsion system for the Titan III core stages I and II is produced by the Aerojet General Corporation. The Atlas Centaur is launched from the Eastern Test Range and the Titan Centaur will be launched from the ITL (Integrate-Transfer-Launch) facility also located at the Eastern Test Range.

In FY 1970, funds are being utilized to continue previously initiated vehicle procurements, to sustain the Centaur capability, and to initiate

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new hardware procurement to support missions planned for launch in the next few years. These missions include the OAO, Mariner Mars 1971, and Pioneer F and G missions. In addition, two major improvement efforts are being continued with FY 1970 funds. The first concerns improvements to the Centaur stage which will enhance reliability and flexibility of the vehicle. The changes include a new guidance computer, a standard forward adapter, and fixed insulation. The second improvement consists of the integration of the Centaur stage with the Titan III booster, and the establishment of an operational capability for Titan Centaur at the Eastern Test Range required to support the Viking mission. This effort includes funding for a proof flight of the Titan Centaur configuration, in order that this vehicle and launch facility may be adequately tested prior to the Viking mission.

During FY 1971, funds will be required to continue funding of vehicle hardware contracts for the Pioneer, Mariner Mars 1971, Proof flight, and OAO missions. In addition, funding will be required to begin efforts on the vehicle hardware and support of Mariner Mercury 1973 and Helios A missions. Effort required to continue the vehicle improvements begun in prior years, will also be funded.

Titan III C

	1969	1970	1971
Hardware procurement.....	$3,000,000	$3,700,000	$4,700,000
Supporting activities.....	100,000	---	---
Total.....	$3,100,000	$3,700,000	$4,700,000

The Titan III C launch vehicle is a four stage solid and liquid fuel vehicle developed and managed by the United States Air Force. Since the performance of the Titan III C vehicle is greater than that of the Atlas Centaur vehicle at synchronous velocities, NASA is using this vehicle for launch of the Applications Technology Satellites F and G missions. Depending on mission requirements, the Titan III C will be considered for other future synchronous altitude missions.

The NASA Headquarters will have primary management responsibility for the NASA Titan III C activity. The vehicles will be procured through the United States Air Force, 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, respectively. Martin will provide mission integration services; Martin along with its associate contractor will provide launch operation services. Launches will be from the Titan ITL (Integrate-Transfer-Launch) facilities at the Eastern Test Range in Florida.

During FY 1971, funds are required to continue hardware procurements and supporting services initiated in prior years in support of the ATS-F and G missions which are planned for launch in 1973 and 1975.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1971 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 will be phased to an orderly conclusion.

SUMMARY OF RESOURCES REQUIREMENTS:

	1969	1970	1971
Sustaining university program.....	$9,000,000	$7,000,000	---
Total.....	$9,000,000	$7,000,000	---

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1971 ESTIMATES

RESEARCH AND DEVELOPMENT BUDGET PLAN FOR

ADVANCED RESEARCH AND TECHNOLOGY PROGRAMS

Program	Fiscal Year 1969	Fiscal Year 1970	Fiscal Year 1971
Basic research.....	$20,220,000	$18,902,000	$17,600,000
Space vehicle systems.....	31,349,000	30,670,000	30,000,000
Electronics systems.....	34,460,000	33,500,000	22,400,000
Human factor systems.....	19,402,000	21,900,000	17,900,000
Space power and electric propulsion systems.....	38,787,000	34,450,000	30,900,000
Nuclear rockets.....	33,502,000	36,500,000	38,000,000
Chemical propulsion.....	25,752,000	20,480,000	20,300,000
Aeronautical vehicles.....	74,748,000	75,900,000	87,100,000
Total.....	$278,220,000	$272,302,000	$264,200,000

ART 1

FISCAL YEAR 1971 ESTIMATES

The Advanced Research and Technology programs shown in the preceding table supports research in two major technological areas, Space Technology and Aviation Technology. The division of effort between these two areas is shown below:

	1969	1970	1971
SPACE TECHNOLOGY			
Program			
Basic Research	$14,320,000	$12,712,000	$11,000,000
Space Vehicle Systems	31,349,000	30,670,000	30,000,000
Electronics Systems	23,360,000	23,005,000	16,600,000
Human Factor Systems	16,402,000	18,305,000	15,800,000
Space Power and Electric Propulsion Systems	38,787,000	34,250,000	30,500,000
Nuclear Rockets	33,502,000	36,500,000	38,000,000
Chemical Propulsion	25,752,000	20,480,000	20,300,000
Total 1/	$183,472,000	$175,922,000	$162,200,000
AVIATION TECHNOLOGY			
Program			
Basic Research	5,900,000	6,190,000	6,600,000
Electronics Systems	11,100,000	10,495,000	5,800,000
Human Factor Systems	3,000,000	3,595,000	2,100,000
Space Power and Electric Propulsion Systems	---	200,000	400,000
Aeronautical Vehicles	74,748,000	75,900,000	87,100,000
Total	$94,748,000	$96,380,000	$102,000,000
TOTAL, ADVANCED RESEARCH AND TECHNOLOGY 1/	$278,220,000	$272,302,000	$264,200,000

Aviation technology includes supporting research and technology effort conducted under Basic Research, Electronics Systems, Human Factor Systems, and Space Power and Electric Propulsion Systems programs related to aeronautics, in addition to all projects itemized under the Aeronautical Vehicles program.

1/ Excludes Launch Vehicle Procurement as follows:

1969	$2,394,000
1970	450,000
1971	2,100,000

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — BASIC RESEARCH PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Basic Research program supports fundamental research in the physical and mathematical sciences. It is aimed at providing an understanding of the physical phenomena pertinent to other NASA programs concerned with current and future aircraft and space activities. This basic research is carried out principally in NASA's research and space flight centers supplemented by investigations at universities, industrial research laboratories, and other Government research centers. Fundamental understanding of physical phenomena in many fields of science is required to develop the technology for NASA's programs. Basic research in NASA, therefore, must encompass a wide spectrum of disciplines. It ranges from very fundamental studies into the nature and properties of atoms and molecules to the more applied research areas such as determining the best materials for the space shuttle.

The Basic Research program is divided into four broad disciplines: Fluid Physics, Electrophysics, Materials, and Applied Mathematics. These are discussed below, as applicable to Aeronautics and Space. The division of the Basic Research Program into these two categories is somewhat arbitrary where the Program is applicable to both categories.

Aeronautics Research and Technology

The Fluid Physics subprogram promotes basic research on aerodynamic and gas-dynamic problems relevant to NASA objectives in aeronautics. During the past year, new research programs have been initiated on air pollution from aeronautics sources, noise generation from turbofan systems, and supersonic engine exhaust jets. Substantial progress has been made in the understanding and reducing of sonic boom and noise, and also, in understanding the origin and mechanisms of clear air turbulence.

The Materials subprogram conducts basic studies to understand the relationship between the structure and properties of materials that are used in aircraft. Typical examples are studies of surface physics to understand and improve the performance of avionics devices, alloys research to increase the performance of both structural and power plant materials and basic studies to better understand such failure mechanisms as fatigue and corrosion.

The objective of the Applied Mathematics subprogram is to develop new mathematical models and methods so that problems in aeronautics may be solved more readily or efficiently than possible today. Research is currently being carried out in data representation, ranking of alternatives, and in new methods of representing stochastic processes. Future plans include work in simulation, information retrieval, and adaptive control.

Space Research and Technology

The Fluid Physics subprogram promotes basic research on aerodynamic and gas-dynamic problems relevant to NASA objectives in space. During the past year, entry gas-dynamic research has been continued with studies primarily concerned with experimental simulation and verification of theories regarding high speed entry. A significant advancement in gas-dynamic laser research has been made by the recent demonstration of an all chemical laser.

The Electrophysics subprogram is devoted to increasing our understanding of the behavior of electrons, nuclei, atoms and molecules comprising gases, liquids and solids under the influence of acoustic, electric, and magnetic forces. Such new information is applicable toward the advancement of the technologies of electronics, space power and propulsion. In electronics, new paths will be made toward stable wide-band modulated optical and infrared lasers capable of transmitting and receiving increased information, and higher temperature superconductors. For space power and propulsion, progress is being made to achieve stable high density plasmas and to minimize energy losses so that the magnetoplasmadynamic technique may be practical.

The Materials subprogram is conducting basic studies to understand the behavior and properties of materials for use in space. The research is concerned with materials for use in electronic devices such as semi-conductors and thin films, and with structural materials for spacecraft, in particular for their use at high temperature. In the next year, a sizable portion of these studies will be directed toward materials for the space shuttle.

The goal of the Applied Mathematics subprogram is to achieve new mathematical techniques for the solution of problems related to space flight. Future plans include work in mathematical approaches to pattern recognition, information retrieval, automatic theorem proving, and adaptive systems. This work will be applicable to many social and technological problems in addition to the NASA requirements.

SUMMARY OF RESOURCES REQUIREMENTS:

	1969	1970	1971
Aeronautics research and technology	$5,900,000	$6,190,000	$6,600,000
Space research and technology.....	14,320,000	12,712,000	11,000,000
Total.....	$20,220,000	$18,902,000	$17,600,000

Distribution of Program Amount by Installation:

	1969	1970	1971
Marshall Space Flight Center.....	$820,000	$555,000	$1,588,000
Goddard Space Flight Center.....	122,000	100,000	100,000
Jet Propulsion Laboratory.....	3,155,000	2,435,000	2,200,000
Ames Research Center.....	2,561,000	2,775,000	2,805,000
Electronics Research Center.....	1,952,000	2,060,000	---
Langley Research Center.....	2,457,000	2,310,000	2,175,000
Lewis Research Center.....	2,895,000	4,247,000	4,510,000
NASA Headquarters.....	6,258,000	4,420,000	4,222,000

BASIS OF FUND REQUIREMENTS:

Aeronautics Research and Technology

Fluid physics.....	1,500,000	1,640,000	1,750,000
Materials.....	4,300,000	4,350,000	4,650,000
Applied mathematics.....	100,000	200,000	200,000
Total.....	$5,900,000	$6,190,000	$6,600,000

During the past year, Fluid Physics research has resulted in substantial progress in sonic boom and clear air turbulence research. New research programs were initiated on fluid dynamic mechanisms of atmospheric pollution from airborne and ground sources, and aerodynamic noise from engine turbofan systems and engine exhaust jets.

The research program on sonic boom prediction and reduction has provided techniques for predicting the pressure waves from aircraft maneuvering through a nonuniform atmosphere. Current theories have been extended to include the effects of unsteady winds and atmospheric turbulence. Results of several theoretical investigations of aircraft configurations have indicated that significant boom reductions are potentially feasible. The theoretical concepts are being evaluated experimentally in the NASA wind tunnels.

Progress has been made in understanding the origin and mechanisms of clear air turbulence which is an important operational problem of present jet transports. The results of these studies should contribute to eventual detection and avoidance.

The new research program on atmospheric pollution is an investigation of the fluid dynamic mechanisms of the interaction and dispersion of pollutants from airborne and ground sources in urban areas. Wind tunnel tests of gas concentrations around model buildings are expected to provide quantitative data on pollution concentrations caused by aircraft and motor vehicles, in terms of the strength of the source. Preliminary visual data of smoke flow experiments involving a building and street model in a wind tunnel have

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shown that, perpendicular to the wind direction, there appears to be low ventilation, i.e. high pollutant concentrations, into the adjacent streets. Further research in this program will provide quantitative data for a variety of atmospheric and pollution source conditions.

New research programs have been initiated to gain an understanding of the mechanisms of noise generation from turbofan systems and supersonic engine exhaust jets. Some progress has already been made, theoretically, for predicting noise from supersonic jet exhausts. Also, studies are being continued to determine the flow mechanisms by which noise reductions are achieved in the jets.

Materials research seeks to determine why engineering materials fail under the various mechanical, chemical and thermal environments that they encounter in aircraft structures and propulsion systems. Part of the research is motivated by the need for improved avionics for advanced aircraft. One such program is in the area of the surface physics and chemistry of solids and is concerned with studying the effects of surface oxygen on the electrical properties of germanium. This research is useful for predicting device performance and reliability.

In the coming year, alloys for advanced aircraft structures and power plants will receive increased emphasis. Basic studies of the stability and oxidation characteristics of the nickel, cobalt, and chromium based alloys together with compatibility with various ceramic oxidation resistant coatings are expected to yield information which will increase materials performance in these applications.

Research on the newer composite materials including high strength and high modulus fibers, higher temperature resins, and oxidation resistant metal-matrix composites will be maintained because they continue to offer the best potential for significant savings in weight for advanced aircraft.

Basic studies of such phenomena as fatigue, corrosion, and friction will continue to be supported on a modest scale. Because such research tends to be long term it will have to lag behind higher priority items.

The Applied Mathematics subprogram is supporting research directed at the ultimate solution of problems in aeronautics. Examples of the research are mathematics of aircraft environment, e.g., solutions to nonlinear integral equations arising from adsorption kinetics; mathematics of aircraft performance, e.g., transforms related to generalized heat equations; and mathematics of aircraft control, e.g., adaptive control methods of optimizing climb rate, fuel consumption, etc.

In addition, much of the space related research is of considerable value to aeronautical problems. For example, both space and aeronautical problems generate nonlinear differential equations that require new techniques for solution.

Space Research and Technology

	1969	1970	1971
Fluid physics.....	$3,485,000	$2,855,000	$2,120,000
Electrophysics.....	6,260,000	4,910,000	3,350,000
Materials.....	3,455,000	3,987,000	4,555,000
Applied mathematics.....	1,120,000	960,000	975,000
Total.....	$14,320,000	$12,712,000	$11,000,000

During the past year, Fluid Physics research has resulted in a significant advancement in gas-dynamic laser research with the recent demonstration of an all chemical laser. This new chemical laser is the first for which continuous operation is achieved solely by mixing commercially available bottled gases together. The potential advantages of this chemical CO_2 laser (in comparison with those of the highest power, conventional, electrically-excited CO_2 lasers) are its compactness and simplicity, and the fact that no electrical power or thermal sources are required for excitation. High power, high efficiency gas-dynamic lasers, with their compactness and simplicity, show great promise for such applications as space communications and power transmission to satellites.

A research program on the flow field analysis of rarefied gas has provided an exact analytical method for predicting heat transfer, skin friction coefficients, and pressure coefficients on space vehicles flying through the upper atmosphere. Accurate prediction of such rarefied gas-dynamic quantities can become significant for certain designs of the space shuttle. Other methods currently being used start to lose accuracy in the slip flow regime (20 - 40 mile altitude) and eventually become invalid in the transition flow regime (40 - 80 mile altitude). This exact method of prediction will also provide a guide for obtaining good experimental data in low density wind tunnels.

Recent research in the Electrophysics subprogram resulted in internally modulating a semiconductor laser which consequently transmits in a manner similar to an FM broadcast station. Because of its small size, this type laser should be useful in spacecraft communications.

Last year a new and very sensitive gallium antimonide pressure transducer was described, mounted at the tip of a catheter, to monitor blood pressure variations. Further progress has been made in reducing the size so that the transducer can now be placed in a hypodermic needle. Several hospitals have become interested in experimenting with the device.

Research on superconductors to increase the transition temperature will be continued by investigating the effect of depositing a polarizable inorganic film on a superconductor to induce some electron-pair formation without the intervention of phonons. A further step will be the laying of a more highly polarizable organic film on a superconductor to accentuate

pair formation still further through the interaction of electrons with the positive charges in the film. Hopefully, the transition temperature will be greater than the present upper limit of 21° K because of additional electron pairs induced in the superconductor by the polarized film.

Thin film amorphous semiconductors possess unusual switching and memory characteristics. This behavior could lead to useful applications in computer systems. Intensive research is underway to determine the responsible fundamental mechanisms in order to later develop reliable components.

For applications in space propulsion and power, plasma dynamics research is concerned presently with high power density ionized gases and their interactions with electromagnetic fields and confining wall structures. In this context, the unique characteristics of uranium plasmas are being explored, such as the radiation, spectra, and transport of the charged fission fragments. Plasma instabilities and boundary layer effects are also being investigated.

Space-related materials research ranges from studies of the relationship between the electronic structure of solids and their physical and mechanical properties to investigations of how materials behave in a space environment.

In the past, research on materials for electronic applications has yielded improvements in the performance of lithium ferrites for memory cores for high speed computers. This improved material has now been incorporated into onboard spacecraft computers. The continuing requirement for improved computer memories has stimulated additional research projects for this coming year on new and potentially higher memory storage capacity magnetic materials for future spacecraft.

In the area of alloys research, added emphasis was placed on increasing the use temperature of nickel and cobalt base superalloys for the space shuttle. The principal direction of the work in the next year will be on strengthening these alloys by dispersing inert oxides in the alloys. It is believed that such materials are a prime candidate for large areas of the skin of the space shuttle. Efforts on fiber reinforced superalloys will be continued at about the same level as last year to provide an alternate research approach to increasing the use temperature of these alloys. High temperature materials research will also be maintained in the refractory materials which in the past have been primarily of interest for space power but are now finding additional interest for the space shuttle.

Most high strength materials fail in a brittle and catastrophic manner, because as the strength of ceramics and composite materials increases, their ductility generally decreases. The Materials subprogram will increase its emphasis during the coming year on studies of fracture and failure mechanisms particularly as they relate to the use of these materials for advanced space missions. The knowledge gained will also be used to develop theories for predicting the life of such materials when they are subjected to complex patterns of temperatures and loads for long times. This data is particularly needed for advanced spacecraft having long mission times.

Applied mathematics research is currently being carried out on many diverse space related problems. Among the most significant are new ways to reduce, represent, and interpret data, a method for ranking and selecting among several alternatives, development of methods for scientists and non-scientists to interpret research results, and new methods of representing stochastic or random processes.

The results of the research in progress will not only help solve some of NASA's important problems; they will augment other technological approaches in pollution, health, transportation, and education.

In the immediate future, the Applied Mathematics subprogram will focus on mathematical approaches for recognizing patterns (e.g. cloud cover, ocean currents, crop damage, etc.), methods for retrieving information from very large stores of documents and data, new automatic problem solving methods using modern theorem-proving research, and research into adaptive robots for taking over some of man's functions in an unfriendly environment.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1971 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — SPACE VEHICLE SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Space Vehicle Systems program is an applied research and technology program. The primary objectives within the disciplinary areas of aerothermodynamics, structures, and space environmental protection and control are to (1) conduct focused research and technology efforts on critical problems associated with the reusable space shuttle, the space station, lunar exploration, and planetary vehicles, and (2) conduct carefully selected advanced technological research of particular importance for all types of unmanned and manned space vehicles.

The program also includes the formulation of space vehicle design criteria documents as well as a special activity concerning aerospace safety.

SUMMARY OF RESOURCES REQUIREMENTS:

	1969	1970	1971
Research and Technology:			
Space vehicle aerothermodynamics.	$9,116,000	$9,673,000	$7,300,000
Space vehicle structures.....	9,496,000	10,355,000	12,050,000
Space environmental protection and control.....	10,603,000	8,048,000	7,800,000
Space vehicle design criteria....	1,669,000	1,394,000	1,350,000
Aerospace safety research.....	465,000	1,200,000	1,500,000
Total.....	$31,349,000	$30,670,000	$30,000,000

Distribution of Program Amount by Installation:

Manned Spacecraft Center.....	$947,000	$1,740,000	$1,050,000
Marshall Space Flight Center.....	3,462,000	3,943,000	3,035,000
Goddard Space Flight Center.....	2,351,000	2,400,000	1,475,000
Jet Propulsion Laboratory.....	1,710,000	1,465,000	1,475,000
Ames Research Center.....	3,560,000	3,165,000	3,100,000
Electronics Research Center.....	425,000	389,000	---
Flight Research Center.....	1,220,000	1,205,000	1,200,000
Langley Research Center.....	13,482,000	12,452,000	13,985,000
Lewis Research Center.....	3,070,000	2,910,000	3,300,000
NASA Headquarters.....	1,122,000	1,001,000	1,380,000

BASIS OF FUND REQUIREMENTS:

Space Vehicle Aerothermodynamics

	1969	1970	1971
Research and technology.....	$9,116,000	$9,673,000	$7,300,000
Subtotal.....	$9,116,000	$9,673,000	$7,300,000
Scout (Launch Vehicle Procurement Program).....	($200,000)	($300,000)	($1,000,000)
Total (including Launch Vehicles).....	($9,316,000)	($9,973,000)	($8,300,000)

The main thrust of this subprogram in FY 1971 is research focused on critical aerothermodynamic problems associated with conceptual vehicle configurations and with detailed aerothermodynamic design of (1) the manned space shuttle and (2) advanced unmanned planetary atmospheric probes. Beyond these focused efforts, an important body of more generalized aerothermodynamic research is conducted that is broadly applicable to all types of space vehicles.

The stringent requirements of reuse and operational economy of large multistage space shuttle vehicles pose unique problems in aerodynamic stability, control, atmospheric entry heating, and in heat protection system design. These important factors interface strongly with the need for new, more efficient structural concepts and with consideration of payload, volume, crew quarters, fuel tanks, and other operational necessities. Emphasis will be directed toward (1) investigating the aerodynamic performance, stability, control and flying qualities of promising space shuttle concepts and (2) more accurate determination of the aerodynamic heating environment to permit efficient design of heat protection systems all within the realistic limits of vehicle weight and structural considerations.

The cooperative NASA and USAF lifting-body flight research program is investigating piloting problems and flying and handling qualities of configurations representing concepts of manned reentry vehicles during the terminal phases of space flight, i.e., from supersonic speeds to landing. Fifty-five glide and powered flights have been accomplished on three separate vehicles as of January 1. The powered HL-10 has been flown to a Mach number of 1.6 and an altitude of 80,000 feet. During FY 1971, the HL-10 will be used to study powered approach and landing and terminal guidance, and to complete the investigation of flight stability and control at transonic speeds begun during FY 1970. The X-24A had its initial flight in April 1969, and will be flight tested through its design envelope up to a Mach number of 2.0 at an altitude of 80,000 feet. The rebuilt M2-F3 will resume flights to investigate modifications made to the vehicle to improve its aerodynamic characteristics and to investigate reaction jets for controlling the vehicle.

Research will continue on promising concepts for advanced unmanned planetary atmospheric probes and soft landers. Investigations will be conducted to provide improved ablation heat protection from the extreme heating encountered during Venus and Jupiter atmospheric entry. Technology for advanced inflatable systems to decelerate vehicles during Mars atmospheric entry will be developed to increase instrument payload capability. Flight experiments are planned to confirm deployment, drag, stability, and performance of a promising decelerator concept.

Development of a planetary atmosphere experiment scheduled for a flight test in the Earth's atmosphere in FY 1971 will continue. The planned high-speed trajectory will simulate the entry conditions for a planetary mission. The test will investigate the ability to determine in flight the structure and composition of an unknown planetary atmosphere from measurements of the probe vehicle motion and the ambient gas characteristics.

Broader, longer range advanced technology activities include detailed investigations of the complex interactions of the by-products of ablation, advanced methods for predicting vehicle motions during flight, the conditions of extreme heating of vehicles experienced upon reentering the earth's atmosphere at planetary return speeds of 50,000 feet per second or more, and special programs in support of the Department of Defense.

Space Vehicle Structures

	1969	1970	1971
Research and technology.....	$9,496,000	$10,355,000	$12,050,000
Total.....	$9,496,000	$10,355,000	$12,050,000

During FY 1971 efforts will be directed to advancement of structures technology to meet the critical needs of the reusable space shuttle, the space station and space base, lunar exploration systems, and planetary vehicles. Also, continued emphasis will be placed in important areas of structures research having broad ranges of applicability to future space systems and in determining feasibility of promising advanced concepts.

The technology program is directed toward solving the unique and difficult structures problems of reusable space shuttles. Each stage must withstand repeated launch, reentry, cruise, and landing conditions with many critical loading and temperature environments. Increased efforts will be focused on lightweight, highly efficient structures that are a prerequisite to successful space shuttle development. Reusable thermal protection systems and other vital components that must withstand extreme temperatures repeatedly will be studied extensively.

Problems in the structural design of space stations and space bases that will receive attention include the dynamics of very large flexible vehicles, provisions for artificial gravity, docking, maintenance, and repair for long operational life.

Future expansion of lunar exploration activities will require improved systems with lightweight structures. Technology will continue to be developed for shelters and equipment to permit extended and more versatile manned operations.

For planetary missions beyond Viking, research will continue to be focused on critical structures such as advanced aeroshells for entry into planetary atmospheres and larger, lightweight erectable spacecraft antennas for communication during missions to the more distant outer planets.

In addition to the foregoing, structures technology will be advanced for application to critical subsystems for a variety of space vehicles. Significant progress has been made in technology for pressure vessel design and prolonged storage of cryogenic fluids such as liquid hydrogen, but continued research is needed to provide more detailed data to meet the exacting requirements for engineering design of future systems. For some advanced missions, new and unique structural concepts are needed to achieve feasible approaches, and efforts will continue to explore such concepts. Scale models of a proposed large orbital radio telescope will be tested in the laboratory and in flight to confirm the potential of the concept for a future prototype system.

Space Environmental Protection and Control

	1969	1970	1971
Research and technology.....	$10,603,000	$8,048,000	$7,800,000
Subtotal.....	$10,603,000	$8,048,000	$7,800,000
Scout (Launch Vehicle Procurement Program).....	(---)	(---)	($1,100,000)
Total (including launch vehicles).....	($10,603,000)	($8,048,000)	($8,900,000)

This subprogram seeks to understand the effects of the space environment on space vehicle design, and to provide the technology required for environmental protection and control.

During FY 1971, research will be continued in the laboratory and in flight experiments to provide engineering technologies required for design of the space station/space base, the space shuttle, and extended lunar exploration systems. These activities include a more accurate definition of the space radiation environment as it affects vehicle design, development of advanced radiation dosimeters, and investigations of more versatile heat rejection radiator concepts, along with the associated advanced thermal analyses and thermal/vacuum testing techniques. Increased attention will be given to problems of contamination of optical surfaces which have been encountered recently in space. Meteor observations from ground stations will continue. A flight experiment initiated in FY 1969 will be developed for launch in FY

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1972 to measure the effectiveness of a meteoroid bumper in the actual space environment. These measurements, together with secondary measurements of meteoroid velocity and impact flux in the same experiment, as well as in another preliminary flight experiment in late FY 1970, will provide data for design of meteoroid protection systems and correlation with ground-based experiments.

Research will be undertaken to provide technology required for future interplanetary missions. Work will continue on meteoroid technology experiments to be carried on Pioneer F and G spacecraft. These experiments will assess the meteoroid hazard to spacecraft as the vehicles pass through the asteroid belt. In other ground-based research, emphasis will be placed on studies of active spacecraft temperature control techniques, with particular attention to heat pipes. Also, attention will be given to improvement of solar simulation capabilities at the high intensities encountered on missions to the inner planets.

As in prior years, an advanced technology program of broad applicability will include refinement of radiation shielding design techniques, improvement of understanding of the mechanics of hypervelocity impact and related simulation testing capabilities, the development of more stable thermal coatings, and the improvement of thermal/vacuum simulation and testing techniques.

Space Vehicle Design Criteria

	1969	1970	1971
Research and technology.....	$1,669,000	$1,394,000	$1,350,000
Total.....	$1,669,000	$1,394,000	$1,350,000

In this subprogram, criteria and models of the environment applicable to the design of space vehicle structures, propulsion systems, and guidance and control systems are developed, documented and published. Technical experts at the NASA field centers, the Jet Propulsion Laboratory, the aerospace industry and universities work together to formulate the criteria and recommend approaches to be followed to insure the continued development of reliable and efficient space vehicles. These criteria are based on the experience gained from past design and operational experience and the latest results from research.

Activities during FY 1969 and FY 1970 are expected to lead to the release of approximately twenty new design criteria monographs. The FY 1971 funds will be used to contract for the services of technical experts from outside the Government who have the knowledge and experience to continue this effort.

Aerospace Safety Research

	1969	1970	1971
Aerospace safety research.....	$465,000	$1,200,000	$1,500,000
Total.....	$465,000	$1,200,000	$1,500,000

The Aerospace Safety Research and Data Institute (ASRDI), which was recently established, has played an active and increasing role in support of aerospace safety improvement. A key responsibility of the ASRDI is the Aerospace Safety Data Bank which was established to collect and disseminate information on aerospace safety and is scheduled for initial operation in early 1970.

Initial implementation of reference storage and retrieval is planned for February 1970. At this time, the ASRDI staff shall have on-line acess to the NBS Cryogenic Information Center files and the AEC Nuclear Safety Information Center files, as well as the NASA Scientific and Technology Information Aeropsace reference files.

Several research programs, planned for FY 1971, will seek practical solutions to extremely pressing safety problems. A program to identify and develop improved techniques for detecting and extinguishing fires in manned spacecraft which was initiated in FY 1970 at the request of the OMSF will be continued. Much of the work will also intrinsically have application to aircraft. Other programs are being pursued (1) to develop practical engineering safety criteria for roadable cryogenic dewars to assist the Department of Transportation in establishing testing standards, (2) to provide increased understanding of the potential shrapnel hazards resulting from explosion of liquid propellant systems on launch pads, and (3) to study in detail the operational safety problems related to the use of liquid hydrogen in large quantities as proposed for the manned shuttle spacecraft.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1971 ESTIMATES

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — ELECTRONICS SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

Aeronautics Research and Technology

Modern aircraft rely heavily upon electronic systems both in the fundamental operations necessary to atmospheric flight and in the interactive functions between the vehicle and its external environment. As aircraft speed, size, complexity and the density of air traffic increase, the dependence on electronic aids in all aspects of aircraft operations multiplies rapidly. The objectives of applied research and development efforts in aircraft electronics, or avionics, are to provide advances in technology which significantly improve the performance, cost effectiveness and reliability of avionic systems, offer important new functional capabilities and solve interface problems between flight operations and the operating environment.

While a broad base of fundamental knowledge in avionic systems and components is necessary to maintain competency over a period of years, specific techniques and components which are pacing items in near term aeronautical applications must be selected and developed in periods of constrained resources. This program is aimed at the development of such items including economical collision avoidance systems, all-weather landing techniques, improved display systems, effective vertical and short take-off and landing techniques and advanced components for control, communications, navigation and guidance.

Space Research and Technology

Achievement of space mission objectives is completely dependent on the successful operation of the systems and subsystems which comprise the space vehicle and couple it to the terrestrial world. Electronics is a key element in most of these systems. The objective of the Electronics Systems program is to insure the availability of components, subsystems and systems which will permit continued success in future space missions. This objective is pursued through a selected program of applied research and development in the functional areas of guidance, control, communications, tracking, instrumentation and data processing. Common to each of these areas and supporting their development is a more fundamental research and development effort in electronic techniques and components which applies recent advances in solid state physics to the development of new and improved electronic devices for system applications.

Special emphasis is being devoted this year to the development of technology which will provide an integrated electronics system for the Space Shuttle Vehicle and an advanced information processing system for the Space

Station/Base program. This effort is drawing on the broad base of fundamental electronics knowledge established through prior years' research and development activity. The work is accomplished through a coordinated program of in-house research among the various NASA centers supplemented by contractual efforts with academic and industrial facilities where necessary.

SUMMARY OF RESOURCES REQUIREMENTS

	1969	1970	1971
Aeronautics research and technology	$11,100,000	$10,495,000	$5,800,000
Space research and technology			
Supporting research and technology	22,960,000	22,705,000	16,600,000
Flight projects	400,000	300,000	---
Total	$34,460,000	$33,500,000	$22,400,000

Distribution of Program Amount by Installation:

Manned Spacecraft Center	---	$425,000	$700,000
Marshall Space Flight Center	$2,180,000	2,870,000	3,790,000
Goddard Space Flight Center	2,801,000	3,130,000	3,940,000
Jet Propulsion Laboratory	2,891,000	3,540,000	2,660,000
Ames Research Center	3,231,000	3,235,000	4,787,000
Electronics Research Center	16,048,000	13,665,000	---
Flight Research Center	740,000	725,000	900,000
Langley Research Center	4,555,000	4,510,000	4,723,000
NASA Headquarters	2,014,000	1,400,000	900,000

BASIS OF FUND REQUIREMENTS:

Aeronautics Research and Technology

Advanced concepts	$3,120,000	$3,280,000	$1,200,000
Guidance systems	3,000,000	3,100,000	1,260,000
Control systems	3,000,000	2,507,000	1,857,000
Communications	200,000	125,000	125,000
Tracking and data acquisition	400,000	100,000	150,000
Data handling and processing	140,000	175,000	175,000
Instrumentation	1,240,000	1,208,000	1,033,000
Total	$11,100,000	$10,495,000	$5,800,000

Advanced Concepts

Advanced Concepts research is directed toward defining future electronic systems and their applications. Objectives include the understanding of the interactions between system, subsystem and environment, and the development

of advanced technology and new techniques relative to system accomplishment. Concentration, as in previous years, continues to be placed on aircraft, or avionic systems.

A research effort being conducted under the Advanced Concepts area is aimed at aiding in the solution of the air traffic congestion problem. The landing rate per instrumented runway can be significantly increased if the basic aircraft separation standards are reduced. This reduction cannot occur under all-weather conditions without violating safety standards until it can be demonstrated that aircraft can fly precise time and path constrained trajectories. The proposed use of inertially derived translational information in conjunction with ILS and automatic flight control equipment is a new concept that has been shown analytically to be capable of up to a factor of four improvement in lateral dispersion at touchdown. A joint NASA-FAA flight evaluation of this development will be conducted in late FY 1970. With the closure of the Electronics Research Center (ERC) this effort will be transferred to the Langley Research Center for completion.

The continuing effort in V/STOL avionics will begin flight test of several system components in FY 1971. The basic avionics system will serve as a test bed for the evaluation of advanced components such as a laser gyro inertial reference unit and a redundant sensor system. Through FY 1970, this program was conducted at ERC. In light of the closing of that facility, the FY 1971 effort will be transferred to the Ames Research Center.

The current commercial jet aircraft and the "jumbo" jet now in service are incorporating into their control, guidance and navigation systems a high degree of automation. Because of advances in electronic systems, these aircraft will also have some increased capacity for precision in enroute and terminal area navigation. A research effort is underway to develop systems criteria for defining the pilot's role in systems with varying levels of automation. Efforts in FY 1971 will emphasize both simulation and flight test of representative pilot managed systems.

Guidance Systems

In the area of backup or independent landing aids for aircraft, the first pilot flight evaluation of STOL aircraft landing under low visibility conditions using a pilot display generated by onboard equipment and ground based beacons has demonstrated the feasibility of the technique. Further efforts will include evaluation of improved displays and incorporation of simplified inertial sensors in the system. A new effort to determine the feasibility of using passive radiometric techniques for low visibility landing is currently under study. Hardware efforts planned to begin during the last half of FY 1970 will be continued in FY 1971.

Efforts on optimization of guidance and navigation for supersonic aircraft climb and cruise will be continued. This will include the application of fixed time of arrival techniques developed for space to aircraft navigation.

Control Systems

Proper integration of man into a complex aeronautical vehicle's control and guidance system requires a detailed quantitative description of the human operator performance characteristics. Design of both the display and control systems are heavily dependent upon the humans capabilities and limitations. A continuing research effort is directed toward defining the capabilities and requirements of the human operator when he is placed as an active element in the control system. A result of this program has been the development of techniques and a body of knowledge useful in determining optimal information display-pilot-vehicle control interfacing.

Current efforts will extend these techniques and knowledge to include the prediction of pilot workload and the optimization of human performance in multidimensioned tasks such as an aircraft approach and landing.

In the aircraft components area, emphasis is on reliable, low cost performance for general aviation applications. Fluidic components for autopilot subsystems have shown considerable promise and development efforts will be continued in FY 1971.

The results of efforts on fluidic components will be incorporated in fluidic subsystems for light airplane flight evaluation. An X-14 aircraft is being modified to be a flight test bed for VTOL aircraft control investigations. These investigations will be aimed at developing advanced techniques for improved attitude, altitude and translational stability and control.

Communications, Tracking and Data Acquisition

Flyable models of both microwave and optical pilot warning indicators have been constructed. The microwave system performed satisfactorily in flight tests, and future effort will be directed toward making it light and inexpensive enough for use by general aviation. The optical system will be flight tested and the results turned over to the Federal Aviation Administration and industry for decisions on rule making and for construction of production models.

Data Handling and Processing

Digital computer systems play leading roles in the analysis of aircraft configurations and design factors. Research on techniques for utilization of large ground computer complexes has yielded important contributions in several NASA studies of aircraft design for the DOD in the past year. In FY 1971 efforts in this area will continue with emphasis on techniques for increasing the real-time simulation processing power of computer systems, reducing the down-time of elements in these systems, and developing methods of measuring and analyzing the efficiency of large ground computer complexes in solving complex simulation and design problems.

Instrumentation

In support of future aeronautic programs and associated test facilities, advancement of measurement capabilities is needed for a wide variety of physical parameters.

An instrument technique based on use of a vibrating diaphragm and originally developed with considerable success to measure aerodynamic pressure in wind tunnels has been applied to a variety of other uses because of its excellent characteristics of ruggedness, small volume and wide measuring range - 8 decades. Its potential capability as an aircraft altimeter with a predicted resolution of 10 feet at 100,000 feet altitude is planned to be tested in high altitude aircraft flights during FY 1971.

Supporting the V/STOL program, progress was made in the development of a fluidic wind velocity indicator to accurately measure low relative air speeds during transition and hover. Wind speeds as low as .3 ft/sec have been measured in wind tunnel tests with a single axis model. Continuation of prototype development and flight testing is planned for FY 1971.

The laser backscatter technique discussed in prior years, for measuring atmospheric density, was used during 1969 as part of NASA participation in the Barbados Oceanographic and Meteorological Experiment project. The laser instrumentation was successfully used aboard ship for the first time to measure spatial and temporal distribution of aerosols and the reflectivity of thin clouds and moisture layers. This knowledge will contribute to better meteorological forecasting and better understanding of the errors in sea surface temperature measurement by satellite. In FY 1971 the technique will be extended to multifrequency operation to permit identification of atmospheric components (molecules and aerosols) and remote measurement of water vapor profile data to better describe the meteorological state of the lower atmosphere.

Progress was also made in development of systems to detect flow turbulence remotely. Laser instrumentation techniques developed to measure flow velocities in wind tunnels by the Doppler effect were adapted to measurements of near field atmospheric turbulence caused by the trailing vortices of jet aircraft during landing or takeoff. An experimental airborne system for detecting clear air turbulence, which uses a microwave radiometer to measure temperature fluctations as a function of atmospheric oxygen absorption has been developed, and aircraft installation and flight tests are planned for FY 1971.

Space Research and Technology

	1969	1970	1971
Supporting Research and Technology			
Advanced concepts.....	$1,872,000	$420,000	---
Guidance systems.....	2,372,000	2,743,000	$2,336,000
Control systems.....	2,617,000	1,480,000	1,659,000
Communications.....	3,493,000	3,310,000	2,750,000
Tracking and data acquisition...	3,995,000	3,685,000	1,912,000
Data handling and processing....	3,088,000	3,975,000	3,504,000
Instrumentation.....	1,995,000	2,692,000	1,788,000
Electronic techniques and components.....	3,528,000	4,400,000	2,651,000
Total.....	$22,960,000	$22,705,000	$16,600,000

Guidance Systems

The feasibility of onboard spacecraft guidance for planetary approach was successfully demonstrated in an experiment on Mariner Mars 69. A new concept for increasing accuracy by using the moons of planets for approach guidance is being explored with the objective of performing an advanced experiment on Mariner Mars 71. Research on strapdown celestial sensors using conventional as well as holographic star mapping techniques will be continued for use as earth orbital spacecraft attitude references.

Development of electromagnetic sensors for more reliable horizon sensors, star tracker and planet approach guidance will be continued. Efforts on devices for calibrating infrared radiometers have yielded a factor of five improvement in calibration accuracy. These results will be incorporated in a calibration system to be completed in FY 1971. Design of a precision horizon measurement radiometer will be completed early in FY 1971 and development of a breadboard system initiated.

Automatic reentry, approach and landing of space shuttle vehicles has been identified as a significant technology area. Studies to develop guidance techniques for all of these phases will be initiated in FY 1970 and continued in FY 1971. In the landing phase, this effort will be closely coordinated with on-going work to evaluate, in flight, the applicability of inertial filtering of Instrument Landing System reference beams used by conventional aircraft.

The optical laser rendezvous and docking radar is a strong candidate for space shuttle application. Along with continued efforts to refine its performance, a study is being initiated to determine the parameters needed for shuttle application. This effort will lead to a laboratory prototype development in FY 1971.

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Control Systems

In automatic control systems, areas of effort include components, systems, and flight experimentation. The space vehicle components effort emphasizes devices for improving the lifetime, precision and reliability of control systems. As a follow-on to the successful development of brushless, direct current motors, a motor combining magnetic suspension and a brushless commutator has been developed. This technology will be applied as the motor for a long-life reaction wheel control device.

Passive gravity gradient stabilization techniques developed in previous years have shown considerable promise but because of limited accuracy and technical problems, they have been used in one or two axis systems for applications requiring only modest performance. Recent control theory results have produced a technique for improving attitude estimation and prediction which offers promise for application to advanced earth resources satellites and will receive increased emphasis in FY 1971.

A major effort in the space vehicle control systems area is directed towards control of the space station/base and the experiment platforms requiring precision pointing. In addition to this effort, the change to a Saturn V launched workshop in the Apollo Applications program has required additional supporting control system analysis and simulation.

Current efforts on components for extending the operating life and improving the performance of the large control moment gyro (CMG) will continue in FY 1971, aimed at space station requirements for long term mission reliability. These efforts include advanced designs of speed reducers and control systems incorporating brushless DC motor torquers. Advanced bearing technology has yielded promising results for inertial and large control gyros and will be continued.

Communications, Tracking and Data Acquisition

Space communication and tracking systems of the future require unusual technological progress in three specific areas: electronically steered antennas, use of higher frequencies, and longer life. Progress is also needed on a broad front in all areas of technology, but these are the limiting factors in the most important mission areas of the future and will be main thrusts of the fiscal year 1971 research program.

Future electronically steered (phased array) antennas are particularly important to NASA space missions and are in some cases an actual necessity to meet mission requirements. An example of this is the Navigation/Traffic Control Satellite now under study which must communicate rapidly and sequentially to different aircraft in transit over the Atlantic or Pacific oceans.

The need for expansion of communication services continues to grow and considerable effort will be devoted to the development of circuit components of all kinds for the higher wavelengths which offer the only room for

expansion. One example of this is the waveguide which is used to carry millimeter wave signals from place to place within a receiver or transmitter. Traditionally these have been made by extruding square pipes or waveguides which at millimeter wavelengths become so small, they are almost unmanageable. A new technique developed at the Goddard Space Flight Center uses flat strips of metal or dielectric material with fences on each side. This structure operates at the same wavelengths, permits easier access to the guided signal and is larger and, therefore, more manageable. This, and similar activities, will be continued in FY 1971.

Long life components are required for all NASA missions but especially for the outer planetary scientific spacecraft. A broad spectrum of effort will be devoted to increasing component lifetime in fiscal year 1971. An example of this work is a turret cathode developed at the Jet Propulsion Laboratory. This device permits automatic replacement of a deteriorated cathode in a microwave tube by the simple process of rotating the turret to a new position.

Work will also continue in the broad areas of telescope technology, optical communications and tracking, coding for high data rate communication, and microwave solid state components.

Data Handling and Processing

The need for automated monitoring and control of more onboard functions plus demands for greater reliability and longer lifetimes have added to the technological challenge of advances in computer performance and data processing techniques. Laminated ferrite memory development, started in 1964 to obtain a high capacity, radiation resistant, low cost computer memory, was found to be applicable also to computer logic circuits and offers promise of "all magnetic" digital circuits with few interconnections. During the past year problems in material production were solved and considerable progress was made in the fabrication of memory components. This technology will be actively pursued in FY 1971 for application to computing devices required for Space Shuttle/Station and Grand Tour missions.

In the longer range research program to obtain large computer memory capacities of 10^{10} and 10^{12} bits, progress was made in the investigation of photochromic and magneto optic materials in system studies of laser deflection techniques and in volume holographic storage techniques. These efforts will be continued in FY 1971.

In the field of onboard computers, a reliability model of the self test and repair concept was developed last year which indicated the possibility of 12 years of operation with 90% reliability if triple redundancy is used. Originally started as a guidance computer system, this effort is being expanded to perform functions such as automated in-flight testing and maintenance monitoring for a space station.

Two general approaches are being pursued to provide maximum information from large volumes of video data - one is to extract only required, useful,

information by means of techniques such as pattern recognition and automated image classification; the other is to use "compression" techniques so that more information can be transmitted over a given telemetry channel. In the past year, progress was made in both the development of mathematical pattern recognition techniques and in the development of a system for onboard image data compression using coherent optics to yield a data compression ratio of 100 to 1. These efforts will be continued in FY 1971.

In a concentrated effort to obtain solutions to aerospace software problems (SOFIX), grants were awarded in FY 1970 to 8 universities and one nonprofit organization in the areas of language, parallel computation and computer system design. Initial results of this effort will be evaluated in FY 1971 and support will be continued in the areas which promise maximum benefit.

Instrumentation

Research efforts to advance sensing capabilities in many parts of the electromagnetic spectrum are required to support future space measurement efforts.

For example, astronomy and earth orbital missions use photomultipliers in many experiments to detect low level light signals although their efficiency is low. Optical enhancement techniques were developed in the past year which achieved sensitivity increases by a factor of 2 to 5 permitting detection of fainter signals or use of smaller diameter telescopes. Application of the technique to image intensifiers and TV vidicons will be pursued in FY 1971.

To permit future astronomical observations from a space base to fully utilize diffraction limited space telescopes, high grade optical subsystems and image recording systems compatible with the high resolution of such telescopes are required. Development of large aspheric gratings, light converter/intensifier systems, and combined imaging and recording systems such as the dielectric camera will be initiated in FY 1971.

Electron beam flow visualization techniques for hypersonic aerodynamic studies mentioned in last years report are now in operational use and have found wide application. This method permits viewing of the complete flow field around a model and was recently used to test space shuttle configurations at Mach 20. It was possible to identify shock patterns and flow disturbances which would have been very difficult to distinguish by other methods. Additional applications of the technique will be investigated in FY 1971.

Previously, instrumentation circuits with inductive components could not be fully miniaturized. Significant progress was made in the past year on the development of "active" networks of integrated circuits as replacements for inductive components. A size reduction from 120 to 4.5cc and a weight reduction from 100 to 5 grams was achieved when applied to a magnetometer filter which originally used inductive components. Active filters will have wide application commercially in radio and TV circuits which now use inductors

and transformers. Another instrument circuit innovation was achieved in the design of a self tuning band pass filter. Filters commonly used for rejecting noise in instrument systems are limited in performance when the input signal varies over a wide range. The self tuning filter improves noise rejection by using a narrow band-width which is automatically aligned to the varying signal frequency. These techniques will be applied to instrument system designs in FY 1971.

Electronic Techniques and Components

Solid state technology offers the electronic system design engineer great new opportunities to create systems of reduced size, weight and cost while increasing their versatility, performance and reliability. To keep pace with the system designers, a vigorous research and development program in solid state materials, components and techniques for fabrication and test of these devices is required.

Research on new materials and their applications in component form will continue to provide the electronic functions needed in system design. Particular emphasis will be placed on solid state display devices, data storage and microwave components to support Space Station technology development. As electronic devices become smaller, yet more complex, new techniques for their design, fabrication and test must be evolved. Automation of the screening and testing steps in medium and large scale integrated circuit manufacture was initiated during FY 1970 and will continue in FY 1971. Special emphasis is being given to this effort to ensure the availability of qualified devices in the Space Shuttle and Space Station Technology Programs. Standards for the design, qualification and test of these devices will be developed to guide the systems engineers in their applications work. Instrumentation and techniques to assess the reliability, and improved methods for assembling and packaging solid state devices are being developed to increase the yield and economy of the fabrication process and provide long life components for use in missions of extended duration such as the Space Station and outer planet explorations. These efforts will be continued in FY 1971.

Flight projects

	1969	1970	1971
Radio attenuation measurements (RAM-C)	$400,000	$300,000	---
Scout (Launch Vehicle Procurement Program)	(300,000)	(---)	(---)
Total (including Launch Vehicles)	($700,000)	($300,000)	(---)

Radio Attenuation Measurement (RAM)

The purpose of the Radio Attenuation Measurement (RAM) project was to verify the theory of the interaction of radio waves with a plasma by laboratory and flight tests, and to apply this theory to the prediction and prevention of radio blackout in practical circumstances. Two successful flights have been completed in this series. The first, RAM-C-I, demonstrated the use of water injection to ameliorate communication blackout during re-entry, and the second, RAM-C-II, provided valuable flight information to support the work of the theoreticians. The project will be concluded in FY 1970 with a third flight, using an available backup spacecraft, to explore the potential of electrophilic materials as a means to alleviate blackout conditions in a realistic re-entry environment. This flight is scheduled for May 1970.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — HUMAN FACTOR SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

Aeronautics Research and Technology

Aeronautical vehicles are causing significant changes in the environment of people within and outside the vehicles. The Human Factor Systems program is developing techniques to characterize those changes and conducts research to determine the extent of their effects on man. The program examines man's requirements, his capabilities, and his limitations and translates these into design criteria for future aeronautical systems including both airborne and ground based components. Since the human is a critical element in most advanced systems, studies are being made on decision making functions and the information processing aspects of human performance, and on the effects of stress on human operators.

Space Research and Technology

In order to determine and insure man's role in future extended space operations, it is necessary to qualify both man and his supporting equipment. The qualification of man implies a detailed understanding of the unique capabilities and capacities of the human organism in space, the optimal contributions of this organism to the performance of a wide variety of space flight objectives, and the development of an ability to predict potential physiological and behavioral changes.

To accomplish this goal, both ground based research and flight projects are necessary. The ground based studies must be of such sophistication and depth as to be applicable not only to identified and predictable problems but to unpredicted problems as well. The Human Factor Systems program was initiated in the pattern of traditional medical research, but it is evolving by developing and utilizing more advanced methodologies. Innovative methods and techniques are employed. Mathematical modeling and systems analysis are already being applied to problems of the cardiovascular system.

The Human Factor Systems program includes these elements: (1) Human Research and Performance, (2) Man-Systems Integration, and (3) Life Support and Protective Systems. By necessity, the work is accomplished through a multidisciplinary approach which includes research in physiology, psychology, medicine, biology, engineering, physics, chemistry, mathematics, and electronics. It is carried out at the various NASA Centers, Department of Defense aerospace medical laboratories, other Government facilities, universities, and industry.

SUMMARY OF RESOURCES REQUIREMENTS:

	1969	1970	1971
Aeronautics research and technology.....	$3,000,000	$3,595,000	$2,100,000
Space Research and Technology			
Supporting research and technology.....	14,329,000	16,010,000	14,200,000
Biotechnology flight projects.....	2,073,000	2,295,000	1,600,000
Total.....	$19,402,000	$21,900,000	$17,900,000

Distribution of Program Amount by Installation:

Manned Spacecraft Center.....	$3,089,000	$4,150,000	$2,900,000
Marshall Space Flight Center.	287,000	200,000	150,000
Jet Propulsion Laboratory....	50,000	---	---
Wallops Station.....	1,073,000	1,115,000	100,000
Ames Research Center.....	5,815,000	5,180,000	5,700,000
Electronics Research Center..	975,000	1,240,000	---
Flight Research Center.....	899,000	800,000	800,000
Langley Research Center.....	5,407,000	6,880,000	6,900,000
NASA Headquarters.....	1,807,000	2,335,000	1,350,000

BASIS OF FUND REQUIREMENTS:

Aeronautics Research and Technology

Human research and performance.	$1,100,000	$1,445,000	$675,000
Man-systems integration.....	1,900,000	2,150,000	1,425,000
Total.....	$3,000,000	$3,595,000	$2,100,000

Human Research and Performance

Aircraft operations will increase rapidly as jumbo jets and V/STOL and supersonic transports are introduced while the number of private aircraft continues to grow. Noise pollution will become intolerable unless steps are taken to combat it systematically. The Human Research and Performance subprogram is developing techniques for predicting the level of noise an aircraft will produce before it is actually built and the effects of such noise on man. These techniques will be made available to aircraft manufacturers for use in designing less noisy vehicles and to the Federal Aviation Administration for preparing certification standards.

The utilization of man in operational aeronautical systems must be planned in a manner which will optimize overall system performance. To do this it is necessary to develop advanced techniques for evaluating the performance of the system with the human element in it. The environment

which the system imposes on the human will affect his performance both directly and indirectly; for example, directly by so vibrating the man that he may not be able to control the vehicle, and indirectly by, imposing psychological stress which alters his body system functions. A major research and development effort is necessary to provide measures of both the stresses and their effects.

Man-Systems Integration

The issues related to pilot workload during reduced visibility landing operations are being studied, including the type of information provided the pilot. Several different devices are available to project flight data, such as flight path angle, vertical velocity, airspeed, etc., on the aircraft windshield in a collimated image in the pilot's forward external field of view. The ultimate value of different data elements in landing aids displays will be determined.

Space Research and Technology

	1969	1970	1971
Supporting research and technology			
Advanced concepts.....	$453,000	$465,000	---
Human research and performance..	5,213,000	6,087,000	$4,860,000
Man-systems integration.....	2,457,000	2,105,000	2,020,000
Life support and protective systems.....	6,206,000	7,353,000	7,320,000
Total.....	$14,329,000	$16,010,000	$14,200,000

Human Research and Performance

The Human Research and Performance subprogram includes research to: (a) determine the effects of flight environments on cardiovascular, respiratory, vestibular and other physiological functions, (b) develop advanced instrumentation for measuring the physiological and psychological changes caused by flight stresses, (c) identify and develop means to control the microbiological problems which may arise with crews in closed or semiclosed ecological systems in space vehicles, and (d) insure food acceptability.

As is apparent from the above listing of research areas, extensive and varied research efforts are necessary. Much has been learned but much yet remains to be done if we are to "achieve a depth of understanding about man and his role in space that will permit his optimal integration into future space programs." This requirement was set forth in November 1969 by the President's Science Advisory Committee.

In FY 1971, work will continue on the development of a test which permits the identification of viruses within as short a period as 24 hours in contrast to the normal 10 to 14 days. This fluorescent antibody

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technique may be applied to preflight screening of astronauts. It may also be used for early identification of infection developed in flight so they may be treated promptly.

In cardiovascular physiology, studies will be continued on identifying the mechanisms of blood pressure control, the role of hormones in governing cardiovascular function, and the renal aspects of orthostatic hypotension. At NASA's request, a subgroup under the National Academy of Sciences' Space Science Board annually reviews the NASA cardiovascular research program to insure its scientific validity and its relevance to aerospace requirements.

Studies now in progress will be continued in order to determine the mechanism by which hypogravic environments modify the composition and morphology of bone.

Man-Systems Integration

Man-Systems Integration issues are crucial ones in the development of space vehicles. The President's Science Advisory Committee noted, "Major engineering decisions, controlling the character of possible future space stations, logistic systems, and other manned spacecraft depend on evaluation of man's potential for useful work in space..."

The Man-Systems Integration subprogram is attempting to: (a) quantify human capabilities for performing physical and mental work as an operator of space systems, and as a scientific investigator, (b) develop methods for flight and ground crew selection and identify training requirements, (c) determine man's individual behavior characteristics and group dynamics in aerospace missions, and (d) develop the technology for living and working in space vehicles and on extraterrestrial surfaces.

In FY 1971, work will continue on the development of equipment to meet the expressed needs of astronauts for off-duty activities and on the design of more efficient but habitable, work and living spaces.

The Tektite Project, early in 1969, required four scientists to live for 60 days in an underwater habitat pressurized at a nominal 42-foot depth. Data were obtained on crew selection; habitability criteria for working, sleeping, eating, waste management, and recreation; architectural design; and psychomotor performance. With continuing cooperation between NASA, the Navy, the Department of the Interior, the College of the Virgin Islands, the government of the Virgin Islands, the Smithsonian Institution, the National Science Foundation, the National Institutes of Health, and the General Electric Company, a second experiment, Tektite II, will be conducted in 1970. Further data will be obtained on the effects of isolation and confinement in a semihostile environment on crew behavior and interaction. Such data will provide a firm basis for space crew

selection and monitoring procedures and vehicle design requirements.

Life Support and Protective Systems

As the duration of man's stay in the space environment increases, the need for reliable and maintainable life support and protective systems become tremendously important.

The Life Support and Protective Systems subprogram has been designed to (a) develop techniques and hardware for personal hygiene and waste management, for the reclamation of potable water from urine, wash water, and humidity condensate, and for converting metabolic wastes into food; (b) develop techniques and hardware for regenerating oxygen and diluents (e.g., nitrogen) for extended mission durations, and for maintaining the carbon dioxide, humidity, and contaminant characteristics of cabin atmospheres within acceptable limits, (c) develop instrumentation for monitoring and controlling atmospheric composition, thermal environment, chemical and microbial contaminant levels, and system functions; and (d) develop the garments, portable Environmental Thermal Control/Life Support (ETC/LS) systems, and other aids for astronauts to perform intravehicular and extravehicular tasks.

Work has been initiated and will be continued in FY 1971 on the advanced integrated life support systems (AILSS) for missions of two years duration without resupply. This will include new components, subsystems, and systems; each will be carried through the stages of proof-of-concept, prototype, and validation in a complete system test. This must include extended life testing of all components, detailed failure modes and effects analyses, complete reliability studies, and finally manned tests to determine the man-system interactions.

Also in FY 1971, work will continue on astronaut protective systems which will maintain and support an environment in which useful work may be performed. These systems must protect man from harsh thermal radiation, micrometeoroids, and the vacuum conditions of the extravehicular environs. They must provide acceptable personal environmental conditions under both normal and emergency conditions. This technical area includes work on: (1) fire resistant materials and thermal protective garments, (2) space suits with constant volume, and (3) portable life support systems which provide five hours or more effective life support at increased work levels and such mobility as is required within anticipated mission constraints.

Biotechnology Flight Projects

	1969	1970	1971
Biotechnology flight projects.....	$2,073,000	$2,295,000	$1,600,000
Scout (Launch Vehicle Procurement Program).....	($1,100,000)	(---)	(---)
Total (including launch vehicles).....	($3,173,000)	($2,295,000)	($1,600,000)

The Biotechnology Flight projects consist of packages of experiments to fulfill needs for data relevant to the Human Factor Systems program. To the extent possible, the program's data needs are fulfilled through ground based research, using simulated flight conditions when necessary and possible. In some cases, however, the flight environment conditions can not be simulated and the data required can be obtained only in flight experiments. When possible these experiments are carried on vehicles flown for other purposes, and only when necessary are special flights scheduled.

In FY 1971, two kinds of activities will be carried out under the Biotechnology Flight projects. One will be the analysis of data obtained and preparation of a report on the Orbiting Frog Otolith experiment which is scheduled to be flown in 1970 on a Scout vehicle launched for this specific purpose. The objective of the experiment is to obtain information on the functioning of the otolith, the balance mechanism in the inner ear, which will contribute to our understanding of this mechanism and its relation to the issue of artificial gravity for long duration manned flights.

The remaining flight project activity in FY 1971 will be on experiment definition for future flights. Work will continue on the definition of experiments on the effects of weightlessness on major body systems. Other flight experiment efforts will be directed toward increasing understanding of the various regenerative life support processes in weightlessness as well as a quantification of the metabolic cost of performing useful work in space.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY

SPACE POWER AND ELECTRIC PROPULSION SYSTEMS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The principal objective of the Space Power and Electric Propulsion program is to provide the advanced technology base necessary for the development of electric power generation and electric propulsion systems for anticipated aeronautical and space applications.

The power distribution, regulation, and control systems presently employed in aircraft are based on design concepts that are 20 or more years old. The objective of this portion of the electric power generation program is to determine whether more recent technology concepts emanating from the space program can be employed to advantage in aircraft systems.

Future missions such as the space station/base, shuttle, applications satellites and outer planets exploration require the development of electric power systems having power levels, endurances, and reliabilities far beyond those attainable with current systems which were designed to meet the relatively short duration, low power requirements associated with the first ten years of the nation's space program. Within this program, the need for nuclear system technology is becoming particularly pressing as the NASA mission requirements begin to exceed the capability of solar power systems.

The Electric Propulsion program continues to aim at early applications to achieve the potential advantages of mission flexibility and increased payload. The need for long-life, auxiliary electric propulsion systems for future manned space stations and synchronous satellites to perform station keeping is becoming evident. Studies continue to show the advantages of primary electric propulsion in performing difficult interplanetary missions. Continuing good progress is being achieved in both the auxiliary and primary propulsion systems technology areas as demonstrated by ground tests and the SERT II flight program.

SUMMARY OF RESOURCES REQUIREMENTS:

	1969	1970	1971
Aeronautics research and technology			
Supporting research and technology.....	---	$200,000	$400,000
Space research and technology			
Supporting research and technology.....	$37,287,000	33,750,000	30,225,000
Space electric rocket test (SERT).....	1,500,000	500,000	275,000
Total.....	$38,787,000	$34,450,000	$30,900,000

Distribution of Program Amount by Installation:

Manned Spacecraft Center.....	$135,000	$1,405,000	---
Marshall Space Flight Center.....	200,000	220,000	---
Goddard Space Flight Center.....	3,306,000	3,150,000	$2,925,000
Jet Propulsion Laboratory.....	10,805,000	8,450,000	7,075,000
Ames Research Center.....	408,000	349,000	250,000
Electronics Research Center.....	1,093,000	1,420,000	---
Langley Research Center.....	1,377,000	1,375,000	1,820,000
Lewis Research Center.....	20,348,000	16,985,000	17,925,000
NASA Headquarters.....	1,115,000	1,096,000	905,000

BASIS OF FUND REQUIREMENTS:

Aeronautics Research and Technology

Power processing and distribution..	---	$200,000	$400,000
Total.....	---	$200,000	$400,000

A thorough study of present and future needs in aircraft electrical systems is underway, together with a low level effort toward reducing the maintenance requirements, weight and complexity of aircraft electrical systems. This work will continue in FY 1971 with a moderate increase in level of effort.

Space Research and Technology

Supporting research and technology			
Nuclear flight safety.....	$166,000	$200,000	$200,000
Electric propulsion.....	7,080,000	5,820,000	5,775,000
Nuclear power generation.....	17,378,000	16,625,000	16,130,000
Solar power generation.....	6,467,000	5,190,000	2,850,000
Chemical power generation.....	4,369,000	3,955,000	3,120,000
Power processing and distribution	1,827,000	1,960,000	2,150,000
Total.....	$37,287,000	$33,750,000	$30,225,000

Nuclear Flight Safety

The objectives of the NASA Nuclear Flight Safety program continue to include: (1) the coordination and direction of the NASA portion of the joint AEC/DOD/NASA reviews and analyses of proposed missions utilizing nuclear space power systems, (2) providing guidelines to the NASA Centers for future mission applications, (3) developing specific design information in such areas as re-entry aerodynamics where NASA has special competence and facilities, and (4) the recovery of NASA launched spacecraft carrying significant quantities of nuclear materials in those cases where a determination is made that recovery is feasible and desirable.

Electric Propulsion

The continuing goals of the Electric Propulsion program are to provide the technology necessary for spacecraft position control systems and the early use of ion engines for primary propulsion of planetary spacecraft.

The major reasons for interest in this technology are the potential for increased mission capability and flexibility, and reduced launch vehicle size and/or costs as compared with existing chemical propulsion systems. These advantages stem primarily from the high specific impulse and accompanying lower propellant expenditure rates achievable with electric thrusters. In these thrusters, electrical energy is used to accelerate a propellant to exhaust velocities considerably higher than achievable by any other known method. Spacecraft utilizing such systems can accomplish missions considered impractical for chemical propulsion such as long duration north-south station keeping of a synchronous satellite, an orbiter of Mercury, out of the ecliptic at one astronomical unit, and a close solar probe. Advantages can also accrue from other characteristics of electric propulsion such as the capability to use biowastes for propellant in manned space stations and the availability of relatively large amounts of electrical power during non-propulsion periods.

The ion engine, an electric thruster of the class which accelerate charged particles in electrostatic fields, will continue to receive the major emphasis in this program during FY 1971. Resistojet thrusters, which produce thrust by means of expansion of an electrically heated gas, and plasma thrusters which depend upon interactions between electric current and magnetic fields, are the subject of the remainder of the program.

Very low thrust (10^{-5} lbs.) cesium contact ion engines with electric thrust vectoring capability, offer advantages for gravity-gradient stabilized geosynchronous satellite to perform east-west station keeping. Experimental contact engines designed for this function were successfully operated on the ATS-IV spacecraft in 1968, and were included as an experiment on ATS-V launched in the summer of 1969. Operation of the ion engines on this latter spacecraft will depend on whether satisfactory spacecraft performance can be achieved. A much higher thrust level (10^{-3} lbs) is required to perform

north-south station keeping on geosynchronous missions and because of its economical use of electrical power, the bombardment ion engine appears best suited for this role. During FY 1970, effort was initiated on an engine of this type and plans made to include it as an experiment on the forthcoming ATS-F. This work will continue in FY 1971 along with efforts aimed at improved performance and electrostatic thrust vectoring. Evaluation of pulsed plasma microthrusters which, because of their rapid and accurate controllable thrust pulses, offer potential for control of spin stabilized vehicles will also be carried out in FY 1971.

Auxiliary propulsion requirements for manned space station atmospheric drag cancellation and attitude control, are appreciable. Studies have shown that high temperature (3600°F-4000°F) resistojet systems operating with either ammonia or hydrogen at high specific impulse not only reduced the propellant requirement, but also reduced the complexity and increased the safety of resupply operations. Resistojets using biowastes as propellants provide added advantages such as elimination of propellant resupply.

A major milestone in this effort was passed in FY 1970 with the successful conclusion of long term life tests on ammonia and hydrogen units. Four ammonia thrusters completed 8000 hours without incident and one hydrogen thruster completed 6000 hours satisfactorily. During the test program, a second hydrogen thruster operated at 80 percent performance which was attributed to a leak. Upon disassembly of several thrusters, it was determined that no significant material degradation had taken place. This eliminated the concern that material sublimation would limit life at high temperature.

Initial tests of resistojets capable of operating on biowastes, such as carbon dioxide, methane, urine, and water, were also carried out in FY 1970. In FY 1971, this effort is to be continued with emphasis on evaluating materials compatible with the biowastes. In addition to thruster research, the subsystem technology development required for integration with life support systems, will be initiated.

Electron bombardment ion thruster systems continue to show significant promise for interplanetary spacecraft prime propulsion applications at thrust levels from 10^{-2} to 10^{-1} lbs. The two major elements of the program directed toward such applications are: (1) the SERT II flight discussed in a later section; and (2) a systems technology program to simulate as realistically as possible in ground tests all of the required operational functions for a typical interplanetary mission. Spacecraft design analyses of solar powered electric propulsion missions have defined these requirements. An initial laboratory investigation completed in FY 1970, verified stable behavior of the key components during system operation in open loop (manually controlled) configuration. This test provided the information required to proceed with closed loop (automatically controlled) operation of a system closely simulating mission requirements. The necessary hardware and various logic subsystems for this investigation are being assembled for test in FY 1971. With the successful completion of this test program and the SERT II flight,

electric propulsion technology based on mercury electron bombardment ion engines will have achieved a major milestone in its advancement to initial mission use.

Nuclear Power Generation

The primary objective of the Nuclear Electric Power Technology program is to obtain the experimental and analytical data needed to permit the ultimate development of the energy conversion equipment to be used in advanced nuclear electric power generating systems required for such future missions as space station/base and outer planets exploration. The conversion systems will utilize isotope and nuclear reactor heat sources furnished by the AEC and are therefore closely coordinated with the AEC programs.

Two nuclear power generation programs are aimed at supporting the space station/space base program to cover power needs which have now been identified by mission studies to range up to 100KWe, perhaps higher. These are the SNAP-8 and Brayton cycle programs. The space station itself is estimated to need power at about the 25KWe level from the primary power system. Possibly independent experimental modules will require from 2-5KWe. The space base, which will evolve from the station, will require the higher power levels.

The NASA SNAP-8 program has been aimed at developing the technology of a long-life space reactor power system in the 30-50KWe power range. The development of the reactor is the responsibility of the Atomic Energy Commission, while NASA is developing the mercury turbogenerator power conversion system for use with this reactor. During FY 1970, emphasis in the NASA program has been placed on continuing the endurance development of the major components of the power conversion system, and obtaining systems data using two existing breadboarded power conversion systems.

In the past year, both the boiler and turbine, two components which had previously given major difficulty, have been successfully tested for 10,000 hours. The turbine was coupled to an alternator and 2KWe was lost over the test period. Post test inspection of both components did not reveal any significant problems and it is concluded that significantly more life is available. This is considered a major milestone toward the successful development of dynamic systems for use in space. The 10,000 hour boiler is now being disassembled for inspection and results are not yet available. A shorter test of another boiler, however, confirms that the problem of corrosion of boiler tubes by mercury has been solved.

Testing of the power conversion system located at the contractor's plant has given valuable data on component interactions in long-term operation and a dynamic test program to determine transient data in system start-up and shutdown was completed in FY 1970 using the second breadboarded power conversion system (PCS) located at the Lewis Research Center.

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Testing by the AEC of the second SNAP-8 reactor for 7,000 hours has revealed that the problem of fuel element cracking found in the first reactor has not been solved. The test of this reactor has been terminated to inspect for the causes of this problem. A study of the test data indicates that adequate corrective action can be taken in the next design. In addition, consideration is being given to reducing the PCS operating temperature in order to increase assurance of achieving long reactor life.

For the remainder of FY 1970 and in FY 1971, the SNAP-8 program will continue with life and performance development of power conversion system components and other development necessary for the combined test of the power conversion system with the reactor. Modifications will be made to current components as necessary for operation with a reduced temperature reactor.

NASA has undertaken the development of Brayton cycle for use in space because of its potentially high energy conversion efficiencies and because the single inert gas phase working fluid of the Brayton cycle will ease development problems. Development has been initially aimed at an isotope system at a power level of 2-10KWe where the efficiencies obtainable with conventional systems would require impractically large quantities of expensive, hard to obtain isotope fuel. The conversion equipment is designed for a turbine inlet temperature of 1600°F.

In 1969, start-up, shutdown, and performance tests were completed on the first combined Brayton gas bearing, turbo-alternator-compressor unit. This unit operated for 1013 hours demonstrating performance as predicted. A complete isotope Brayton power conversion system was assembled and has been run for 592 hours in the Plum Brook Space Power facility using an electrical heat source. These tests, which will be continued through FY 1970, are aimed at obtaining experimental data on system characteristics. A conversion efficiency of 22 percent has been demonstrated. In early CY 1970, long term endurance development of the major power conversion system components will be initiated in a separate component facility specifically designed for this purpose. Based on test results to date, some modification to the current equipment has been shown as necessary to achieve the very long life desired and to determine the operating limits of the current hardware. Also, work will be continued on the development of those components and structural elements associated with the high temperature isotope heat source which will be needed for test of the existing power conversion system with isotope capsules to be developed by the Atomic Energy Commission.

In the past year, estimates of eventual power needs for the space station/base program have grown to 100 to 200 KWe. Because of the importance of high conversion efficiency in achieving maximum power and the very long life desired from the reactor, and because of the initial success achieved in the isotope Brayton program, it is believed that Brayton conversion is the most appropriate approach for this power range. Therefore, in FY 1971, the Brayton cycle program will be expanded toward evaluation by test of key high power components.

The advanced, alkali metal Rankine program is aimed at achieving low power system weights for power in the hundreds of kilowatts to the few megawatts. Eventual applications are for very high power near-earth and electric propulsion planetary exploration missions. The development approach is based on proceeding through progressive development phases which will eventually lead to the test of a complete power conversion system with a reactor. Currently, the program is aimed at developing a sound component technology base.

In FY 1970, 1700 hours were accumulated on a reworked three-stage potassium vapor turbine operating at 1500°F in further investigations of blade erosion. 3000 hours of endurance test of an 1100°F potassium electromagnetic boiler feed pump has been achieved without indications of difficulty. A 3-loop boiler/tube facility is nearing completion, and initial design studies of a potassium vapor turboalternator and reactor loop electromagnetic pump have been completed. Testing of the boiler feed pump and the 3-stage turbine will be continued through FY 1970.

In FY 1971, the major emphasis will be placed on turbine and boiler related experimental investigations necessary to support subsequent fullscale component final designs. Support material and alloy technology investigations will be continued.

Work aimed at developing the technology of thermionic reactor systems continued to make progress during FY 1970. Important results have been obtained in all areas of work outlined in the FY 1970 budget request. These include: (1) analytical reactor and electric propelled spacecraft studies of a system suitable for a Jupiter orbiter mission; (2) completion of two long-term thermionic fuel in-pile tests at the NASA Plum Brook Reactor; (3) a thermionic diode kinetics experiment at the Jet Propulsion Laboratory to study fast thermionic reactor system dynamics and control; and, (4) out-of-pile tests on the redistribution and venting of uranium oxide fueled capsules.

These problem solving efforts will continue in FY 1971 with major emphasis on fuel/emitter technology and an investigation of the uninsulated externally-fueled diode concept. The NASA program assists the National Thermionic Technology program being undertaken by the AEC.

Two SNAP-19 radioisotope thermoelectric generator (RTG) power units supplied to NASA by the AEC were launched aboard the Nimbus B2 on April 14, 1969, as an experiment to demonstrate feasibility and to investigate RTG/spacecraft integration and operational problems. While the RTG performance was satisfactory for the purposes of this mission, differences have been observed between the performance of the isotope fueled units in space and electrically heated units operated in ground vacuum tanks. Studies are in progress to identify the reasons for the observed differences in performance.

An AEC developed and furnished SNAP-27 RTG power source for the lunar surface experiment package (ALSEP) was placed on the moon during the Apollo 12 mission. Performance to date has been as predicted and satisfactory.

Plans to use SNAP-27 RTG's on the Apollo 13, 14 and 15 missions remain firm. Use of improved SNAP-27 units for subsequent Apollo missions is being evaluated by the AEC and NASA.

NASA's Office of Space Science and Applications has selected RTG's to power the Pioneer F and G missions and the Viking Mars Lander. Arrangements have been made to obtain suitable units through the AEC. Several required experiments to define RTG/spacecraft interactions in these missions were identified.

During FY 1971 work will be continued to identify and resolve RTG/spacecraft interactions and operational problems, and will continue testing of RTG's for stability and long-term reliability.

An urgently needed facility for this work is the Isotope Thermoelectric Systems Applications Laboratory, described under the FY 1971 construction of facilities request. This facility is essential to the accomplishment of work vital to the integration of radioisotope thermoelectric generators with scientific instruments and other spacecraft subsystems for future missions to the outer planets.

Solar Power Generation

Goals of the Solar Power System program continue to be (1) investigation of methods for compact stowage and reliable, automatic deployment of large area, lightweight solar cell arrays; (2) adaptation of such arrays to the requirements for manned space station power; (3) understanding the structural and flight dynamic interactions of large, flexible solar cell arrays with guidance, control and propulsion subsystems; (4) development of reliable, long life mechanical drive mechanisms for large solar cell arrays; (5) development of solar cell array designs for application to spacecraft flights on Venus-Mercury flybys, solar probes, Mars landers and Jupiter flybys and orbiters; (6) substantial improvement in the resistance of solar cells to degradation in the space radiation environment; (7) better metal-to-silicon contacts needed to withstand new extremes of temperature and thermal cycling; and (8) new solar cells having greatly improved efficiency and reduced cost.

Fabrication of a 250 square foot (2.5KW) engineering model of a flexible rollup solar cell array is scheduled for completion early in FY 1971. The goal of 30 watts per pound for this array segment is expected to be achieved for planetary spacecraft applications. For manned applications, especially for a manned space station, this unmanned solar array technology will require adaptation to withstand the more severe dynamic interactions with the vehicle during shuttle docking, orbit changes and attitude maneuvers. These mechanical loads are estimated to be an order of magnitude more severe than for the present unmanned planetary application. Thermal cycling will be more extreme and the number of cycles several orders of magnitude greater.

Preliminary studies have indicated that a high voltage power distribution system offers important advantages over conventional low voltage systems for large applications satellites and space stations. Methods are being developed for obtaining high voltages directly from solar arrays with voltage regulation devices mounted integral to the array. A high voltage, self-regulating array should improve reliability and minimize heat loads and power conditioning inefficiency. Work will continue on the effect of ionized particle radiation on solar cells at temperature and solar illumination levels encountered out to the planet Jupiter. Preliminary findings suggest that the near earth superiority of N on P silicon solar cells is no longer valid at the Jupiter orbit conditions of temperature and solar intensity. Under these far from the sun conditions, P on N type doping appears to offer superior radiation resistance. These results were unexpected and will be investigated further in FY 1971. Work will continue in FY 1971 on the lithium doped solar cell to determine its potential radiation resistance and efficiency advantages for use in earth orbit. Work will continue on thin film cadmium sulfide cells which have the potential of reduced cost and compact stowage, providing environmental instability problems can be solved and the efficiency increased substantially.

Chemical Power Generation

The Chemical Power Generation program is aimed at achieving a new technological plateau for batteries, fuel cells and engine generator systems. Batteries are required that are reliable, exhibit a high energy/weight ratio, and fulfill the specific requirements of the various missions, such as long cycle life, long shelf life, high power density, operability at extreme temperatures, or sterilizability. Almost every launch vehicle and spacecraft requires one or more batteries, e.g., the Saturn V/Apollo uses 24 batteries. Traditional materials and methods of manufacture for rechargeable space fuel cells and batteries are being investigated with a view toward improving quality control and upgrading the electrodes that go into nickel oxide/cadmium cells. Life testing of rechargeable batteries under this program has already revealed some of the wearout modes of long-lived cells. These tests have indicated the need for improved separators and more closely controlled pore-size distributions in electrodes in order to function for years in space. Useful as the past tests have been, these results have also highlighted short comings and revealed that more carefully chosen test procedures could result in more useful data from future test efforts. Work is almost complete on defining an improved test procedure with a three-fold purpose (1) it shall be an accelerated, nondestructive test, consuming at most 1 percent of the cell's useful life; (2) it shall permit prediction of cell life with a high degree of confidence; (3) it shall be useable (or modifiable for use) by any spacecraft engineer, so he can pick and match cells for his spacecraft batteries.

A limited technological capability is expected to be in hand by the end of FY 1970 for: (1) heat sterilizable, impact resistant, small primary silver oxide/zinc cells; (2) rechargeable silver oxide/zinc cells; and, (3) nickel oxide/cadmium cells. In FY 1971, efforts to further improve these

capabilities will continue and emphasis will be placed on the complete battery (a series group of cells) and battery monitoring and control electronics. Remote activation of batteries, as well as batteries capable of long-life under wet storage conditions, is being studied; batteries for planetary orbiters are being designed and battery control logic is being developed to obtain more information per channel, to aid in controlling the battery, and to bypass faulty cells.

The space shuttle has re-emphasized the need for fuel cells, so that the current modest level of effort on relatively basic electrochemistry and engineering is being increased to meet the anticipated shuttle needs. Foremost among these is a long-lived, maintenance free system. A promising candidate is the capillary matrix type fuel cell. With further improvements this system has a potential to meet the ruggedness, versatility, and potential longevity required by shuttle missions. A program will be initiated in late FY 1970 for major engineering improvements in such capillary matrix systems.

Substantial quantities of electrical and hydraulic power will be required to operate the flight systems on shuttle vehicles. This year, an in-house study effort at the Lewis Research Center has been initiated to identify the peak power needs, such as for control surfaces, jet engine deployment, etc., for the shuttle, and to define promising chemically-powered auxiliary power units (ADU's) to meet these needs.

During FY 1971, a combined in-house and contract effort will be conducted to study specific APU configurations, develop preliminary designs, identify technology problem areas and initiate component procurement for development testing.

Power Processing and Distribution

The highest capacity space electrical power system flown to date is rated only about four kilowatts and the longest mission duration previously demonstrated for any man-rated spacecraft is less than one month. This compares to an electrical power level of 25-100 kilowatts estimated for space station/base applications and operating life times of 5-10 years for both station/base and shuttle. The shuttle imposes additional constraints of weight sensitivity, onboard checkout and automatic inflight monitoring, not possible within existing power processing and distribution technology. In addition, an important early objective is to identify electrical power processing and distribution concepts permitting the fullest possible degree of commonality between shuttle and station/base.

Solid state distribution systems, circuits and devices require further investigation and development to extend the technology to meet the needs of the shuttle and station/base. Work will be increased in electrical fault identification, isolation and energy management, with an objective of onboard electrical system checkout and automatic inflight monitoring--primary operating characteristics sought for the space shuttle. This necessitates a continuation of analytical and experimental work to identify, measure and control

the thermal, electrostatic and other stresses which induce failure in power processing components and circuits. A developmental wide-band wattmeter resulting from earlier work under this program has proven to be a very useful diagnostic instrument for this purpose.

Ongoing work will be continued in the specialized areas of power processing for use with isotope-fueled thermoelectric generators (goal is unattended life of 12 years or more) and for use in electric propulsion applications (goal is a weight of one kilogram per kilowatt or less). The usefulness of the previously developed standardized multi-purpose control module for power processors, is being fully verified through application to both of these programs.

Space Electric Rocket Test (SERT)

	1969	1970	1971
Spacecraft and experiment development.....	$1,500,000	$500,000	$275,000
Agena (Launch Vehicle Procurement Program).....	(794,000)	(150,000)	(---)
Total (including launch vehicle).....	$(2,294,000)	$(650,000)	$(275,000)

The objective of SERT II, the second flight in the SERT series, is the verification of long-term ion thruster performance in space. SERT I, a sub-orbital flight, launched in July 1964, proved the basic feasibility of ion propulsion.

The SERT II spacecraft is to be launched in the first quarter of CY 1970 from the Western Test Range into a near polar sunlit orbit by a Thorad-Agena. Primary power from a 1.5KW solar array will be used to sequentially power two 1kw thrusters. The major goal is to accumulate 6 months operation on one of these thrusters. Experiments aimed at evaluating the interactions between the electric propulsion system and spacecraft are also carried. This flight is considered to be the next major step in primary electric propulsion.

The launch date was changed from CY 1969 to the first quarter of CY 1970 to allow additional testing of the power conditioner and thruster. The expected long-duration operation of the spacecraft will require FY 1971 funding for data analysis.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY NUCLEAR ROCKETS PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The overall aim of the Nuclear Rockets program is to provide a significant increase in propulsion capability for future space activities. The principal objective is to develop a 75,000 pound thrust engine, NERVA, for incorporation in a reusable nuclear stage. Apart from NERVA development, the program includes certain supporting research and technology activities. The objectives of these activities are: (1) to provide support to the NERVA engine design and 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 payloads, specific impulse becomes an extremely important performance requirement. The first generation nuclear rocket engine, NERVA, on which work is now underway will provide approximately twice the specific impulse of the best chemical rockets. As an integral part of a new capability for space transportation, this engine incorporated in a reusable nuclear stage can be used to move men, spacecraft and supplies between earth orbit and lunar orbit and between low earth orbit and geosynchronous orbit. It also offers major advantages for transporting heavy payloads into deep space. The increased propulsion energy it makes available can be used for any of a variety of purposes in such missions, e.g., to increase payloads, to reduce trip times and to provide greater reliability for the completion of the mission.

Development of the NERVA engine is being accomplished using a base of technology which took nearly fifteen years of extensive analytical and experimental research to acquire. Through this technology phase, the important aspects of nuclear rocket operation required to develop a flight engine were investigated. This work has now been completed, and all technology goals have been met. In the course of this research, twelve reactors and engines were tested, from which more than fourteen hours of power operating experience were obtained. Approximately four hours of this experience was at high power. In addition to the valuable experience obtained in operating nuclear rocket reactors, engines, and facilities, these tests provided a preliminary assessment of the more obvious needs of a nuclear rocket system, e.g., rapid startup, shielding, liquid hydrogen propellant, high power density, long endurance and self-energized startups (bootstrapping).

The NERVA engine is being designed as a throttleable, restartable, and reusable system so that it can be applied to a "shuttle" stage. The engine is being designed so that any improvements in reactor fuel element capability, and thereby in lifetime, which are the result of the continuing AEC research and technology program, can be incorporated.

The NERVA engine will be approximately 34 feet in length from the bottom of the propellant tank to the exit plane of the nozzle. Its largest diameter will be approximately 10 feet. The engine reactor will have a rating of 1,500 megawatts. Engine weight will be approximately 20,000 pounds, including a shield weight of approximately 3,000 pounds. For certain missions, additional shielding may be required, depending upon the design of the payload and the command module structure. Engine performance goals are as follows:

Thrust	75,000 pounds
Specific Impulse	825 seconds
Endurance	Up to 10 hours
Operating Cycles	Up to 60 cycles

The primary function of NERVA will be to power a reusable nuclear stage. This stage is being studied in the conceptual design phase by several contractors under the supervision of the Marshall Space Flight Center. Both engine and stage will be man rated, have an extended endurance capability, and include maintainability features. The stage will be able to be used over a period of years in space.

SUMMARY OF RESOURCES REQUIREMENTS:

	1969	1970	1971
Supporting research and technology	$6,002,000	$8,000,000	$5,000,000
NERVA	23,000,000	27,085,000	32,000,000
NRDS operations	4,500,000	1,415,000	1,000,000
Total	$33,502,000	$36,500,000	$38,000,000

Distribution of Program Amount by Installation:

Marshall Space Flight Center	$860,000	$1,575,000	$1,600,000
Lewis Research Center	1,145,000	1,000,000	800,000
Space Nuclear Propulsion Office	31,497,000	33,925,000	35,600,000

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BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

	1969	1970	1971
Rocket reactor research.....	$3,751,000	$3,300,000	$1,500,000
Nuclear rocket engine systems.	1,236,000	2,900,000	1,700,000
Safety.....	15,000	200,000	200,000
Vehicle technology.....	1,000,000	1,600,000	1,600,000
Total.....	$6,002,000	$8,000,000	$5,000,000

Rocket Reactor Research

The funding in this portion of the program supports: (1) the research and testing of nonreactor components for reactor testing (nozzles, turbopumps, controls, etc.) including the propellants necessary for experimental analyses; and (2) the investigation of advanced concepts and design studies of reactors for future application.

A significant portion of the funds applied in this area are used to provide propellant and nonnuclear components, such as propellant feed systems, for the Los Alamos Scientific Laboratory series of PEWEE and nuclear furnace test bed reactors. The second PEWEE reactor is scheduled for testing in the autumn of 1970. The first nuclear furnace is scheduled for testing in the winter of 1971.

While the NERVA class of nuclear rocket is clearly the first type of nuclear rocket which will be used, exploratory research will continue in FY 1971 on advanced nuclear propulsion concepts, such as gas core reactors, which have theoretical performance capabilities more than twice that of the solid core NERVA type reactors. These reactors, if shown to be feasible, would operate with the nuclear fuel in a gaseous state and would transfer thermal energy from the ultra high temperature uranium plasma to the propellant, by thermal radiation. Therefore, the research emphasis will be placed on determining the high temperature behavior of materials and fluid dynamic systems, and in improving the radiant heat transfer to seeded propellant streams.

Nuclear Rocket Engine Systems

The research conducted in this area provides information for specifying characteristics for improved nuclear rockets as well as establishing a general base of information on the design and operation of components and engines. Therefore, the FY 1971 research will continue to be directed toward the enhancement of the basic design reliability of selected components of a nuclear rocket engine such as the nozzle, turbopump, valves, actuators and

instrumentation. Specifically, work on nozzle coatings, nozzle skirts, and rotor dynamics are typical of the types of activities to be supported.

Other important efforts are directed toward improved instrumentation, fluidic control system components and the analysis of engine transients. Effort is also conducted on the effects of radiation on nuclear engine components, materials and systems. The purpose of this work is to define the behavior of materials in a combined radiation and cryogenic environment. Such information supports all Nuclear Rockets program activities and is essential for the design effort.

Safety

The effort in this area is directed toward the base of knowledge required to define and resolve the new and unique safety problems associated with nuclear rocket propulsion system development. While most of this information stems from the mainstream activities of the Nuclear Rockets program, certain specially directed research and analysis must be conducted outside of these disciplines. Work in progress or planned for FY 1971 will be directed toward identification of the nuclear flight system safety requirements and will include information on the safety requirements originating from operations and interactions with other systems (nonnuclear) during a typical mission. For example, blind spots in the tracking network (if any) would be identified, and their effects on the nuclear flight system safety requirements would be analyzed.

Vehicle Technology

A twofold approach is being followed in the vehicle technology area -- provision of technical information to support a design of a nuclear stage; and conceptual/feasibility studies of nuclear stages for a variety of applications, with primary emphasis on earth and lunar orbit ferry activities.

A continuing technology program has been underway at Marshall Space Flight Center for a number of years, concentrating mainly on radiation effects testing and propellant heating analyses and experiments. These investigations will be continued to extend the operating time capabilities of the nuclear stage, i.e., a stage lifetime which includes exposure to full power engine radiation for at least 10 hours.

The conceptual/feasibility studies are continuing, extending the results of previous years' activity, to include the effects of longer operating times. Examination will be made of orbital maintainability concepts, and a minimum cost development, manufacturing and test program based on first flight in the late 1970's.

NERVA

	1969	1970	1971
Engine system component and subsystem	$11,501,133	$16,728,000	$24,900,000
Ground test and operations support	10,896,867	9,223,000	5,700,000
Propellants	602,000	1,134,000	1,400,000
Total	$23,000,000	$27,085,000	$32,000,000

Engine System Development

During FY 1971, specifications for all of the engine components will be completed, and the preliminary design review of the engine system and components will be conducted. This will involve engine system analyses, engineering and design which will be a continuing part of the development of the NERVA engine.

Component and Subsystem Development

The following is representative of the work that will be accomplished in this area:

1. Reactor subsystem: This effort is largely funded by the AEC and will be carried out by the Westinghouse Astronuclear Laboratory. During FY 1971, work will be concentrated on selected long lead items, including full scale reactor test hardware. Development of control drum actuators also will be continued during the fiscal year.

2. Turbopump assembly: The detailed design, fabrication and testing of the development hardware for this assembly will be continued during FY 1971. The emphasis in this area will be on the development of turbopump bearings to satisfy the 10 hour NERVA performance objective, and the design and analysis of the pump impeller and turbine disc.

3. Thrust chamber assembly: The basis for the design of the NERVA nozzle is the regeneratively cooled, U-tube nozzle development under the NERVA technology phase. Materials research conducted under the SR&T program also supports this effort. During FY 1971, the preliminary design review of the nozzle will be completed, and the detailed design, fabrication and development testing of critical nozzle parts, e.g., tubes, nozzle shells, will be initiated. Design activities associated with the nozzle extension and graphite nozzle skirt will also be initiated.

4. Lines, valves and actuators: The design of lines, valves and actuators for the NERVA engine will be continued in FY 1971. Line sizes will be

optimized with respect to pressure losses and weight. Valves for operation in the radiation environment, e.g., check valves, blocking valves, bypass valves and the main propellant shutoff valve, will be selected for their ability to function over an extended, multicycle engine operating life. The preliminary design review of these components will be conducted, and long lead hardware procurement will be initiated. The actuators for these valves will also undergo similar design and development.

5. Thrust structure and attitude control: During FY 1971, the design of thrust structure and attitude control components (gimbal, actuators, bellows, etc.) will be continued and the preliminary design review will be conducted.

6. Engine system control: The FY 1971 activity in this area will include the design, test and evaluation of instrumentation and controls for the NERVA engine control system. This effort will be based on information from the XE ground experimental test program, LASL, Phoebus and PEWEE reactor programs and laboratory analyses of subsystems and components evaluated under SR&T programs.

Ground Test Operations and Support

The funding in this area provides for: continuation of the design and modification of ETS-1 for the development testing of the NERVA engine; continuation of the design and modification of GSE for the handling, check-out and maintenance of NERVA engine hardware at the Nuclear Rocket Development Station (NRDS); and the operational support necessary to continue NERVA component test activities at NRDS.

Propellants

Funding provided under this heading will be used primarily for the procurement of liquid hydrogen and liquid nitrogen for use in the turbopump bearing test program, and for actuator development and engine simulation tests at NRDS.

Nuclear Rocket Development Station Operations

	1969	1970	1971
General site support.....	$4,492,495	$1,412,000	$995,000
Capital equipment.....	7,505	3,000	5,000
Total.....	$4,500,000	$1,415,000	$1,000,000

This estimate provides for NASA's share of the cost of general support and station operations for the Nuclear Rocket Development Station. NRDS is the national site for the ground static testing of nuclear rocket reactors and

engines. Eventually, it will be used to test the propulsion modules or rocket stages. Overall management of the site is provided by the AEC/NASA Space Nuclear Propulsion Office-Nevada Extension.

The major reactor test activities to be conducted at NRDS during FY 1971 are the PEWEE-2 and nuclear furnace test programs. In addition, NERVA component testing will continue.

Maintenance, housekeeping, and management functions must be provided at the site. These functions, taken together, constitute general site support. They include routine maintenance and operation of site facilities, e.g., custodial services; maintenance of roads, grounds and utility systems; the furnishing of utilities; fire protection; and cafeteria services. Also included are the services of a support contractor to maintain and operate electrical, plumbing, carpenter, welding and machine shops.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY — CHEMICAL PROPULSION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The Chemical Propulsion program is designed to provide the engineering theory and experimental data on which new and advanced propulsion capabilities necessary to support the nation's space goals can be projected. The program includes: (1) identification of future mission propulsion requirements, (2) research in fundamental propulsion concepts to meet the requirements, (3) studies of principal design parameters, (4) investigation of key design problems with a view to sound technical solutions, (5) development of experimental design, fabrication, and test techniques, (6) testing of component designs and demonstrations of experimental engines and motors, and (7) evaluation of concepts and technical verification of capability to accomplish mission requirements. This effort is a precursor to actual system development.

Research and experimental work is conducted on two principal types of propulsion: systems using propellants in liquid form, and motors which use cast solid propellants. Thrust levels range from millipounds, used in attitude stabilization of spacecraft, to millions of pounds for first stage booster application. The goals of the future space program demand extension of both the performance and long service life of propulsion systems, and these must not jeopardize reliability of the operational system.

Propulsion processes, performance improvements, combustion, engine design, engine materials and fabrication technology are major categories of active research. Propellant properties, gas dynamics, heat transfer, fluid and solid mechanics, elastic properties, and chemical reaction are studied, both theoretically and experimentally, in their relationship to chemical propulsion. Basic theory and experimental findings are supported by complementary demonstrations to establish the validity and practicality of the propulsion systems concepts generated by the program.

The technical projects under the Chemical Propulsion program are managed by NASA field centers and the Jet Propulsion Laboratory (JPL), using in-house research and engineering personnel and unique equipment available at these facilities. Their work is supplemented by contracted work with several industrial and university groups specializing in the fields that apply to chemical propulsion research and technology development.

The information developed by these efforts is published as NASA technical reports or in contractually required reports available at major technical libraries and through government publishing services. It is also discussed

at technical meetings sponsored by professional organizations and by JANNAF (Joint Army, Navy, NASA, Air Force) Chemical Propulsion Group. These presentations are usually published in technical journals. Coordination of the program with Department of Defense agencies is carried out formally through the Aeronautics and Astronautics Coordination Board and through JANNAF, and informally by frequent information exchanges.

SUMMARY OF RESOURCES REQUIREMENTS:

	1969	1970	1971
Supporting research and technology.....	$25,752,000	$20,480,000	$20,300,000
Total.....	$25,752,000	$20,480,000	$20,300,000

Distribution of Program Amount by Installation:

Manned Spacecraft Center.....	$790,000	$970,000	$1,650,000
Marshall Space Flight Center...	2,850,000	1,510,000	2,720,000
Goddard Space Flight Center....	210,000	50,000	---
Jet Propulsion Laboratory.....	4,552,000	4,357,000	3,800,000
Langley Research Center.....	2,310,000	1,295,000	800,000
Lewis Research Center.....	10,843,000	8,629,000	9,205,000
NASA Headquarters.....	1,005,000	1,061,000	590,000
NASA Pasadena Office.....	3,192,000	2,608,000	1,535,000

BASIS OF FUND REQUIREMENTS:

Supporting Research and Technology

Liquid rocket research and advanced technology.....	$10,790,000	$8,637,000	$5,565,000
Liquid rocket experimental engineering.....	5,501,000	7,195,000	11,275,000
Solid propulsion research and advanced technology.....	4,394,000	2,971,000	2,725,000
Solid rocket experimental engineering.....	5,067,000	1,677,000	735,000
Total.....	$25,752,000	$20,480,000	$20,300,000

Liquid Rocket Research and Advanced Technology

The Liquid Rocket Research and Advanced Technology project is directed toward propulsion requirements consistent with future space program goals. The program in applied research includes key component technology, advancement in reliability of components, their space operation, and improved capability

in engineering data and disciplines pertinent to this work. It covers research into combustion, hydraulics, mechanics, and materials fabrication. Roughly one-third of this work is conducted under contract with industry and with universities.

The effort on component reliability responds to problems of operating space station components for periods of years, and of flying unmanned spacecraft for flights of over ten years. Future unmanned propulsion systems designed for these long durations require new methods of accelerated meaningful testing. Manned vehicle problems will focus on design of components for easy refurbishment from within the spacecraft, with emphasis on facilitating onboard checkout.

Space operation of components is an allied field. To avoid future operational problems we are investigating space ignition, venting, and similar problems with the high energy propellants that can fulfill our future mission requirements.

Supporting technology effort for the shuttle vehicle engines will also be conducted under this project. This effort will include clarification of the role of high speed turbopump inducers in "Pogo-type" low frequency instability, injector improvements and thrust chamber heat transfer improvements to obtain maximum performance, and improved design criteria for reliability of large cryogenic valves. Some of this effort will involve the large engine verification of design parameters derived on smaller engines such as those for acoustic absorbers to control high frequency instability.

Work on engineering problems such as combustion, ignition, injection, combustion stability and heat transfer continue to make steady progress. Significant progress has been made in designing acoustic liners for controlling combustion stability. Parameters affecting transpiration cooling are better defined.

A specific thrust of 508 seconds was measured in an altitude facility with the high energy tripropellant system, lithium-fluorine-hydrogen. This is the highest chemical rocket performance ever recorded, to our knowledge. Further work on tripropellants will be held in abeyance until funding is available and a suitable mission has been identified.

Liquid Rocket Experimental Engineering

The Liquid Rocket Experimental Engineering project has been established to translate the improved components from the Research and Advanced Technology project into working systems. Drawing on mission studies and prior development experience, advanced propulsion systems are defined, fabricated, and then tested over a wide range of operating conditions. New or unanticipated problems or limitations are frequently identified during these tests which require additional work at the component level. In addition such tests

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identify real performance potential, define operating limits, assess design and fabrication methods and give an insight into probable schedule, cost, and facility requirements of a potential hardware development program. Performing these services without the inherent pressures in a schedule-oriented hardware development program is very efficient.

Launch Vehicle Propulsion Systems - A significant part of the Chemical Propulsion budget for FY 1971 is identified with a reusable space transportation system. It consists of several vehicles which provide routine transportation of men, materials, and experimental hardware to orbit around the earth and to the surface of the moon. The first link in this chain, the Earth-to-Orbit Shuttle is conceived as a two stage launch vehicle which would be launched to orbit vertically like a rocket and return to earth by accomplishing a horizontal landing on conventional airfields.

Main Engines - In such an application, where the true payload or cargo is a relatively small fraction of the total weight placed in orbit, engine performance becomes an overriding consideration. The performance of the J-2 engine which is used in the SIVB and SII stages of Saturn V, is totally inadequate for the shuttle vehicles. Fortunately, the work on the high pressure engine which has been pursued in previous years, provides the basis for confidence that the required engine performance can be obtained.

The most recent high performance engine program carried through to production was initiated in 1960. Meanwhile the state-of-the-art for hydrogen-oxygen engines has been considerably advanced by technology contracts in the disciplines of combustion stability, advanced fabrication techniques, and experimental hardware work with turbopumps and combustion chambers. The task of developing a new engine which meets the performance and weight requirements of the shuttle and which has the operational flexibility and long life desired will benefit from an early start and a sustained high level of effort. Detailed design of several conceptual approaches will be carried out in competitive contracts funded by the Office of Manned Space Flight. Supporting technology effort will be conducted under the Chemical Propulsion program.

In addition work will continue at a modest pace on future propulsion systems. In particular, advanced fabrication methods will be used to build segments of a very large thrust chamber which promises to sustain high performance at relatively low development and procurement cost.

Space Propulsion Systems - Development of advanced space storable propellants will allow significantly higher payloads when used on upper stages of existing launch vehicles. The high performance potential demonstrated in the last year, along with high density and other desirable physical characteristics, makes these propellants attractive for planetary orbiters, landers, ascent vehicles, and earth return stages.

Work directed toward assembly of propulsion modules, including engines, tankage and control systems, is underway for both the oxygen difluoride-diborane and mixed fluorine-oxygen (FLOX) and methane propellant combinations. These two efforts are complementary, inasmuch as the pressure fed oxygen difluoride-diborane combination optimizes at a small size (1000 pounds thrust) and the pump fed FLOX-methane combination optimizes at larger sizes (more than 5000 pounds thrust). Complete propulsion systems will be tested in existing facilities which allow simulation of the space environment.

Auxiliary Propulsion - In addition to the small thrust requirements for attitude control of orbiting and planetary spacecraft, auxiliary propulsion requirements of the space shuttle vehicle have been shown to involve a number of very large thrusters. In order to simplify logistics problems and increase commonality, hydrogen-oxygen has been chosen as the propellant combination for both maneuvering propulsion and attitude control of booster and orbiter.

The problems with the auxiliary propulsion system of the shuttle are not in the thruster development but in the layout of the system itself. A large number of individual thrusters, approximately 40, must be supplied with cryogenic propellants carried to the extremities of the vehicle system. These thrusters must be capable of providing brief thrust pulses for attitude control and docking of the shuttle with a space station. They must also provide substantial changes in vehicle velocity, which requires long burning duration, in order to effect rendezvous, adjust orbital plane or altitude, and accomplish retro-orbit and reentry maneuvers.

System layouts to define the system characteristics have been undertaken by the Chemical Propulsion program. These studies along with hardware experimentation have the purpose of defining an adequate system in terms of system weight, redundancy, life, ease of refurbishment, and initial cost. Such work will be continued intensively.

Technology efforts in the field of cryogenic pressure vessels, valves, controls, insulation, pressurization systems, heat exchangers and thrusters will be supported. Several fundamental choices - between low pressure and high pressure systems for instance - will have to be made early in the overall layout of the shuttle vehicles.

Work will continue to demonstrate reliability and operational life of monopropellant and earth storable bipropellant auxiliary propulsion systems.

Solid Propulsion Research and Advanced Technology

The principal goal of the Solid Propulsion Research and Advanced Technology project during the next several years is to insure the proper utilization of solid propellant motors in the space environment. For some applications the use of solid propellant motors is exceptionally attractive because of their compactness and their relatively low development cost and short development schedules.

Emphasis will be placed on improving the technology base for variable thrust motors; for long burn time, low acceleration motors; for sterilizable systems; for wide temperature range capability; and for ten year storage life in space.

Major improvements in nozzles for hotter propellants, long duration motors and restartable systems are needed. Liner and insulation materials for new propellants will be studied.

Structural composite materials, insulating polymers and fuel polymers need improved polydirectional strength and better characterization to predict their behavior over long durations in space. Propellant development emphasis will be on binder development, processing and handling of more energetic systems, and mission suitability. Also required are lower rate propellants that do not sacrifice performance. These are important for planetary spacecraft application.

Combustion and kinetics research will be directed to better data on flame structures and processes, and on improved modeling to make the information available in a form useful to the design engineer.

Solid propellant application to emergency systems and ancillary applications--gas generation, auxiliary or emergency power generation, welding, and metal cutting, antenna and experiment deployment devices, and emergency jettisoning will be given attention.

Solid Rocket Experimental Engineering

This effort includes the advanced technology and vehicle systems technology necessary to bring solid motors to a point where enough data is available to allow development for specific missions.

The primary effort in FY 1971 will be toward improved planetary propulsion technology. The high energy restartable motor which was initiated last year will be continued to prove out the details of re-igniting a water quenched motor and then quenching it a second time. The program will be aimed toward a firing with a high expansion ratio nozzle at a simulated altitude facility. This motor, weighing 3,000 pounds with a 15,000 pound thrust level, will develop 10% more specific impulse than the solid motors currently being used in the spacecraft. The quench and restart capability should allow this motor a coast period to a higher altitude before re-ignition, thereby eliminating the need for an additional stage. These features are valuable to future spacecraft propulsion systems.

Another spacecraft propulsion system currently in prototype testing is the low thrust-to-weight, long burning system. This motor will be used in spacecraft that have deployed experiments and therefore are sensitive to acceleration. Technology advances are required to prove that high energy propellants can be burned efficiently at very low rates and at low combustion

pressure. The nozzles must be developed to withstand the high flame temperature for three or four minute burning duration. Typical of near-space system technology is the work to support efficient, low cost sounding rockets. A program has been started to test a prototype model of a dual thrust, single stage sounding rocket capable of boosting 250 pound payloads to altitudes of 230 statute miles. This system employs prior technology advances in nozzles, propellant, and case fabrication techniques. It will replace two stage systems. Such motors should be of value to the solar physics and astronomy experimenters.

Electro-explosives (pyrotechnic) devices are used extensively in almost all manned and unmanned flight programs. A part of this program is to improve their long term, severe environment reliability for future flight programs.

OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY AERONAUTICAL VEHICLES PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The role of the Aeronautical Vehicles program is to provide leadership in the application of principles developed in basic research programs for improvements in safety, efficiency and utility of all classes of military and civil aircraft. In order to provide this leadership necessary for the United States to retain its pre-eminent position in aeronautics, the NASA conducts a very broad program aimed at the application of vehicle oriented disciplinary technologies of aircraft aerodynamics, aircraft loads and structures, aircraft propulsion, operating environment problems and aircraft flight dynamics to the following classes of vehicles: general aviation aircraft, V/STOL aircraft, subsonic aircraft, supersonic aircraft and hypersonic aircraft - both civil and military. In the Advanced Research program, the disciplinary technologies are not focused on any one specific class of vehicle whereas in the Vehicle Technology program these disciplinary approaches are focused on specific vehicles. To further reinforce the research and to assist in ferreting out problems which may be overlooked or not evident in analytical and small scale experimental approaches, emphasis is placed, as required, on flight test programs and proof-of-concept or large scale experimental hardware evaluations. This combined disciplinary and experimental hardware approach provides the advanced data which may be applied by the aircraft industry and government agencies to the development of safer and superior civil aircraft, advanced aircraft concepts, regulatory criteria, new operational concepts and the integration of the pilot/aircraft system into the total air transportation network.

As has been noted in previous program justifications the XV-5A fan-in-wing aircraft, the tilt-wing XC-142A V/STOL transport and the variable-sweep wing F-111 are examples of promising NASA research concepts developed by the military into operational vehicles. In the recent past, the NASA has mounted a concerted effort to solve the aircraft noise problem and has provided the government and the aircraft industry with the background information necessary for aircraft steep approaches, optimized take-off and landing profiles and noise alleviation for four engine commercial transport aircraft, as well as the technology for quiet military helicopters and observation aircraft. Other promising major NASA aeronautical vehicles research programs now in progress and scheduled for continuation into FY 1971 include flight tests of a supercritical wing for improved performance and maneuverability, the design and construction of a quiet, experimental research engine, a rotating-cylinder flap system for improving the STOL performance of propeller driven aircraft and a jet-augmentor wing concept for jet powered STOL aircraft.

The total program 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 and civil aircraft procurements and in response to requests 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.

The aeronautical vehicles technology programs for FY 1971 will include the continuation of studies to improve the safety of general aviation aircraft, studies of lightweight propulsion systems and advanced propulsion concepts for STOL aircraft; studies of advanced rotors for helicopters and rotor-driven V/STOL's; continuation of quiet engine research into experimental hardware phases; studies of airbreathing propulsion systems and their integration and dynamic problems for application to supersonic and hypersonic aircraft, and flight dynamics studies for each class of vehicle to insure increased compatibility of the pilot-vehicle system, including terminal area and all-weather operations.

Experimental research and development aircraft and engineering test-pilot proficiency aircraft necessary to carry out and support the total aeronautics effort are included in this program.

SUMMARY OF RESOURCES REQUIREMENTS:

	1969	1970	1971
Advanced research.....	$16,857,000	$31,005,000	$31,565,000
General aviation aircraft technology.....	507,000	950,000	925,000
V/STOL aircraft technology.....	8,060,000	9,560,000	15,030,000
Subsonic aircraft technology.....	19,291,000	9,425,000	11,900,000
Supersonic aircraft technology....	20,348,000	18,900,000	21,905,000
Hypersonic aircraft technology....	9,685,000	6,060,000	5,775,000
Total.....	$74,748,000	$75,900,000	$87,100,000

Distribution of Program Amount by Installation:

Marshall Space Flight Center....	$445,000	$1,225,000	$900,000
Jet Propulsion Laboratory.....	---	181,000	200,000
Ames Research Center.....	10,100,000	13,810,000	17,580,000
Electronics Research Center.....	---	200,000	---
Flight Research Center.....	12,220,000	7,800,000	10,465,000
Langley Research Center.....	27,460,000	23,167,000	27,135,000
Lewis Research Center.....	22,145,000	26,630,000	28,770,000
NASA Headquarters.....	2,378,000	2,887,000	2,050,000

BASIS OF FUND REQUIREMENTS:

Advanced Research

	1969	1970	1971
Aircraft aerodynamics.....	$2,461,000	$2,190,000	$2,350,000
Aircraft loads and structures.....	1,403,000	3,110,000	4,380,000
Air breathing propulsion.....	3,466,000	3,515,000	2,800,000
Aircraft operating environment....	3,373,000	6,057,000	6,205,000
Aircraft flight dynamics.....	1,456,000	830,000	1,310,000
Support of facilities and aircraft	4,698,000	15,303,000	14,520,000
Total.....	$16,857,000	$31,005,000	$31,565,000

Aircraft Aerodynamics

Advanced research information and techniques are required for better predicting and improving the aerodynamic characteristics of various aircraft types. A continuing in-house and contract activity is carried out, not only for achieving aerodynamic refinement of conventional airframes, but also for fostering advanced aerodynamic concepts leading to revolutionary aeronautical vehicles. The scope of the work includes critical investigation of the shock wave flow fields generated by supersonic lifting wings and wing-body combinations, of their propagation from the source through the atmosphere, and of minimizing their effects (sonic boom) on the earth.

Theoretical and experimental aerodynamic investigations of components and research combinations will be made throughout the speed range for useful atmospheric flight. Studies will be continued of subsonic and supersonic boundary layers, boundary layer separation on complex shapes, and vortex and interference flows. Particular attention will be devoted to the latter flow phenomena at transonic speeds where adequate theory is not available for solution of practical problems; for example, suppression of aircraft drag rise and buffet due to shock-induced boundary-layer separation and excessive transonic wave drag associated with bluff aircraft configurations.

Computer graphic techniques will be developed for rapid assessment of supersonic design variations with respect to their influence on performance, stability, and sonic boom characteristics. Ways of extending available methods to higher supersonic and hypersonic mach numbers will be sought. The effects of atmospheric turbulence and winds, and focusing due to terrain or aircraft maneuvers on sonic boom pressure signatures will be pursued. Research activity of sonic boom generation and propagation will be planned and coordinated closely with the Interagency Aircraft Noise Abatement Program (IANAP).

Aircraft Loads and Structures

Increased effort will be placed on attaining automation of the aircraft wing structural design process by utilization of large, high-speed computers. The necessary computer programs are being developed to furnish minimum weight

designs which simultaneously satisfy requirements of static and dynamic strength, stiffness and freedom from flutter. The development of similar automated programs for other aircraft components such as the fuselage will also be initiated. The longer range goal is the achievement of automated structural design of the entire airframe on a rational, efficient basis.

Prevention of flutter is a design problem for all aircraft and in most designs entails compromises and structural weight penalties. Analytical and experimental studies will be continued, directed toward improved understanding and representation of the aerodynamic forces and moments on oscillating lifting surfaces, with particular emphasis on the transonic speed range, and on more accurate means for predicting the static and dynamic behavior of aircraft structures.

Research studies will be continued to develop the technology whereby the airplane control system can be used to suppress or alleviate the dynamic structural response for flight through turbulence. Such suppression, particularly for large airplanes, will greatly reduce pilot and passenger discomfort and increase structural reliability. In addition to studies to develop improved analytical methods of calculating aircraft response, wind tunnel tests of a flexible, dynamically scaled model will be made in a wind tunnel in which the model will be subjected to a gust environment.

Basic structural studies of high strength and high stiffness boron filaments bonded to conventional metallic structures have confirmed the promising weight saving potential of this concept. This research will be extended to include design and manufacturing of representative aircraft components to obtain realistic assessment of the fabrication, reliability and cost aspects.

Research on the engineering aspects of structural fracture under repeated loadings (fatigue) will be continued. The emphasis will be on crack propagation and residual strength of sheet-stiffener configurations typically used in airplane construction as affected by loading, choice of material, structural geometry and the atmospheric environment. Studies will also be undertaken of the fatigue characteristics of metallic structures reinforced with boron or graphite filaments.

Air Breathing Propulsion

The objective of the research in this program area is to examine advanced energy conversion processes and problems either identified over a broad range of aircraft applications or else not readily identified with specific aircraft applications. Analytical and experimental studies will be conducted on advanced bearings and lubrication systems, high speed shafting and gearing, and engine seals. Limited research will be conducted on selected engine components, where the emphasis will be on safety and reactor containment, to provide the information necessary for a technological assessment of nuclear power for aircraft use. Advanced propulsion system concepts will also be examined to verify the feasibility of small gas turbine engines, which indicate promise for good performance, simplicity and low cost.

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Aircraft Operating Environment

The programs in this research area are aimed at solving problems related to runway surface and atmospheric environment, operational hazards, flight instrumentation, noise and sonic boom effects. 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 quieter aircraft operations and the basic environmental data for application to design of specific classes 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, 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 and aircraft control on the ground.

In the operational hazards area, protection schemes to avoid critical airplane structural damage from jet engine rotor disk failures will be evaluated. The effects of lightning strikes on aircraft electrical systems will be assessed in laboratory experiments. Research is planned to provide a capability to measure atmospheric winds from a remote location and these research results are expected to have application to the alleviation of the trailing vortex and clear air turbulence hazards.

NASA aircraft noise research is a continuing effort directed primarily at means of minimizing engine noise at its source. A better understanding of the fundamentals of compressor and fan noise generation is sought. Fundamental information on the generation and propagation of noise from the exhaust jets of turbofan engines having high ratios of bypass to primary mass flows will be obtained. Particular emphasis will be placed on the low exhaust velocity range where the turbulence level of exhaust jets may be a dominant factor in noise generation. The experimental studies will be conducted under carefully controlled laboratory conditions with jet velocity and jet turbulence level as the main variables.

Research aircraft often need new or improved sensors to measure the required parameters and a program for the design, development and testing of advanced sensors for flight research programs is planned. Examples of needed sensors are altimeters for use at high speeds and altitudes, miniature pressure transducers to withstand high stagnation temperatures, and instruments to measure pressure and flow direction in a dynamic environment.

The sonic boom research will 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 devised to minimize detrimental effects.

Aircraft Flight Dynamics

Research in this area is aimed at achieving increased knowledge and understanding of the basic elements which influence aircraft handling qualities and piloting performance, at obtaining expanded fundamental knowledge on the flight behavior of aircraft, and at developing, evaluating and applying improved theories, control techniques and piloting aids pertinent to a variety of aircraft types. This research involves theoretical analyses, ground based simulator tests, wind tunnel studies and in-flight investigations with variable stability aircraft. The research program also includes studies to evolve improved flight-test analysis techniques and continued compilation and codification of aircraft flight dynamics characteristics and handling qualities data.

Among the studies planned are investigations to determine the effects of motion cueing on pilot performance during instrument and visual flight rule operations, to establish the influence of erroneous motion and visual cues and control system dynamics on the effectiveness of variable-stability aircraft, and to evaluate the usefulness of an active vibration isolation system in mitigating adverse effects of vibration on pilot performance. Studies of the flight behavior of aircraft will include analysis of optimum maneuvers for tactical aircraft using differential game theory and gradient techniques, and continued investigation of the fundamental nature of aircraft spins. Piloted simulator tests will be made to determine the effects of unsymmetrical aerodynamic characteristics, degraded stability and gyroscopic cross-coupling on aircraft flight at and beyond stall. New control techniques and piloting aids will be studied for improving aircraft flight behavior and piloting performance in severe atmospheric turbulence, and research on the basic interactions of turbulence, aircraft responses and handling qualities will be continued. Theories related to pilot vehicle dynamic response behavior will be evaluated to develop improved simulation techniques and optimum motion wash-out systems.

Support of Facilities and Aircraft

In addition to the advanced research, specific wind tunnel, propulsion and simulation tests are conducted in support of other government agency programs and these require the expenditure of funds for model instrumentation, changes in tunnel and balance configurations, displays and computer programs for simulation and occasionally special flight or model drop tests. NASA support of Department of Defense new military aircraft and missile systems, testing related to Department of Transportation high speed ground transportation programs, and aeronautics support to FAA are covered in this funding category.

NASA's aeronautical research facilities are key to the research effort as well as being essential for the support of other agencies. Thus it is necessary to continue to provide for the upgrading of these facilities in terms of new equipment, instrumentation, and computerization of data acquisition reduction and analysis.

The NASA research centers use various aircraft in direct support of advanced research and technology programs. The maintenance, spare parts and ground support equipment for these R&D aircraft and chase and proficiency aircraft which are used for various missions are also included in this funding category.

General Aviation Aircraft Technology

	1969	1970	1971
Disciplinary technology.....	$507,000	$950,000	$925,000
Total.....	$507,000	$950,000	$925,000

The emphasis in the general aviation technology effort is on aerodynamics, flight dynamics and design, with specific attention being paid to safety aspects. The major thrust of the effort continues to be on flight dynamics to improve handling characteristics of future general aviation aircraft. Studies will be made of the effect of decoupling and/or suitable recoupling of lift, drag, thrust and longitudinal control on the ease of flare and precision of touchdown. The approach to be used is to equip a Navion airplane with variable stability equipment to provide various longitudinal coupling modes and to investigate a variety of flight conditions and coupling modes in flight during approach and landing.

The levels of stability and control and handling qualities that are needed to allow the general aviation pilot to complete a mission safely will be defined, based upon extensive flight testing of a typical light, twin-engine aircraft equipped with a variable stability system, as well as other selected general aviation aircraft.

A flight investigation to establish the characteristics of a typical executive jet aircraft will be conducted using the NASA Lear Jet which, during FY 1970, has been instrumented to provide documentation of both static and dynamic flight characteristics. Special attention will be directed to determining the effects of turbulence for all normal flight regimes. Advanced flight displays will be studied for their potential in providing significant reduction in pilot workload.

In the aerodynamics and design area, analysis and wind tunnel tests of airframe configurations unique to the general aviation class of aircraft will be conducted, and broad summaries of all information from related aerodynamic tests will be prepared for use by the industry.

Flight tests of pilot warning indicator systems will be continued and accelerated as the equipment developed in the avionics program becomes available.

V/STOL Aircraft Technology

	1969	1970	1971
Disciplinary technology.....	$6,700,000	$5,950,000	$11,230,000
Experimental hardware:			
Rotating-cylinder flap.....	1,150,000	300,000	350,000
Jet augmentor wing.....	210,000	1,500,000	2,500,000
Advanced lift fan.....	---	600,000	250,000
DO-31 aircraft.....	---	810,000	---
Tilt rotor aircraft.....	---	300,000	---
Jet-flap rotor aircraft.....	---	100,000	---
Externally-blown flap.....	---	---	500,000
Rotor test vehicle.....	---	---	200,000
Total.....	$8,060,000	$9,560,000	$15,030,000

In the disciplinary technology area, emphasis is being shifted to increase basic experimental and analytical studies leading to improved understanding of helicopter rotor performance, loading, and flutter characteristics. These studies, initiated partly in response to operational problems encountered by the Army, include examination of improved airfoils--such as the supercritical profile, being considered for other conventional aircraft applications--rotor platform and geometry, and new rotorcraft configurations. Effort on advanced rotorcraft concepts enabling performance higher than that possible with a "pure" helicopter will also be increased. Some additional models of VTOL configurations utilizing the lift fan--expected to provide a good compromise between the requirements of high speed cruise, good hover capability, and low noise--will be tested at large scale in the NASA 40- by 80-foot wind tunnel.

In the flight dynamics area, studies recently initiated to examine VTOL operational problems in the descent and landing phases of flight will be augmented. This research is aimed at providing designers and users with information on vehicle control and handling qualities plus stability augmentation and pilot display equipment required to permit safe landings under poor visibility weather conditions, in as short a time as possible to minimize fuel expenditure and reduce use of congested airspace near the terminal, and with acceptable pilot workloads. Primary new vehicles planned to be used include the X-22 tilt-duct aircraft (in a joint program with the Navy and Air Force) whose power and size enable consideration of new research areas; and the CX-84 aircraft (in a joint program with the Canadian Government), which will enable extension of study of the tilt-wing concept and also provide a suitable carrier for planned studies of pilot display requirements, and of examining components of avionics systems aimed at providing an eventual automatic landing capability.

Continued research is planned in the loads and structures area, investigating in particular the aeroelastic stability and control characteristics of hingeless rotors. Related studies of the tilt rotor, the stopped-and-fold rotor, and the variable geometry rotor will also continue. In the area of

V/STOL propulsion research, emphasis is being placed on advancement of the technology base for lift fans. Study of direct-lift jet engines will also continue, particularly to provide an understanding of adverse recirculation effects and methods of avoiding them.

The jet-augmentor wing program is aimed at providing technology applicable to the design of improved STOL transports with both civil and military missions. Based on the promise shown by the results of previous wind tunnel tests and design feasibility studies, a joint program with the Canadian Department of Industry, Trade and Commerce will be continued to provide a research aircraft to demonstrate the validity of the wind tunnel tests and to uncover possible operational problems. In this program, Canada will provide the required propulsion system and the NASA will modify its CV-7A aircraft to incorporate an augmentor wing and the Canadian propulsion package. It is anticipated that about 90 percent of the NASA funding needed for the modification will be required in FY 1970 and 1971, with the remainder in FY 1972. The flight research program will be carried out jointly at the NASA Ames Research Center beginning in FY 1973. Another jet STOL concept which provides less STOL performance capability than the augmentor wing but which may have other installation and cost advantages is the externally-blown flap now receiving extensive wind tunnel model study. Based on the promising results of these tests, a design feasibility study will be conducted in FY 1971 of the possibility of modifying an existing transport aircraft to provide a research vehicle for NASA evaluation.

The objective of the advanced lift-fan aircraft program is to advance information on lift-fan technology to the point where design of a commercial lift-fan V/STOL transport can be initiated with confidence. Results of previous NASA sponsored lift-fan design studies indicate that technology is available to enable the design of the advanced high pressure, low noise level, lift-fans required for such transports. In FY 1971, design studies will be undertaken to indicate the feasibility of modifying a small transport aircraft to incorporate lift-fans to validate the previous wind tunnel and static, ground tests of the fans and to investigate the integration of lift-fans into practical transport design.

In order to obtain realistic, final evaluations of the characteristics of the advanced rotor concepts evolved from wind tunnel model and whirl tower studies, flight investigations will be required. Based on a feasibility study supported in FY 1971, it is planned that an existing helicopter will be modified in FY 1972 to provide this capability.

Subsonic Aircraft Technology

	1969	1970	1971
Disciplinary technology.....	$3,721,000	$855,000	$1,400,000
Experimental hardware:			
Acoustic treatment.....	8,070,000	1,500,000	250,000
Quiet engine.....	7,500,000	5,900,000	10,000,000
Supercritical wing.....	---	1,170,000	250,000
Total.....	$19,291,000	$9,425,000	$11,900,000

As during the past several years, the primary concentration in subsonic aircraft technology is on reduction of noise, with a continuing but modest effort maintained in the remaining subsonic disciplines. The noise reduction programs have successfully demonstrated substantial alleviation by nacelle acoustic treatment and provided valuable data for design as well as regulatory purposes. Design and development of the experimental quiet engine are progressing satisfactorily. Vigorous concentration will be maintained on the combined activity in this vital area. Irrespective of the SST developments, a substantial portion of passenger and cargo transport over the next two decades will be in subsonic jet transports. It is essential that U.S. aircraft continue to show superiority in this field to capture a healthy share of the world market.

Progress in development of the supercritical wing concept has warranted a concerted effort to integrate this technology along with new structural and propulsion concepts into an overall supercritical design technology applicable to a new family of near-sonic transports. Analysis and wind tunnel investigations will be directed toward this end, and will lead subsequently to system studies permitting the determination of experimental hardware requirements for establishing feasibility of new concepts in the flight environment. The near-sonic transport offers the promise of increased aircraft productivity and lower operating costs.

Preliminary study is being directed to the possibilities of improvement in low speed flight capability and precision flight-path control to reduce runway length requirements and improve the safety of all weather operation under congested conditions. Analytical programs in this area, to be followed eventually by wind tunnel and flight research and simulation, will cover means of increasing high lift capability, low speed control effectiveness, and integrated control/display/guidance capability for both automatic and manual flight.

Supersonic Aircraft Technology

	1969	1970	1971
Disciplinary technology.....	$13,993,000	$17,510,000	$16,795,000
Experimental hardware:			
XB-70.....	3,020,000	---	---
F-111.....	550,000	550,000	500,000
YF-12.....	2,785,000	840,000	4,610,000
Total.....	$20,348,000	$18,900,000	$21,905,000

The design of advanced military and commercial supersonic aircraft with high performance level is dependent upon factors such as increased aerodynamic efficiency, decreased structural weight, improvement of power plant characteristics (by decreasing consumption of fuel and the specific weight of the engine), and improving the dependability of all the systems. A wide range

of research activity in the various technologies is being carried out to achieve these goals and to provide the knowledge for the conception of advanced supersonic vehicles.

Analytical and experimental studies of the aerodynamic characteristics of promising configurations and components of proposed supersonic transports will be continued over the range of speeds from subsonic to a Mach number of 3. Performance, stability and control characteristics of supersonic transports at subsonic speeds will be explored to obtain satisfactory take off and landing characteristics by adjustment of aircraft geometry and by the use of artificial stabilization equipment.

A continuing research effort is concerned with providing the aerodynamic technology needed for the conception and design of advanced and highly maneuverable military aircraft. Aerodynamic data will be derived on such items as high lift devices, effects of engine power, engine-airframe integration, buffet, and effects of variations in wing geometry.

A number of metallic and nonmetallic materials that may be suitable for use in supersonic aircraft structural applications are being investigated. This research involves long-time elevated temperature tests of current and advanced materials to determine stability and oxidation resistance under a simulated supersonic aircraft environment. Structural specimens of titanium reinforced with boron or graphite fibers will also be subjected to an experimental program including loading and environmental exposure.

The development of propulsion system technology for advanced military and commercial aircraft will continue. In the area of inlets and nozzles, particular emphasis will be placed on the stability problems of these high performance components at their design speed, on the performance and variable geometry configurations during off-design operation, and on the mutual interaction problems that result when integrating these components into a complete airframe and propulsion system. At transonic speeds, the ground test facilities are complemented by a flight test program which uses a F-106 aircraft with unique modifications for inlet and nozzle research.

Several approaches to reduce compressor and fan component weight and improve performance will be investigated. These components must provide efficient compression, the necessary stall margin and distortion tolerance over the range of flow rates imposed by various flight conditions. Compressor blades will be designed to operate at higher flow Mach numbers encountered at increased rotational speeds made possible by improved materials. Various approaches to delay end wall stall will be studied. Multistage compressors will incorporate the most promising advanced concepts investigated in single stage compressors.

Research will continue in the areas of primary combustors, augmenting burners and fuels for advanced engines. Primary combustors will be designed to give rapid mixing and intense burning in the forward end to provide shorter, more durable liners with low smoke and uniform high temperature profiles at

the combustor exit. The afterburner research program will evaluate and improve the performance, stability, and life of afterburners designed for high temperature engines. Research on fuels will be directed toward utilizing them as heat sinks for cooling hot engine components.

The turbine is undergoing a greater change than any other component in modern engines. The turbine inlet temperatures are steadily increasing and high work turbines are being introduced in order to reduce turbine weight and size. Under the turbine aerodynamics research programs, investigations will be made on the effects of cooling air discharge on turbine performance for both single and multistage turbines, on the performance of both fixed and variable geometry turbines, and on a number of methods of increasing blade loading in order to reduce turbine size and heat transfer surface area. Turbine cooling research is directed at developing methods for predicting the cooling performance of air cooled turbine blades cooled by a variety of methods.

Flight dynamics research is being conducted to develop criteria for aircraft systems that will allow the pilot to easily, economically, and safely control and maneuver supersonic aircraft in accordance with operational requirements. Specific research is directed at the improvement of aircraft under design such as the supersonic transport, and the F-14 and F-15 supersonic fighters. Also, a cooperative research program is directed to providing the information necessary for the FAA to establish certification regulations for supersonic transports and for developing revisions in certification test maneuvers.

An F-111A aircraft is being flown to provide flight dynamics information applicable to the design and development of advanced military aircraft. The program consists of three separate investigations. The first pursuit is concerned with a handling qualities flight control system study with different levels of stability augmentation system sophistication.

The second objective will establish the relative importance of various landing approach variables including direct lift control and approach power compensation on the landing task of a high performance aircraft. The third study will evaluate the effects of various factors such as buffet, buffet intensity, and stability augmentation complexity on piloting precision of closed-loop tracking capability.

The NASA-USAF YF-12 flight research program is obtaining design information applicable to aircraft that have a high sustained supersonic Mach number capability. Air Force interests are oriented primarily toward a further definition of the tactical performance and support requirements of an advanced interceptor. The NASA programs are obtaining data in areas such as airplane structural characteristics, flight loads and deformations, aeroelastic effects on stability and control, propulsion airframe interaction, internal diffuser dynamics, and aerodynamic boundary layer characteristics. Throughout the course of these studies, it is expected that equipment and instrumentation changes and alterations as well as modifications to the aircraft will be required.

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Hypersonic Aircraft Technology

	1969	1970	1971
Disciplinary technology.....	$3,085,000	$4,060,000	$3,775,000
Experimental hardware:			
Hypersonic research engine.....	6,600,000	2,000,000	2,000,000
Total.....	$9,685,000	$6,060,000	$5,775,000

The technology is being developed from continuing theoretical and experimental studies in the various disciplines for long range hypersonic aircraft systems suitable for transports and reuseable boosters. Basic experimental data have been obtained on an early generation of hypersonic air-breathing configurations, on promising lightweight structural concepts, and in the areas of fuel injection and combustion. These data are being used to verify the adequacy of the theories. These analyses and tests further serve the highly useful purpose of exposing problems and of formulating a plan to solve these and other problems.

The program in prediction techniques will be expanded whereby current theories will be improved and new ones developed and corroborated with appropriate experiments. The theoretical and experimental evaluations of airframe-inlet-engine integration effects will be continued and various simulated propulsion systems in combination with wing-body models will be tested. Initial studies of cooling systems have identified attractive methods to reduce both the structural weight and aerodynamic drag of hypersonic aircraft. Further analytical and experimental research are required to evaluate these methods when applied to complete aircraft.

Because of the extremes in temperature, -423°F in the cryogenic fuel tanks, near 1500°F over major portions of the surface, and up to about 4000°F in stagnation regions, various concepts for structures and thermal protection are being explored. Conceptual designs for wing leading edges will be tested in the tunnel and in the structures laboratory. Tests of a carbon dioxide frost thermal protection concept will be continued using liquid nitrogen to simulate cryogenic fuel. As a follow-on to an indepth study of wing structures, an experimental program will be initiated to evaluate promising concepts for wing panels under realistic heating and loading.

Experimental and analytical research programs on the technology of air-breathing hypersonic propulsion engines will be broadened emphasizing supersonic combustion and studies of the associated aerothermodynamic process. Both large and small scale supersonic combustor tests will be conducted. A significant portion of the inlet research effort will be directed to the development of design techniques suitable for high performance systems and to the assessment of the performance potential of various configurations. The feasibility of reducing combustor lengths by injecting fuel on the inlet compression surfaces will be studied experimentally.

The Hypersonic Research Engine program has progressed through the definition and design of all of the components. Assembly of both the aerothermodynamic integration model which has internal passages designed for high propulsion efficiency, and the structural assembly model, which has regeneratively cooled surfaces designed to maintain structural integrity at high operating temperatures, is continuing.

The aerothermodynamic integration model will be water cooled, and will be investigated at the Lewis Research Center's Plum Brook facility to demonstrate overall operating performance and stability with hydrogen fuel injection and either subsonic or supersonic combustion.

The structural assembly model will have liquid hydrogen regeneratively cooled surfaces, and will be tested without combustion in the Langley Research Center's 8-Foot High Temperature Structures Tunnel to determine the structural adequacy of this type of construction when operating in a hypersonic environment.

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1971 ESTIMATES

OFFICE OF TRACKING AND DATA ACQUISITION

TRACKING AND DATA ACQUISITION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

The purpose of this program is to provide responsive and efficient tracking and data acquisition support to meet the requirements of all NASA flight projects. In addition, support is provided, as mutually agreed, for projects of the Department of Defense, other Government agencies, and other countries 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 supplemented by appropriate instrumentation ships, 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 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. The subsequent sections describe plans and related funding requirements to continue the Tracking and Data Acquisition program in each of these areas during FY 1971.

SUMMARY OF RESOURCES REQUIREMENTS:

	1969	1970	1971
Operations	$229,354,000	$233,400,000	$229,600,000
Equipment	39,162,000	32,200,000	55,500,000
Supporting research and technology	11,156,000	12,400,000	12,900,000
Total	$279,672,000	$278,000,000	$298,000,000

Distribution of Program Amount by Installation:

Manned Spacecraft Center	$5,300,000	---	---
Marshall Space Flight Center	300,000	$1,660,000	$400,000
Goddard Space Flight Center	208,221,000	206,405,000	212,127,000
Jet Propulsion Laboratory	47,694,000	51,150,000	66,143,000
Wallops Station	5,409,000	5,985,000	6,240,000
Electronics Research Center	100,000	60,000	---
Flight Research Center	2,000,000	1,875,000	1,630,000
Langley Research Center	1,450,000	845,000	1,160,000
NASA Headquarters	9,198,000	10,020,000	10,300,000

BASIS OF FUND REQUIREMENTS:

Operations

Manned space flight network	$83,493,000	$86,380,000	$79,200,000
Satellite network	43,520,000	42,370,000	44,000,000
Deep space network	32,231,000	36,000,000	39,800,000
Other instrumentation	5,627,000	6,090,000	5,300,000
Communications	48,480,000	45,080,000	42,800,000
Data processing	16,003,000	17,480,000	18,500,000
Total	$229,354,000	$233,400,000	$229,600,000

Manned Space Flight Network Operations

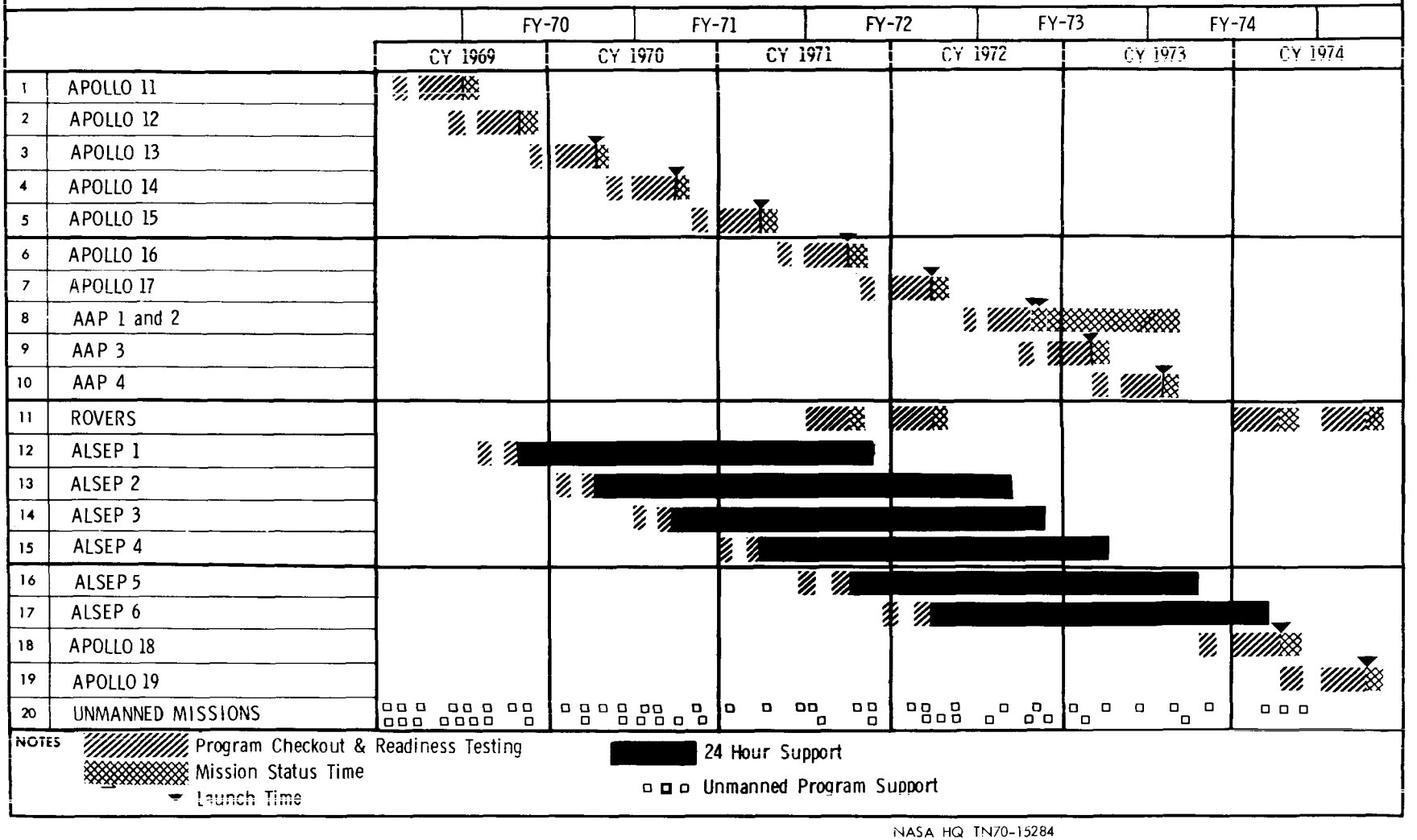
The Manned Space Flight Network was designed to collect and communicate real-time information regarding the precise location of both the Command and Lunar Modules as well as the Saturn launch vehicles, the status of the onboard equipment and experiments, and most importantly, the physical condition of the astronauts. The Manned Space Flight Network presently consists of 12 prime stations, one instrumentation ship, and four instrumented jet aircraft. 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 on the surface of the moon is collected and processed for post-flight analysis.

This worldwide network of stations was established initially for support of the Mercury program in early 1959 and has been continually 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 required increases in the overall level of capability and operations 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 an outstanding manner. Throughout the manned space program, the network has continually supported the exacting requirements for tracking accuracy and high quality communications, including real-time television. This accuracy and quality has contributed significantly to the precise navigation required for the pin-point lunar landings.

The network consists of: (a) nine 30-foot-diameter antenna stations located at Cape Kennedy; Bermuda; Ascension Island; Grand Canary Island; Carnarvon, Australia; Guam; Kauai, Hawaii; Guaymas, Mexico; and Corpus Christi, Texas; and (b) three 85-foot-diameter antenna stations located at Madrid, Spain; Canberra, Australia; and Goldstone, California. In addition, one instrumentation ship and four aircraft, operated by the Department of Defense, and three 85-foot-diameter antenna stations of the NASA Deep Space Network 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 astronauts. The future landing missions will also carry ALSEPs resulting in a continuing and significant workload on the network. During FY 1971, the network will be required to support two lunar landing missions, each including an ALSEP, plus two ALSEPs left by previous landing missions, and a large number of unmanned missions. This overall workload is depicted on the attached chart.

MANNED SPACE FLIGHT NETWORK WORKLOAD



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Network Operations during FY 1971 will be at a reduced level from FY 1970. Operations experience gained through the lunar missions to date has allowed a phaseout of three instrumentation ships, four aircraft, and two land stations. The effect of these decreases is somewhat offset by allowances for cost-of-living increases.

Satellite Network Operations

The principal function of the Satellite Network is to support NASA's unmanned scientific and applications satellite programs. The network includes the electronic stations of the Space Tracking and Data Acquisition Network (STADAN) operated by the Goddard Space Flight Center, supplemented by the optical 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.

Fiscal year 1970 and prior year budget constraints have resulted in the curtailment and cessation of operations at several locations. The STADAN stations at Lima, Peru, and Toowoomba, Australia, have been closed and the station at St. John's, Newfoundland, will be closed in March 1970. Staffing at the Mojave and Rosman stations in support of ATS has been reduced. In addition, the optical network has been severely cut back in both capability and level of operations.

These reductions and curtailments have been made possible by a continuing review of the scientific requirements for the acquisition of data from the spacecraft. As a result of this review, data acquisition from a number of healthy but lower priority satellites has been either completely terminated or severely curtailed.

The current network workload, consisting of some 45 satellites, continues to require around-the-clock operations. Ten new satellites scheduled for launch in FY 1971 will further impact the overall workload and will necessitate continuing adjustments in support priorities within the constrained network capability.

During FY 1971, initial activity associated with the ERTS control center and support of OAO-B will be undertaken. These project-unique requirements, as well as an allowance for cost-of-living increases, are included in the FY 1971 request for funds to operate the network at the currently constrained level.

Deep Space Network Operations

The primary function of the Deep Space Network is to support lunar and planetary space flight missions. The 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 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 1970 the Deep Space Network is supporting four Pioneer spacecraft, the two Mariner 1969 spacecraft in the extended mission phase, and the Apollo manned lunar missions. This on-going workload, reflected in the attached workload chart, will continue on into FY 1971 along with preparation for support of the Mariner 1971 launch.

Extensive network engineering, programming, and computational support is necessary to meet the support requirements of Mariner 1971. The complexity of this support is related to the requirement for the network to support two orbiting spacecraft simultaneously for an extended period of time and at extreme distances. Substantial amounts of visual imaging and other scientific data must be acquired from the spacecraft as they orbit Mars. In addition, precise orbit information must be available in real-time for both spacecraft. The handling and selective display of this data requires significant programming and computational support particularly in the SFOF. Correspondingly, the engineering effort associated with equipment changes, modifications, and implementation will require increasing emphasis in FY 1971.

The FY 1971 request includes funds for the increased support for Mariner 1971. It also includes funds for the engineering and computational support in preparation for the Pioneer F and G missions to Jupiter and the Venus/Mercury 1973.

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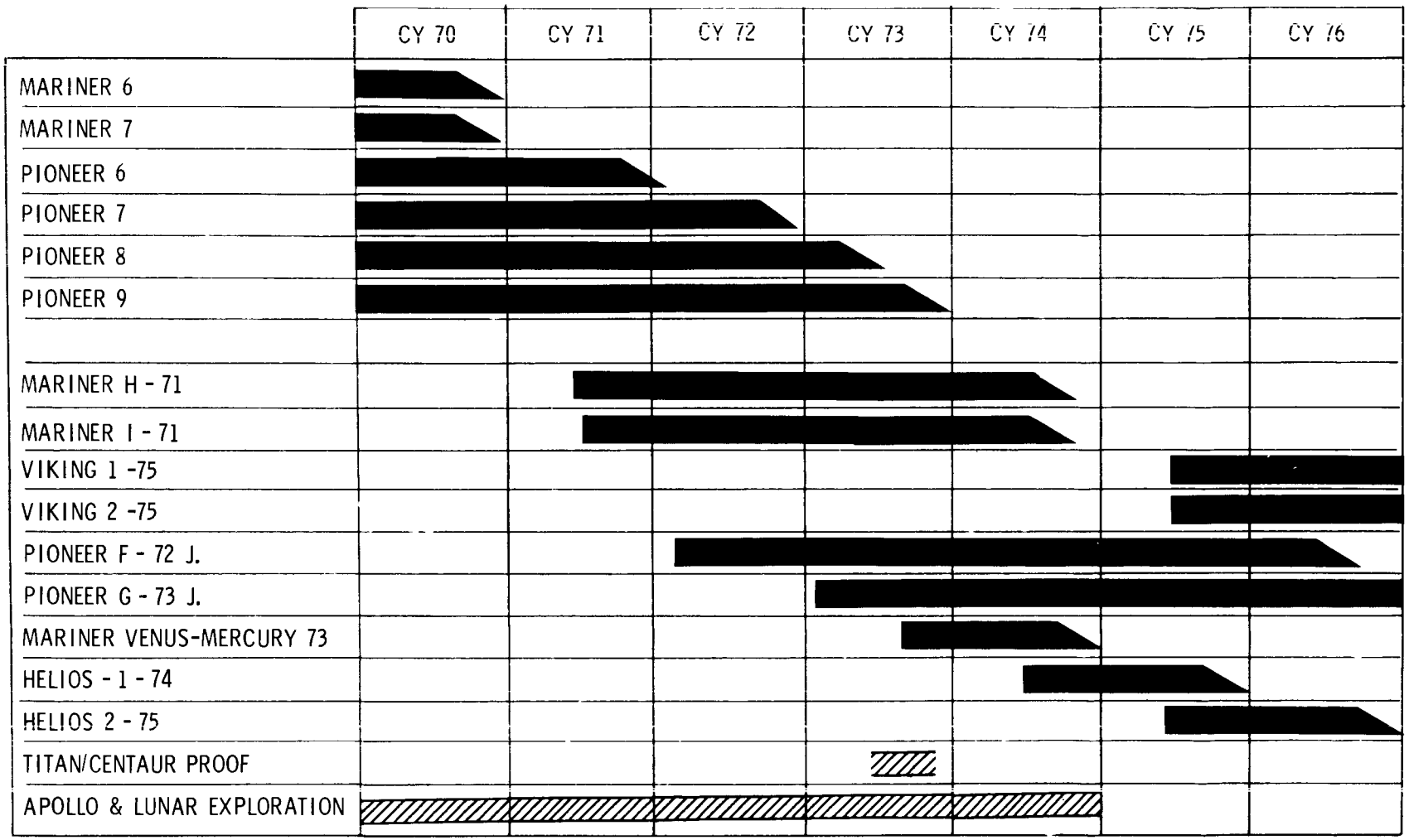
DEEP SPACE NETWORK LOAD

OFFICE OF TRACKING AND DATA ACQUISITION



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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. 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 instrumentation at Wallops Station is operated by NASA contractors and by other Government agencies such as the Environmental Science Services Administration, the National Bureau of Standards, the U. S. Navy, the U. S. Air Force, and the Military Sea Transportation Service. Funds required for FY 1971 will permit approximately the same level of effort as in prior years.

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. Much of this down-Range support is funded by the Langley Research Center.

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, some of which are the F-111, C-5A, F-104, HL-10, X-24A, and YF-12.

Communications Operations

NASA's global communications system (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 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 system and serves as its major switching point. In the interest of economy, reliability, and full utilization of circuitry, subswitching centers have been established at London, Honolulu, Canberra, Madrid, Guam, Pasadena, and Cape Kennedy.

NASCOM has provided outstanding support for all flight projects since its inception and will again, in FY 1971, be called upon to support all new launches along with the large on-going workload of spacecraft remaining in operation from launches in previous years. The network continues to make use of new communications satellite technology as well as conventional means of communications.

The FY 1971 communications budget shows an overall decrease from the FY 1970 budget. Although a scheduled private line rate increase will significantly impact NASCOM's domestic circuits, other economies in the network result in a lower overall budget. During FY 1971, two Apollo missions will be supported whereas in FY 1970 three Apollo missions are being supported. Station closures have also contributed to the reduction.

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, Geophysical, 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, and to provide position information that can be used by the scientific experimenters to determine where in the trajectory the scientific measurements were made.

Telemetry data must be processed to: (a) separate the information obtained from the 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, particularly those in the observatory, radio astronomy, and geodetic classes, 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.

The FY 1971 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. This workload includes an increase in the number of high data rate satellites such as the Nimbus-D, OAO-B, OSO-H, and IMP-I, which will result in additional telemetry data processing and mission related computer support. There will also be an increase in orbit and attitude computations due to greater spacecraft complexity.

The data processing workload is under continuing scrutiny along with the scientific requirements for acquisition of data from spacecraft. During the first half of FY 1970 data acquisition from a number of healthy but lower priority spacecraft was either completely terminated or severely curtailed as a result of this continuing review. These reductions will allow for support of ten new satellites to be launched in FY 1971 without major increases in data processing capability.

Equipment

	1969	1970	1971
Manned space flight network.....	$9,223,000	$7,600,000	$9,800,000
Satellite network.....	8,676,000	8,800,000	16,400,000
Deep space network.....	14,291,000	10,100,000	21,700,000
Other instrumentation.....	3,439,000	3,000,000	3,100,000
Communications.....	1,742,000	1,700,000	2,800,000
Data processing.....	1,791,000	1,000,000	1,700,000
Total.....	$39,162,000	$32,200,000	$55,500,000

Manned Space Flight Network Equipment

The Manned Space Flight Network equipment program encompasses the procurement of equipment and services necessary for incorporation of additional systems in the existing network to meet new requirements for manned space flight missions and appropriate unmanned missions, for modification of existing equipment to improve the network's operational effectiveness and efficiency, and for sustaining the network's continuing capability for reliable mission support.

During FY 1970, the network has been heavily engaged in Apollo mission support. Activity in the equipment program has been solely devoted to maintaining the network in a continuing state of readiness for support of changing Apollo mission requirements as the program has progressed from the successful accomplishment of the first manned lunar landing to the more varied activities of lunar exploration. Fiscal year 1970 funding requirements were reduced from the original plan as a result of the postponement of AAP and through utilization of equipment which became available as a result of ship deactivations following the successful Apollo 11 mission. This equipment has been used in lieu of planned procurements of spares and of replacements of obsolete systems.

The network's support of Apollo lunar missions will continue in FY 1971 and, in addition, virtually continuous operations will be required in support of the Apollo Lunar Surface Experiment Packages (ALSEP). Although provision of the basic capability for this support has been

completed in prior years, a continuing effort will be necessary to maintain a reliable support capability throughout the year. 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 the engineering effort required in system performance evaluation, for provision and modification of test equipment, for continuation of the Test and Training Satellite capability, and for equipment modifications resulting from changes in support requirements from one mission to the next.

Apollo Applications missions will involve a sequence of revisit missions, each requiring network support of the orbiting workshop simultaneously with support of manned rendezvous spacecraft. Network support of ALSEP experiments will be required at the same time. Since the data systems employed on the workshop, the rendezvous spacecraft, and ALSEP differ functionally, changes will be required in station support configuration. Also, since individual network stations will be required to support the AAP vehicles and ALSEP in rapid sequence, the capability for rapid reprogramming and quick configuration turn around will be required in the network stations. Provision of systems to provide these capabilities was initiated in FY 1969; however, the delay in the Apollo Applications mission schedule and funding reductions resulted in a stretch-out of part of the effort. Accordingly, funds are requested for completion of these capabilities in FY 1971.

The Apollo Applications schedule delay also permitted postponement of the procurement of additional pulse code modulation (PCM) decommutation systems required to meet the increased data handling needs of the AAP missions. Pulse Code Modulation decommutators are used in the network stations to prepare data for input to the telemetry data processing systems where flight control parameters are selected and formatted for communication to the Mission Control Center. Accordingly, it is requested that funds be provided for these systems in FY 1971.

Satellite Network Equipment

As in previous years, the equipment program for the Satellite Network in FY 1971 is divided into three major categories with the following objectives: (1) sustaining the basic capability of the network to support on-going missions, (2) improving the utilization of existing equipment to increase operating efficiency, and (3) adding network systems to meet new requirements of approved missions.

Under the sustaining category in FY 1971, funds are requested for the completion of command system replacements which were deferred from FY 1970 due to fund constraints. Operating experience has shown the need for command systems with multi-mission capability which can generate and verify a wide variety of commands that must be sent to the spacecraft

by the network stations. Commands are necessary to maneuver the spacecraft, to switch scientific experiments on and off, and to issue corrective instructions to onboard electronic systems.

Complementary wideband receiving and data handling subsystems are also planned for procurement in FY 1971. As the spacecraft have become more complex in terms of data rates and onboard experiments, the receiving and data handling functions of the stations have also become more complex in order to receive and handle increasing amounts of both recorded and real-time data from the spacecraft. The requirement for real-time data has been significantly increasing due to the more sophisticated onboard experiments which necessitate that quick look data be transmitted from the stations to the control center in real-time for status monitoring and decision making purposes.

In FY 1971, funds are included for the on-going functions associated with maintaining a global network. These include the procurement of test and calibration equipment necessary to insure a high performance level of the electronic systems and subsystems, provision for minor facility repairs and alterations, procurement of specialized nonexpendable spare components and modules, and procurement of station maintenance vehicles such as antenna service cranes.

To improve the utilization of existing equipment, Station Technical Operations Control (STOC) consoles will be procured in FY 1971. Although this item has been deferred by funding constraints in prior years, the need for this operational improvement continues to increase as support requirements grow in complexity. Station technical operations control will provide this improvement by centralizing routine operations at stations and providing a rapid checkout capability. It will also allow station equipment to be made available more quickly to support successive satellite passes, thereby increasing the utilization of existing equipment.

The new capability category includes those equipments which are needed to meet new requirements for recently approved projects. In FY 1971, augmentation for ERTS will be essentially completed with the purchase of control center peripherals, display and control equipment, and on-site wideband recorders to handle both PCM and video signals. Also, in FY 1971 low noise RF equipment and special decoding equipment will be purchased for the lunar RAE-B mission. Similarly, funds are requested for modification of existing station equipment for Nimbus D and for new or modified displays, computer interface equipment, and operations consoles in the control centers for OAO-C and OSO-I, J, and K.

Deep Space Network Equipment

In FY 1971, continued emphasis will be placed on providing the Deep Space Network with a multi-mission support capability for planetary projects in the early to mid-1970's. Initiated in FY 1970, this capability is incrementally phased to meet the support requirements of such approved

projects as Mariner 1971, Pioneer F and G, Venus/Mercury 1973, Helios, and Viking. As in FY 1970, the FY 1971 request also contains the necessary funding for sustaining the existing network which is currently supporting four Pioneers, two Mariners, and the on-going Apollo missions.

Approximately three-quarters of the FY 1971 request is keyed to providing a combined multi-mission support capability for upcoming missions. The workload associated with these missions is characterized by requirements for the network to work with spacecraft at extreme distances (up to 550 million miles), to simultaneously handle critical events from more than one spacecraft, and to acquire large amounts of visual imaging and other scientific data.

To meet such requirements, general purpose command and data handling systems which can work with a variety of spacecraft are being implemented in the network. Implementation of the network systems needed for the Mariner 1971 program was initiated in FY 1970. This included the provisioning of the 210-foot antenna at Goldstone with dual receivers and data handling systems to work with both Mariner 1971 spacecraft simultaneously. This initial implementation phase will be completed with FY 1971 funds, including completion of the 210-foot antenna high power transmitting system which was partially deferred from FY 1970.

In addition, the FY 1971 request contains funds for the second implementation phase which consists of providing general purpose data handling systems at the two 210-foot overseas antennas which are presently under construction. The remaining 85-foot antennas are being augmented to support the on-going programs, including pioneer F and G, Venus/Mercury 1973, and Helios. This equipment will also provide the base to which future systems can be added to provide support to Viking missions.

Concurrently with the station augmentations, a phased implementation plan is also underway at the network control center at Pasadena, California. Initially required for Mariner 1971, equipment augmentations are being made to provide the capability for simultaneously computing precision orbits for the two spacecraft, to retrieve and display TV data, and to process and display information on the attitude and condition of the two spacecraft. Fiscal year 1971 funds are required to complete this initial phase and to provide the additional capability needed for simultaneous support to the planetary missions planned during the 1972-75 time period.

During FY 1971, a long lead time development effort will be undertaken to provide for the eventual operation of the Goldstone 210-foot antenna at X-band frequencies. The X-band is a higher region of the radio frequency spectrum, around 8,000 megahertz, compared with our presently used S-band frequencies around 2,200 megahertz. We can achieve significant improvements in space communications by use of the X-band frequencies in terms of greater quantities of data over greater distances. While this capability will be used initially in the 1973-74 period, it will have particular significance

for later missions to the outer planets. With the potential for the transmission of data at very high densities, the scientific return on planetary missions could be substantially improved with this capability. Funds are included in the FY 1971 request for initial antenna and receiver modifications at Goldstone for this effort.

Also contained in the FY 1971 request are funds for sustaining the network in support of the on-going program consisting of several Pioneers, Mariner 6 and 7 in the extended mission phases, and for Apollo. With the advent of prolonged periods of critical mission support such as the Mariner 1971 Mars orbital flight, there will be an increasing dependency on the integrity of the network. This requires a continuing program to replace obsolete or high maintenance components, modules, and subsystems, and to update equipment to provide the necessary reliability. Among the items normally procured for this effort are test and calibration equipment, cabling assemblies, power distribution equipment, and electronic modules and assemblies for the major equipment systems. This effort also provides for module spares provisioning, minor mission-to-mission changes, and simulation equipment for mission checkout and training purposes.

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 flight research projects conducted by the Flight Research Center and Langley Research Center.

At Wallops Station, these funds in FY 1971 are required to sustain existing capability by the provision of maintenance and spare parts, the procurement of nonrecoverable flight hardware (antennas, transponders, support instrumentation) and the accomplishment of the last phase of the S-band telemetry conversion scheduled for completion in FY 1971, including stabilization for the telemetry antenna on board the Range Recoverer ship.

Two telemetry ground stations are required 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 1971 to complete the procurement of these stations.

The 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, C-5A, F-104, HL-10, X-24A, and YF-12.

During FY 1971, 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.

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Communications Equipment

The FY 1971 budget request contains funds for the on-going sustaining effort required to maintain the integrity and reliability of the NASA Communications Network (NASCOM), and to meet new requirements for approved projects.

The sustaining effort includes replacement spares, computer peripherals such as tape units and core modules, computer interface equipment, test and calibration equipment, and error detection equipment for routine monitoring of data circuits.

In the category of meeting requirements for approved projects, high data rate modems will be procured in FY 1971 for the Deep Space Network to meet Mariner 1971 requirements. These high data rate modems will permit NASCOM to handle up to three times as much data with the existing overseas circuits to the DSN sites. Also, for Mariner 1971, funds are required for peripheral equipment at JPL for the communications processor and for the procurement of voice, teletype, and video equipment.

The FY 1971 request also includes funds to initiate conversion of NASCOM to the eight level American Standard Code for Information Interchange (ASCII). This is a government-wide effort to achieve standardization of communication line terminals. This item was deferred from FY 1970 due to budget constraints.

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 1971 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

	1969	1970	1971
New systems.....	$387,000	$1,250,000	$1,700,000
Integrated systems analysis, development and test.....	2,367,000	3,370,000	3,280,000
Antenna subsystems.....	1,420,000	1,220,000	1,260,000
Receiving and transmitting subsystems.....	2,457,000	2,350,000	2,200,000
Data handling and control.....	1,619,000	1,440,000	1,410,000
Data processing and reduction...	1,001,000	1,220,000	1,200,000
Spacecraft subsystems.....	1,173,000	980,000	1,260,000
Network performance and operations technology.....	732,000	570,000	590,000
Total.....	$11,156,000	$12,400,000	$12,900,000

The Tracking and Data Acquisition Supporting Research and Technology (SRT) program provides funds for the advancements in telecommunications technology needed for tracking and data acquisition support of future space missions. The program is planned to provide the studies and developments of advanced systems and techniques which are required for an orderly evolution of network capability to support future missions and to achieve increased reliability and economy in network operations.

The effort planned for FY 1971 will emphasize developments for the improvement in the overall telecommunications capability of the Deep Space Network and for more cost effective approaches in providing the capabilities needed in the Satellite and Manned Space Flight Networks for future mission support. The primary objectives in deep space telecommunications are to provide the capability to receive spacecraft telemetry at higher rates and at greater distances than now possible, to receive planetary lander telemetry data directly from the lander spacecraft, to allow for simultaneous operation of several spacecraft, and to provide the techniques for obtaining greater tracking accuracies needed for advanced planetary missions. In the Satellite and Manned Space Flight Network areas work will continue on techniques for automation of station operations, on methods for onboard data handling and processing, and on development of network subsystems to meet specific mission needs.

The FY 1971 request is based on continuation of a constrained level of SRT with a small increase for studies of a Tracking Data Relay Satellite System (TDRSS) and for support of an X-band telecommunications experiment in the 1973 time period.

The program for SRT comprises effort in eight task areas as follows:

New Systems

The effort in this category consists primarily of studies to define the configuration and operation of a Tracking Data Relay Satellite System (TDRSS) and to identify potential needs for technology development. The TDRSS would use relay satellites in synchronous orbit to gather data from lower altitude earth-orbiting spacecraft to augment the capability and improve the efficiency of the NASA tracking and data acquisition networks. Studies will continue and expand in FY 1971 to define a system which can economically and reliably satisfy support requirements of NASA flight programs projected for the mid to late 1970's. These studies include appropriate technical and cost trade-off analyses to define the TDRSS such as the number, location, and performance specifications of relay satellites and supporting ground stations, and the characteristics of the telecommunications subsystems of mission spacecraft for which the TDRSS is to provide support.

Integrated Systems Analysis, Development and Test

The main purpose of this effort is to prove the acceptability of hardware models and software concepts in a real or simulated network operating environment before they are committed to field operation of the network stations, control centers, and other facilities. To be continued in this task area in FY 1971 is the development of techniques and computer programming for more precise orbit determination. Effort will also continue on the use of shorter wavelengths for planetary radar and telcommunications experiments and on radio frequency interference problems.

Antenna Subsystems

Effort in this category for FY 1971 is aimed at three primary objectives: to develop the technology for an X-band telecommunications capability at a Deep Space Network station for support of radio science and tracking experiments; to develop multiple purpose antenna feed systems along with the necessary control and monitoring techniques that allow rapid changeover of antenna modes from one mission operation to another; and to conduct trade-off and design studies on the use of arrayed steerable antennas versus single larger antennas for support of future missions to the outer planets.

Receiving and Transmitting Subsystems

The objectives of this category are to design, construct, test, and demonstrate prototype versions of transmitters and receivers needed to meet the requirements of approved flight missions. Most of the effort in FY 1971 is focused on the deep space mission requirement for providing

simultaneous two-way radio communications with orbiting spacecraft and lander vehicles at extreme distances. Development effort will include work on elements of S-band and X-band receiver modules and calibration instrumentation.

Data Handling and Control Subsystems

The objective of this effort is to develop the necessary data handling techniques to improve the flexibility for network managers and mission directors in support of the flight missions. Effort in FY 1971 will be directed to the central monitoring and control of functions of the Satellite Network and Deep Space Network stations. These functions include telemetry, command, tracking, ranging, timing, scheduling, and communications. Primary objectives are: more efficient use of subsystems and manpower in the networks, optimum use of NASCOM broad-band communications links to the stations, and the application of computer technology to the various station functions.

Data Processing and Reduction

The objectives of this task area are to develop the data subsystems needed to perform the telemetry, command, ranging, and tracking functions. The effort in FY 1971 will include the development of digital techniques for detecting and synchronizing extremely low level signals, and the development of new signal decoding techniques to support future missions characterized by higher bit rates and extreme planetary distances. Work will continue on obtaining more efficient methods of displaying, reducing, and processing large volumes of data. Investigations will also be made of techniques for real-time conversion of electrical signals to an optical format using optical data processing equipment.

Spacecraft Subsystems

The main objective of this effort is the development of common usage spacecraft telecommunications subsystems that are compatible with the ground stations and which represent optimum spacecraft/network trade-offs. Development of general purpose spacecraft subsystems will continue in FY 1971, primarily in the area of onboard information processing and control, and on a unified data and radio frequency subsystem for earth satellites. Work will continue on miniature S-band and X-band spacecraft transponders required for future missions.

Network Performance and Operations Technology

The objectives of this task area are to determine the performance and limitations of the networks as a whole and to identify ways of reducing recurring operations costs. In FY 1971, effort will continue on improved techniques for post-flight analysis of tracking data, and on the metric evaluation and calibration of tracking systems used in the networks.

OFFICE OF TECHNOLOGY UTILIZATION — TECHNOLOGY UTILIZATION PROGRAM

PROGRAM OBJECTIVES AND JUSTIFICATION:

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; (4) to contribute to the knowledge of better means of transferring technology from its points of origin to its points of potential use.

New technological developments of use to the aerospace industry are applied almost automatically within that industry. Many of these innovations have potential benefit as well to the nonaerospace community. It is the primary purpose of this program to establish systems and mechanisms to identify, evaluate, publish, and transfer these technological innovations to the general public. This program provides a similar service with regard to management techniques developed for large scale complex research and development activities by creating awareness of and giving wide spread dissemination to new systems and concepts in this area.

SUMMARY OF RESOURCES REQUIREMENTS:

	1969	1970	1971
New technology identification and evaluation	$1,350,000	$1,300,000	$800,000
Publication	550,000	1,100,000	900,000
New technology dissemination	1,900,000	2,200,000	1,900,000
Program evaluation	---	400,000	400,000
Total	$3,800,000	$5,000,000	$4,000,000
Distribution of Program Amount by Installation:			
NASA Headquarters	$3,800,000	$5,000,000	$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 identify and

document those inventions, innovations, improvements, and discoveries that have potential utility to the nonaerospace sector of the economy.

Publication

Transfer of technology is accomplished through publications ranging from reports of single innovations to surveys of contributions to the state-of-the-art in broad technology areas. These are prepared by both private and nonprofit contractors.

New Technology Dissemination

Regional dissemination centers store, retrieve, and interpret the new technology developed by NASA for local industry. Biomedical application teams are also employed to assist 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 assisting in developing cooperative programs with several other agencies such as the National Air Pollution Control Administration, Federal Water Pollution Control Administration, 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

Research institute personnel evaluate technology transfer mechanisms and furnish recommendations for their improvement.

U. S. GOVERNMENT PRINTING OFFICE : 1970 O - 375-539