AMERICA'S NEXT DECADES IN SPACE

A REPORT FOR THE SPACE TASK GROUP

PREPARED BY
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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TABLE OF CONTENTS

PAGE

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I SUMMARY

At the moment of its greatest triumph, the space program of the United States faces a crucial situation. Decisions made this year will affect the course of space activity for decades to come. At stake is America's position of world leadership in technological and scientific progress, the image that 200 million Americans have of their country and its record of achievement, and the multitude of practical benefits that a vigorous space program provides to the people whose taxes support the program. This Administration has a unique opportunity to determine the long-term future of the Nation's space progress.

We recommend that the United States adopt as a continuing goal the exploration of the solar system, with men and machines. To focus our developments and integrate our programs, we recommend that the United States prepare for manned planetary expeditions in the 1980's. We recommend further that the space program for the next decades be conducted so as to provide a continuing output of benefits in practical applications, science, and technology and simultaneously the development of new and improved capabilities required for the exploration of the solar system. A substantial reduction in the cost of space transportation is essential, and we recommend specific research and development to achieve such reductions.

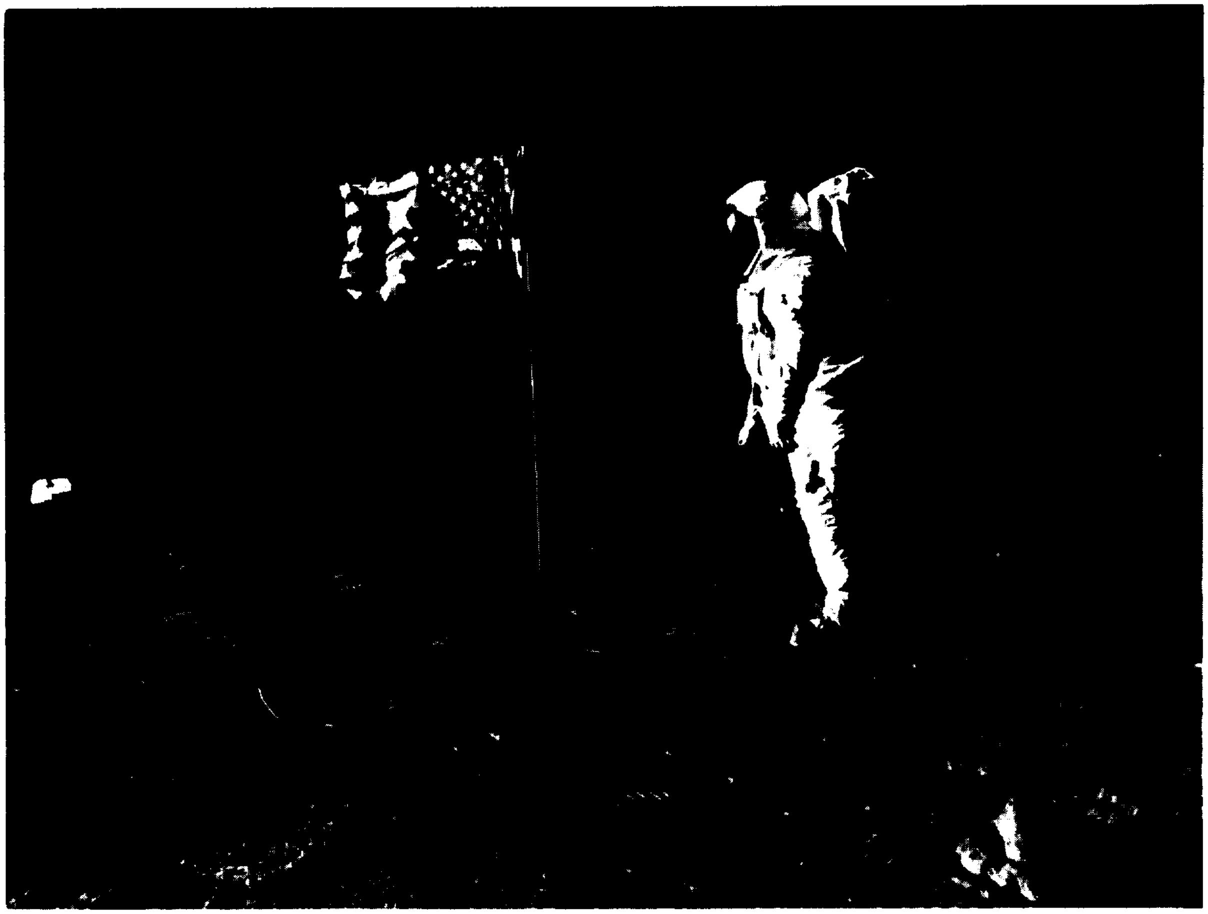
The major elements of the recommended civilian space program include the early development and operation of a permanent manned station in near-earth orbit to provide experience on long-duration manned flight, practical benefits through observation of the earth and its environment, and scientific research. A new and truly low-cost space transportation system is an integral part of the space station concept. Manned exploration of the moon will be extended in scope and economically supported by the new transportation system. A major element of the recommended program is planetary exploration with continuing missions to the near planets, Mars and Venus, followed by missions to Jupiter and the outer planets, Saturn, Uranus, Neptune, and Pluto. A key scientific objective of this exploration will be the search for extraterrestrial life. Manned expeditions to Mars could begin as early as 1981.

The recommended program includes sustained efforts in space astronomy, physics, and biology, relying heavily upon the space station and transportation system. An aggressive program to develop practical applications of space technology will lead during the decade to means for more effective control of our environment and exploration and management of our resources, as well as to new services in communications, navigation, and air-traffic control.

The initial accomplishments of this program will be followed by space stations in polar and synchronous orbit contributing to earth resource surveys and to astronomy; by space station modules combined into a permanent space base employing 50 to 100 men for laboratory research and engineering in space; by space stations in lunar orbit and on the surface that greatly increase the scope and efficiency of our exploration of the moon; and by solar system exploration aimed toward the eventual utilization of man's expanded environment.

In response to the challenge of the Soviet Sputniks, the United States created the National Aeronautics and Space Administration. It has taken a decade for this country to regain world-wide recognition of its leadership in technology and science, a decade in which the space program has accepted difficult challenges and has met its commitments.

We now recommend new commitments -- bold new visions -- a set of goals and objectives that will give purpose and direction to the space efforts of government, industry, and the scientific and educational communities, and that will lead to spiritual and practical benefits to our society.



II INTRODUCTION

Man has left the earth, visited and explored another world a quarter of a million miles away, and returned safely. This will stand as the greatest and most far-reaching achievement of our time. History will refer to our generation as the one that ushered in the Space Age, and in the course of a single decade not only opened up vast reaches of space to man's machines, but made them accessible to man himself. A movement has been started which will not stop, and which will in the course of time extend man's domain throughout the solar system.

Already that movement into space has produced a wide range of benefits. (Values of the space program are discussed in Part VI.) Better weather forecasting, routine intercontinental communications via satellite, improved mapping of the earth's surface, all-weather day or night navigation by satellite, a better understanding of our atmosphere and space environment, and the beginnings of surveying a great variety of earth's resources are among the practical benefits afforded by man's venture into space. Equally significant has been the space effort's stimulus to the advancement of a broad range of technology.

Satellites and space probes have investigated and explored the earth, its atmosphere, interplanetary space, the moon and planets, the sun, and stars. These investigations are proving to be very important in advancing human knowledge. The field of geophysics has become not just a science of the earth, but of all the planets in the solar system. Earth itself is opened up to observation in the entirely new perspective achievable from space. Astronomers, no longer confined to the narrow visible and radio windows of the atmosphere, can observe across the entire spectrum in wavelength regions in which theory indicates the most important information about the birth, evolution, and demise of celestial objects must lie, and in which discoveries so far go beyond what existing theory can explain. In space the physicists and the bioscientists have in effect a vast laboratory in which to experiment with weightlessness, hard vacuum, solar plasmas, and extremely high-energy cosmic ray particles.

These present and near-term results of the space program are substantial. The value of space applications alone, including long-term weather forecasting, has been placed by a number of study groups at billions of dollars annually. Yet while these more immediate returns are important and must be a significant consideration in our present planning, of greater import will be the long-range effects of space on mankind.

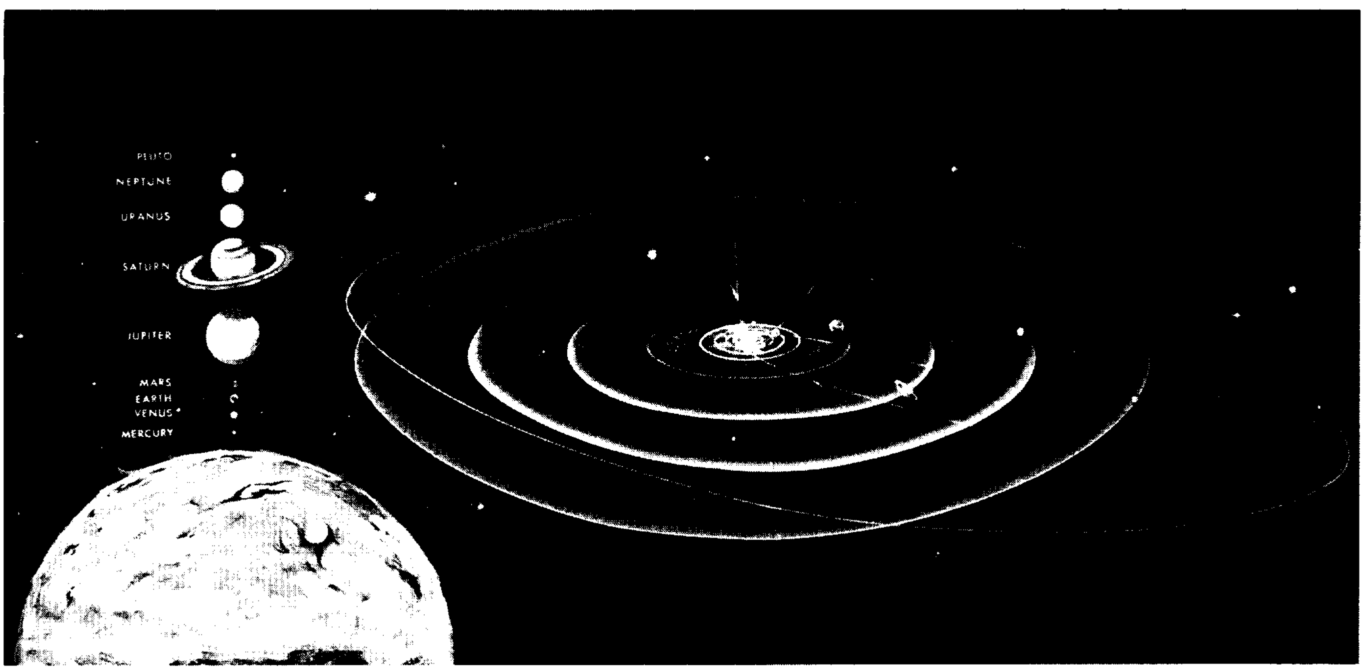
History teaches over and over that the long-range results of great human ventures are often, perhaps usually, of greater importance to human advancement than are the short-term values, even though the shorter-term values may have been the initial driving force. The ancients developed writing and the alphabet primarily to keep commercial records, but the long-term contribution to the development of literature, thought, science, religion, government,--indeed the whole spectrum of human intellectual activity,--far transcends the initial values. The European Age of Exploration was motivated by the quest for new trade routes, and the search for silver and gold. But in the long run, the great value to humankind is represented by the settling of North and South America and the development of the new society that was erected there,--a society which revolutionized western civilization and indeed the world, and is now opening the way to other new worlds.

This report is concerned with the next decades in space, but more importantly with where the next decade can and should lead us in the longer run. In this connection it is important to note that the achievements of the first decade in space are a direct result of proper concern with the longer-range implications of what we initially undertook in space. Russia's first Sputnik shocked us as a country and raised some basic questions as to whether we really were the pioneering people we had thought, and whether we actually had the technical pre-eminence that we assumed. The National Aeronautics and Space Act of 1958, although sparked by Sputnik and seeking to respond to the immediate challenge, went far beyond the immediate problem to our long-term capabilities in and use of space.

The wisdom that went into formulating the Act is attested to by its durability. The goals and objectives stated eleven years ago are still valid. The authorities and instructions of the Act, together with the early steps taken to put them into effect, set the stage for the remarkable accomplishments of the first decade in space. The Eisenhower Administration, in addition to calling for a broad spectrum of science and applications missions, early made the decision to proceed with manned space flight in the form of Project Mercury. The experience and knowledge gained from working on the Mercury project made it possible for President Kennedy to decide to undertake the Apollo project. Here again, although simply described as a project to land men on the moon and return them safely to earth, although sharply motivated to meet competition by the Soviets, the total objective was much broader. The Apollo project was undertaken to spur technology, to open up space to man, and to develop a powerful and versatile national capability to operate in and use cislunar space.

The individual tasks that the Nation set before itself in the first decade of the Space Age have been accomplished, including the development of a broad national space capability. Our hard-won capability now opens up to us a great variety of new opportunities in space for exploration, science, applications, and technology advancement. The country is now faced with a decision as to what it will do next in space, and as to the kind of program it should have during the next decade. These decisions will be as important for the next decade as were those early decisions at the start of the first decade. They will be crucial with respect to America's position of leadership in space exploration.

The crucial decision will not be in the area of the use of space. We will, of course, use our space capabilities for science, applications, and the advancement of technology. Such uses will always constitute a near-term and quite proper return on our investments in space, and clearly should always be a substantial part of our space effort.



THE SOLAR SYSTEM

The crucial question will be what to choose as America's future role in following through on the opening up of the solar system to man, begun with the landing of American astronauts on the moon. We have established what may be characterized as an initial foothold in space. Man will go farther. Will America still be in the lead? Man will permanently occupy cislunar space, and eventually extend his domain to the other planets of the solar system. In the decade to come, there lies before us the possibility of discovering extraterrestrial life, a discovery that probably would rank as the greatest scientific event of the century. Will America continue to lead, or will some other nation build on what we started?

The next natural step for us to take in space will be for us to create permanent space stations in Earth and lunar orbits with low-cost access by reusable chemical and nuclear rocket transportation systems, and to utilize these systems in assembling our capability to explore the planet Mars with men, thereby initiating man's permanent occupancy of outer space. The key to carrying out this step in an effective and efficient manner will be commonality -- the use of a few major systems for a wide variety of missions; reusability -- the use of the same system over a long period of time for a number of missions; and economy -- the reduction in the number of "throw-away" elements in any mission, the reduction in the number of new developments required, the development of new program principles that capitalize on such capabilities as man-tending of space facilities, and the commitment to simplification of space hardware.

There are two kinds of challenges here: the ever present, slowly yielding challenge of nature, and the drive of the Soviet Union for domination of the world. From meeting the former challenge we develop many of the intrinsic values of our efforts in space, while meeting the second challenge maintains for America a very necessary standing in the world community in which a strong America contributes substantially to world stability.

The Soviet challenge is not trivial. The USSR has a long list of impressive space firsts, including the first man in orbit. Where the United States has led, it has been by virtue of vigor and industry as well as competence. The Soviet program has been expanding steadily for many years, and it is comparable in size and scope to our own. Although there has been a hiatus in Soviet manned space flight activity, it is clear from Soviet statements and from their rendezvous and crew-exchange dual manned flights, that the USSR is preparing for significant advances in this area. For the last few years the Soviets have consistently launched more earth-orbital missions than we have. They achieved the first circumlunar, soft landing, and orbital missions to the moon, and from their own statements, continue to have a strong interest in lunar exploration. From the very start of the space program, their planetary effort has been many times ours, and is recently achieving spectacular successes. Although we developed space applications much earlier than the USSR, in recent years the Soviets have made a number of practical applications of space. The Soviets clearly regard the space program as of value not only in itself, but also as a means of maintaining the image of Soviet strength in the eyes of the world. It must be assumed that the Soviets will continue to strive for leadership for a variety of reasons, and especially to minimize for America both the current benefits of world standing and the future plaudits of history.

This report recommends a future course to take in our national space program: the kind of course that will both keep America at the forefront of space exploration and development, and also provide a steady flow of returns in science, applications, and technology from our national investments in space. To achieve this, a national commitment to the dual purpose of steady progress in opening up the solar system to mankind and the utilization of space for human benefit is required. The pace at which we achieve our ends may have to be varied as the broad spectrum of national needs dictates, but by adhering to these long-term commitments we can choose our near-term program so as to give us both immediate returns and progress toward the longer term goals.

III CURRENT PROGRAM AND NATIONAL CAPABILITIES

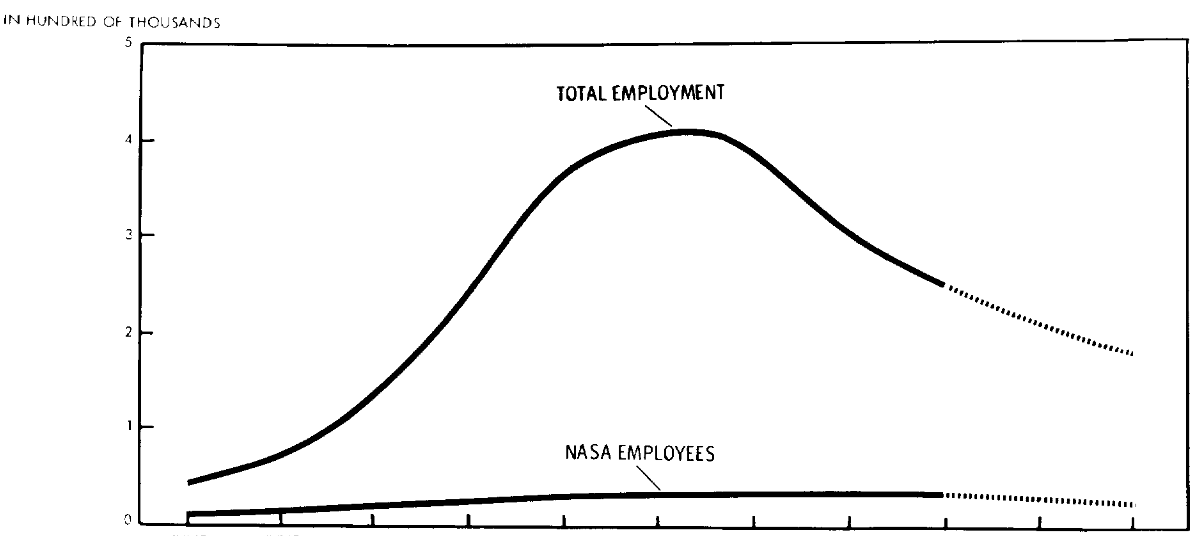
General

In the 11 years since its creation, NASA has conducted a vigorous program of space exploration and application, and has created a broad capability for future U.S. achievements. Plant facilities and equipment worth $4.5 billion have been put in place, as many as 90,000 scientists and engineers have been employed, and over 20,000 industrial firms and 100 universities have been involved in space ventures. Current space programs continue to exercise and develop this Nation's space capabilities.

During its first decade the American space program progressed from the 31-pound Explorer I in earth orbit to Apollo spacecraft weighing 50 tons sent out to the moon; from manned flights of a few thousand miles and 15-minute duration to the 500,000 mile round trip 8-day mission which landed men on the moon and returned them safely to earth; from the rudimentary data of Vanguard to the sophisticated Nimbus and TIROS operational weather satellites used by 50 nations; and from a passive Echo balloon to a commercially successful communications satellite system relaying real-time television around the world.

These accomplishments have involved peak annual expenditures of almost $6 billion, now reduced to about $4 billion; and a peak civil service and contractor work force of 420,000 people, which will be reduced to about 190,000 by the end of FY 1970.

TOTAL EMPLOYMENT ON NASA PROGRAMS



	JUNE 1960	JUNE 1961	JUNE 1962	JUNE 1963	JUNE 1964	JUNE 1965	JUNE 1966	JUNE 1967	JUNE 1968	JUNE 1969	JUNE 1970
TOTAL EMPLOYMENT	46,786	74,577	137,656	246,304	379,084	409,900	393,924	306,926	267,871	218,345	188,600
CONTRACTOR EMPLOYEES	36,500	57,500	115,500	218,400	347,100	376,700	360,000	273,200	235,400	186,600	157,000
NASA EMPLOYEES	10,286	17,077	22,156	27,904	31,984	33,200	33,924	33,726	32,471	31,745	31,600

Manpower

The Nation's most important resource in NASA is its staff of trained and experienced professional employees. The composition of this staff in occupational categories is shown in the adjacent table. They in turn are closely linked to effective teams in industry and universities which multiply their capabilities many times over.

COMPOSITION OF PERMANENT STAFF BY OCCUPATIONAL GROUP

OCCUPATIONAL GROUP	1968 Number	1968 Percent	1969 Number	1969 Percent	1970 Number	1970 Percent
Professional Scientists and Engineers	13,933	42.9	13,706	43.2	13,707	43.4
Technicians	4,399	13.6	4,563	14.4	4,515	14.3
Wage Board	4,515	13.9	4,166	13.1	4,148	13.1
Professional Administrative	4,393	13.5	4,273	13.4	4,218	13.3
Clerical	5,231	16.1	5,037	15.9	5,012	15.9
TOTAL	32,471	100.0	31,745	100.0	31,600	100.0
Undistributed Agency Reduction					-100	

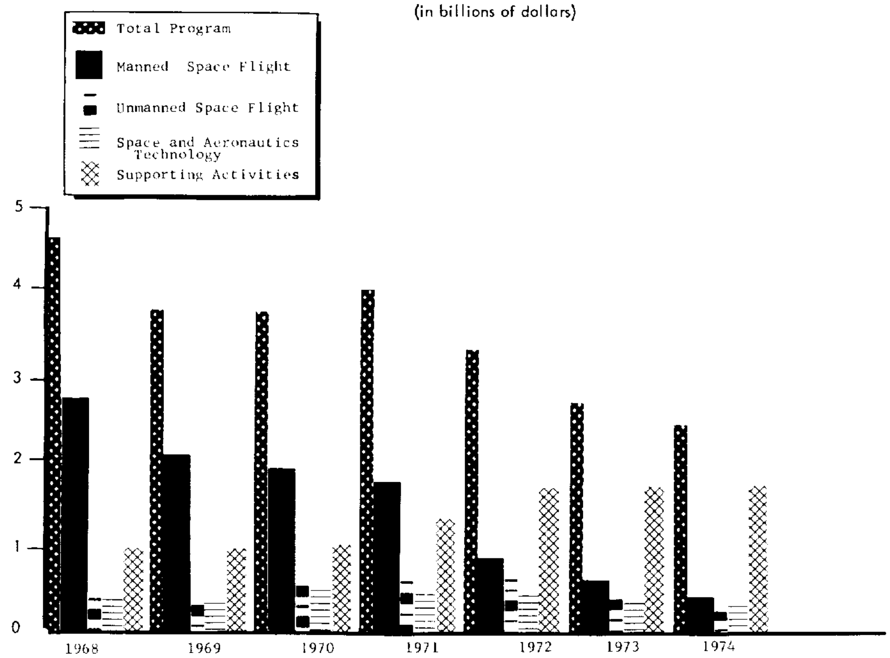
Facilities

Our national space capability rests also on a broad base of facilities and equipment in both government and industry. Space facilities which make it possible to manufacture, assemble, check out, launch, and operate both manned and unmanned spacecraft are now a national resource in being that can be applied to the further development and use of space. The NASA facilities and equipment, which comprise a substantial fraction of this total capability, include five research centers, five space flight centers, the Jet Propulsion Laboratory, and five major special test and development installations. The accompanying pictures and captions serve to illustrate the extent and diversity of this valuable national resource.

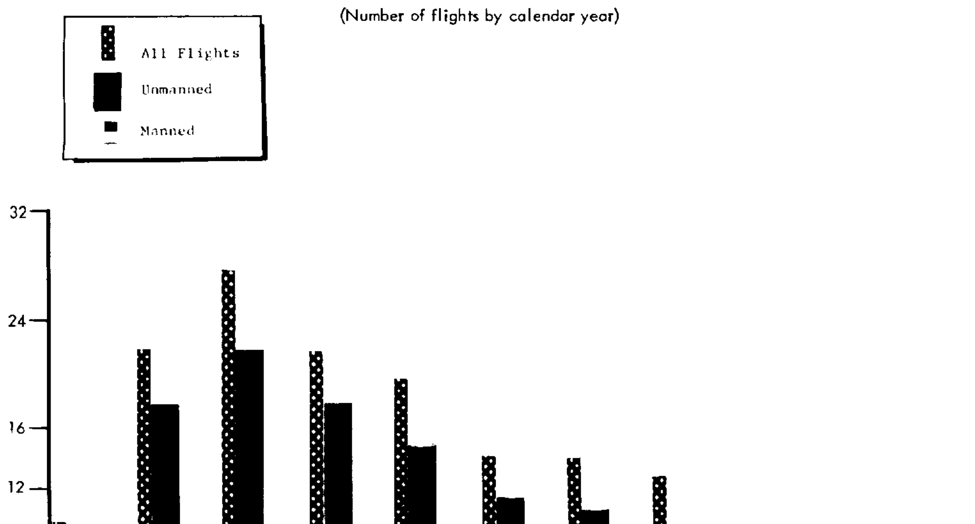
Current Program

The main thrust of our national space program during the first decade was to develop a space capability and to apply it to a variety of uses for science, applications, and technology. The Nation has succeeded in establishing such a capability and using it to land men on the moon and bring them safely back; to conduct scientific investigations of the sun and planets, including earth and moon, and of the stars and galaxies; to experiment with terrestrial life in space; to study man under the conditions of space flight; and to make numerous space applications in the fields of meteorology, communications, navigation, geodesy, and earth surveys. The current program continues previous efforts, but more importantly seeks to lay the groundwork for future, more diversified and productive activities in space. NASA's recent budget and flight activities from 1968 to 1970, and its present commitments, are summarized in the adjacent charts.

NASA FUNDING 1968 - 1974
PROGRAM RUN-OUT COSTS
(in billions of dollars)



FLIGHT SCHEDULE
(Number of flights by calendar year)



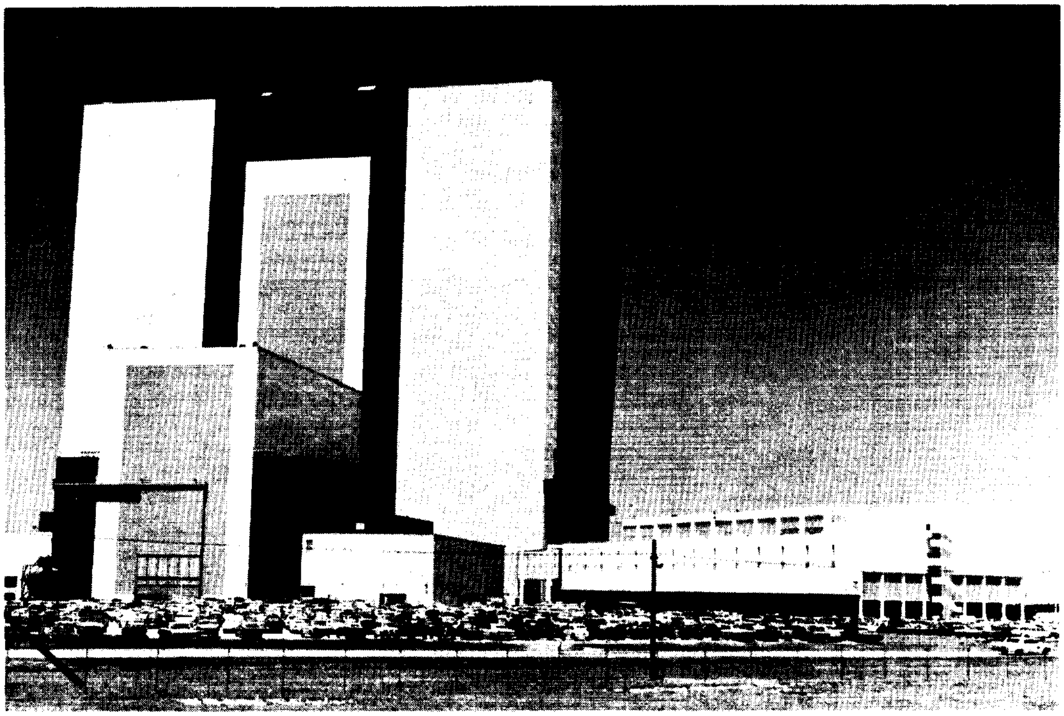
*Annual averages for years specified.

Earth orbital manned space flight. The eventual goal of this effort is the establishment of large, permanent, manned orbiting bases in earth and lunar orbits; the first step would be an orbiting space station module.

Mercury, Gemini, and the earth orbital phases of Apollo have taken the initial steps toward the development of a permanent space station. In the process a number of engineering, medical, geophysics, and astronomy experiments were carried out. Among the most exciting results was the earth photography which, together with TIROS, Nimbus, and Applications Technology Satellite weather pictures has shown clearly and dramatically how important earth observation may be to the discovery, development, and wise management of our earth's resources. On such photographs it is possible to see glaciers, snowfields, total water-sheds, geological provinces, ocean situations, forests, agricultural activities, and even the growth and development of cities and their land use in a broad perspective that is not achievable from the ground or from aircraft.

JOHN F. KENNEDY SPACE CENTER, FLORIDA

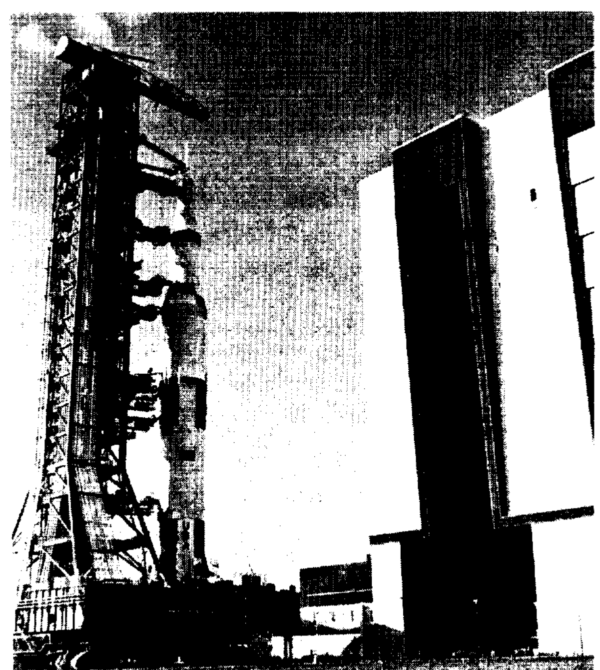
Seen above is an aerial view of a portion of the Kennedy Space Center's industrial area. Kennedy is NASA's prime launch facility.



JOHN F. KENNEDY SPACE CENTER

Kennedy Space Center's massive Vehicle Assembly Building is one of the world's largest buildings.

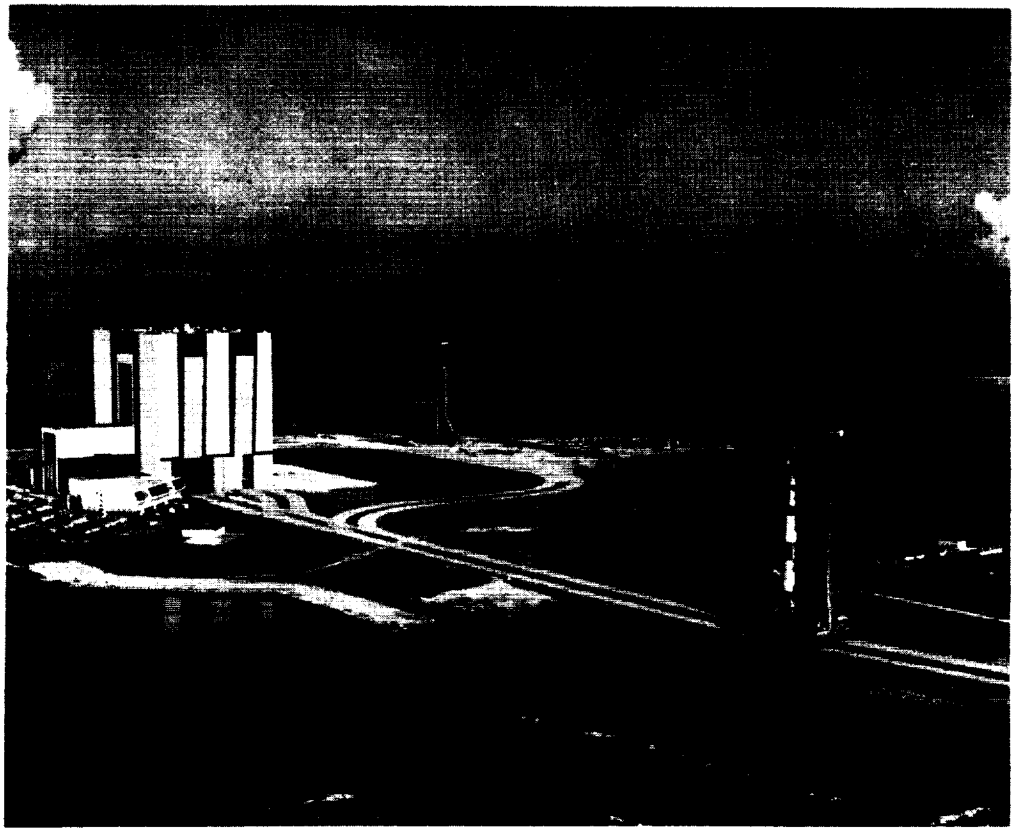
The core of the current earth orbital manned flight effort is the Apollo Applications Program, with flights scheduled to begin in 1972. These flights will use existing hardware and systems to extend manned operations in earth orbit. A workshop will be used to gain experience and knowledge applicable to the design and construction of a space station and in planning for its use. The workshop will be installed in the upper, unfueled stage of a Saturn V launch vehicle using the hydrogen tank as an external structure, and will include operating subsystems for power, life support, thermal control, and experiments to serve as the nucleus of an embryonic space station. An airlock and a docking adapter attached to the primary workshop will be carried in the launch vehicle's adapter section.



JOHN F. KENNEDY SPACE CENTER

The 363 - foot tall Saturn V-Apollo 8 space vehicle is being moved on the crawler-transporter from the Vehicle Assembly Building toward Launch Pad 39A preparatory to launch.

The workshop will provide a means for experimenting with the use of man for doing scientific research in space. A manned solar observatory attached to the docking adapter will incorporate high resolution solar telescopes and spectrographs for observing phenomena on the surface and in the corona of the sun. In addition to obtaining scientific information about the sun, the experiment will provide data for the planning and design of future manned space science experiments.

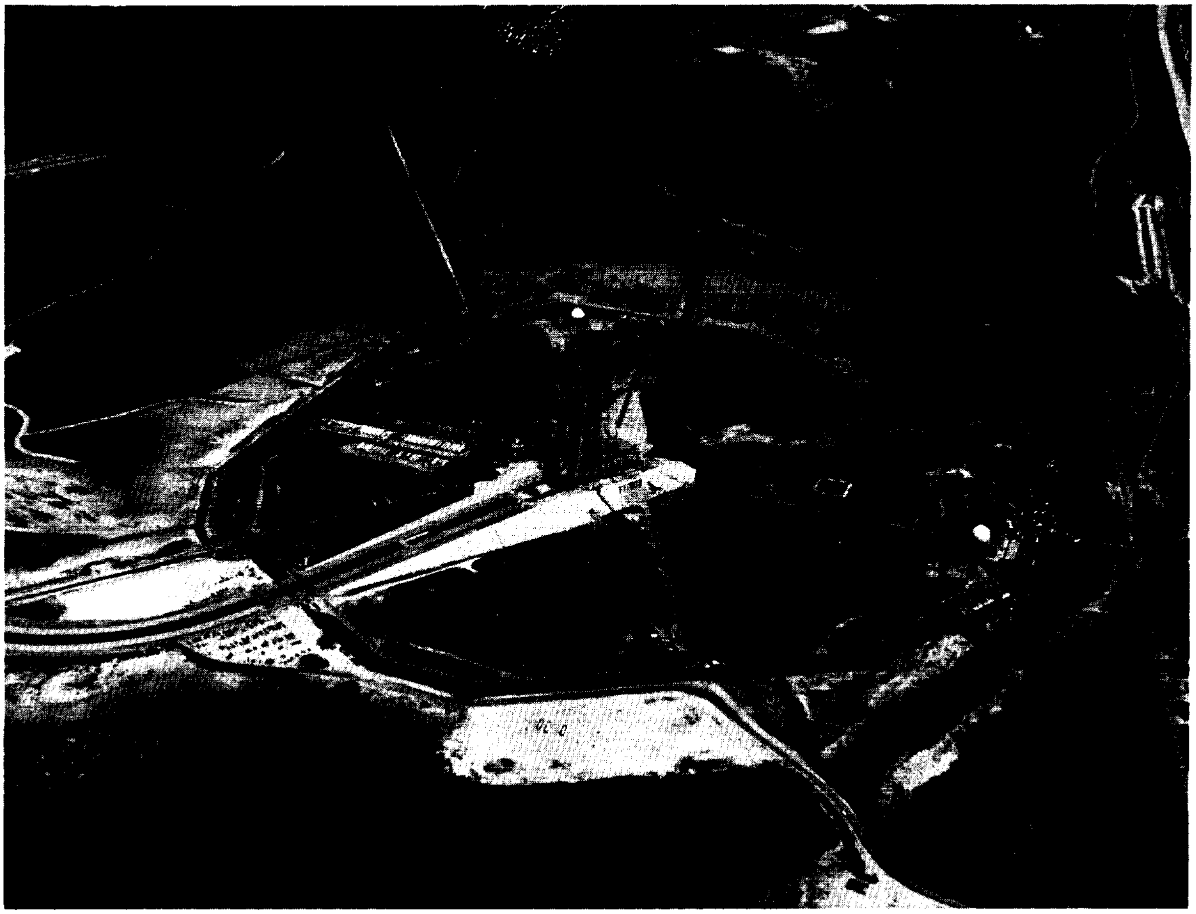


JOHN F. KENNEDY SPACE CENTER

Kennedy Space Center's Vehicle Assembly Building, one of the world's largest buildings is shown above. The Saturn-bearing crawler is seen at the right.

The workshop will be revisited by astronaut crews at several intervals over the span of a year. This will be the first flight test of the concept of reusing a habitable space structure after a period of several months of untended stay in orbit. The initial manned mission is to last 28 days. A manned-flight duration of 56 days will be the next logical step in the progressive extension of mission length and will test the ability of men and equipment to function effectively for longer periods in space. Another 56-day mission will complete the workshop activities. In addition to the work with the solar observatory, the primary in-flight experiments will be medical and will deal with physiological and psychological evaluations of man's functions and task performance capabilities in space.

The flight schedule supported by the FY 1970 budget will have the initial workshop launching and all three manned visits in 1972.



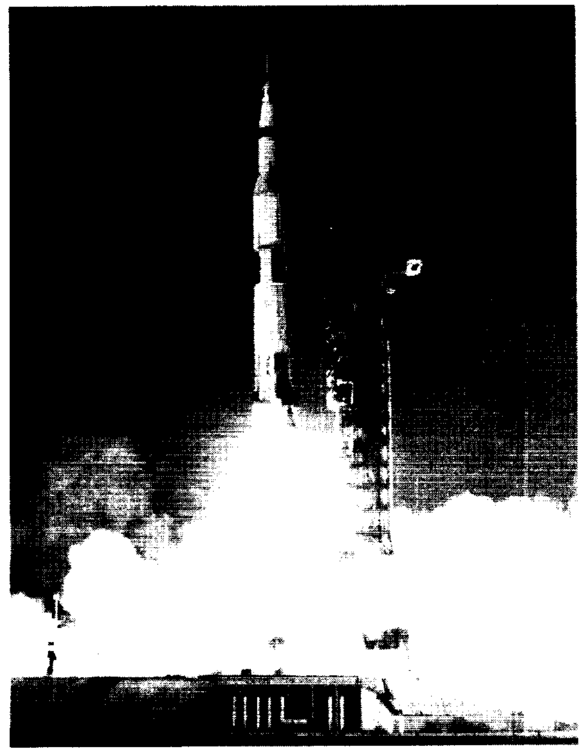
JOHN F. KENNEDY SPACE CENTER

Launch Pad 39A is one of the two pads from which Saturn V-Apollo flights are launched.

Lunar exploration. Our study of the moon is to learn what we can about the origin and history of the solar system, and to lay the groundwork for possible future use of the moon as a scientific observatory or space base. Ranger and Lunar Orbiter spacecraft have photographed almost the entire lunar surface and given important information on the moon's gravity field. Surveyor landed at several spots, giving close-up photographs of the lunar terrain and surface material, information on its ability to sustain a landing, and with equipment operated and commanded from a quarter of a million miles away poked and prodded and dug and analyzed to measure the physical, magnetic, and chemical properties of the lunar material. These data, important in the scientific study of our nearest neighbor in space, were also put to use as fast as they were acquired in checking the Apollo design, in preparing maps of the lunar surface and selecting sites for actual manned landings, and in designing and planning the mission itself. Apollo, with its close-in photography, direct personal observations, collection of lunar samples for laboratory analysis and study, and emplacement of research equipment on the surface, greatly extended the exploration begun with unmanned devices.

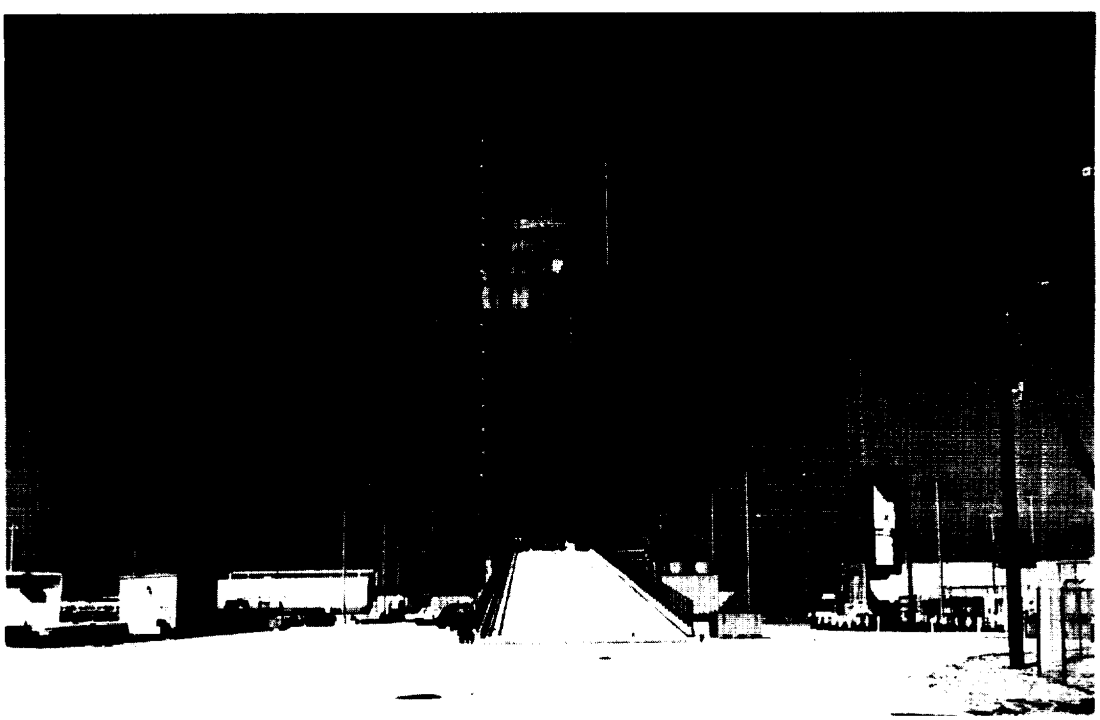
The current plan is to continue manned lunar exploration using the Apollo procured launch vehicles and spacecraft. Beyond the first lunar landing mission, there is sufficient hardware, procured under the Apollo program, for eight additional lunar landings, extending into the 1972 time period. In order to increase the scientific return from these missions, it is planned to increase the staytime of the lunar module from about one day, for the first three or four of these flights, to three days for the final ones.

The early missions will deploy the Apollo Lunar Surface Experiment Package. The objectives of this phase include the establishment of a seismic network, geologic investigation of regional areas (maria and highlands) and the development and use of rough terrain and point landing capabilities



JOHN F. KENNEDY SPACE CENTER

The 363-foot high Saturn V space vehicle lifts off on the start of the Apollo 8 lunar orbital mission.



JOHN F. KENNEDY SPACE CENTER

Kennedy Space Center's Launch Complex 36 is the Centaur launch vehicle facility for unmanned, scientific and applications missions.

MANNED SPACECRAFT CENTER, HOUSTON, TEXAS

Manned Spacecraft Center is NASA's principal installation for manned spacecraft development, astronaut training, and mission control.

The second phase of lunar exploration will continue the investigations initiated in the one-day staytime phase with improvements to allow staytime up to three days and improved mobility. Remote sensing instruments will be employed during the Command and Service Module (CSM) orbital operations. The range of extravehicular activities will be increased to approximately two miles during extravehicular activity periods adding up to approximately 24 hours.

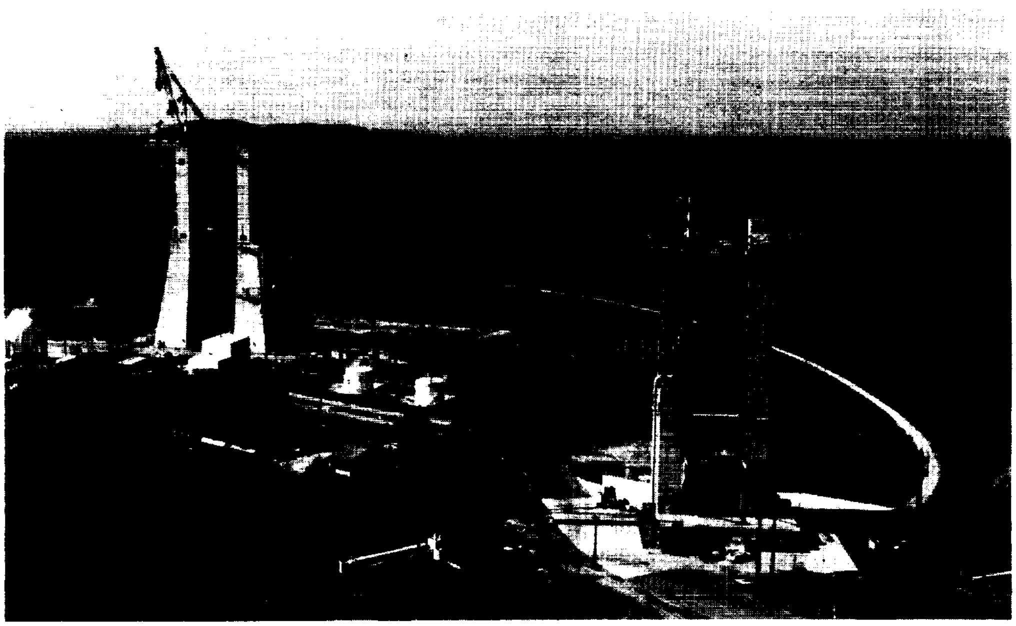
CONTROL ROOM OF MISSION CONTROL CENTER, MANNED SPACECRAFT CENTER

The Manned Spacecraft Center's Mission Control Room is world famous as the guidance and control center for NASA's manned space missions.

MARSHALL SPACE FLIGHT CENTER, HUNTSVILLE, ALABAMA

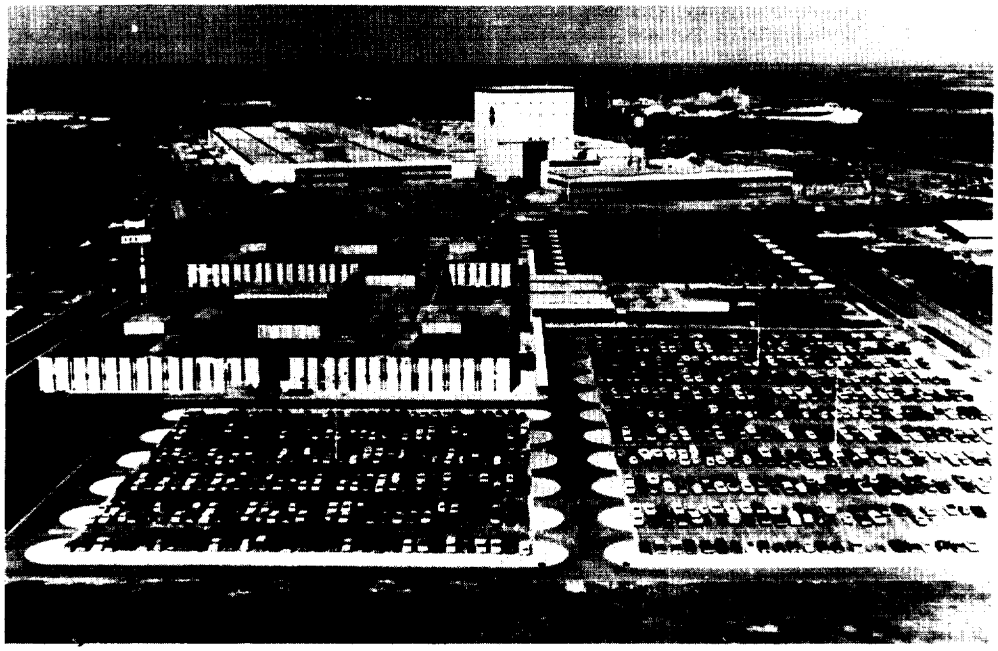
Administration and manufacturing area.

The third set of lunar missions will be characterized by greatly expanded lunar surface mobility and continued orbital observations in conjunction with and following the surface activity. During the three-day staytime the radius of surface activity will be extended by use of a small lunar flyer or rover. The CSM will employ a variety of instruments such as cameras and other remote sensors to study the surface features of the moon in order to supplement the data returned from surface measurements.



MARSHALL SPACE FLIGHT CENTER

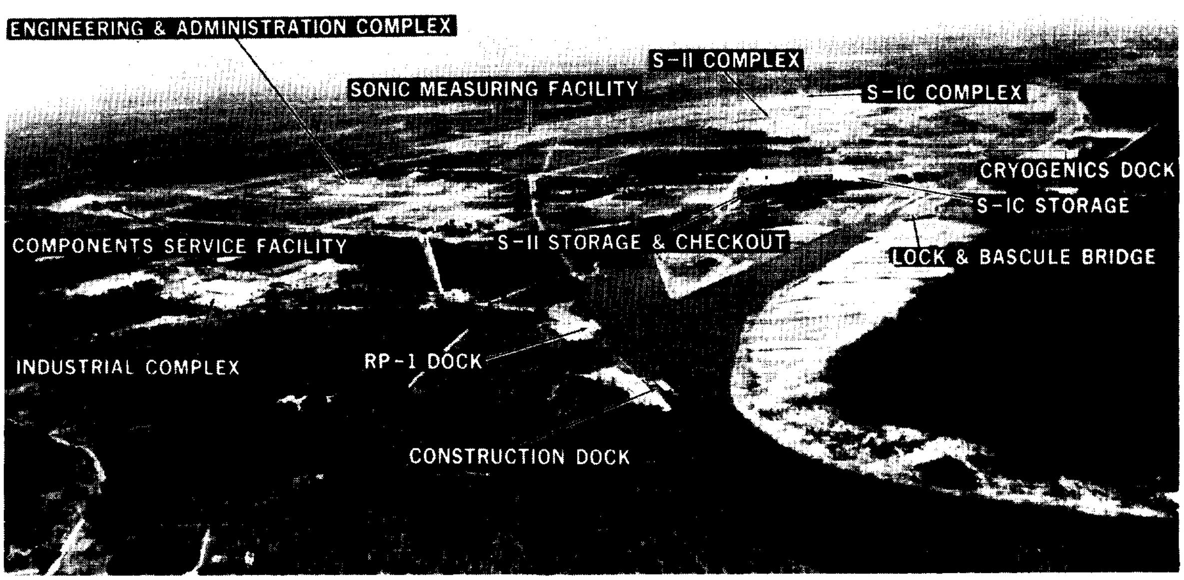
Saturn V rocket stage and engine test stands.



MICHOUD ASSEMBLY FACILITY, LOUISIANA

Michoud Assembly Facility is the Marshall Space Flight Center's launch vehicle fabrication site near New Orleans.

The information obtained during the currently approved lunar exploration program will provide a basis for detailed planning of subsequent activity to provide greater exploration staytimes. Greater exploration staytimes can be achieved through surface sorties from polar lunar orbiting space stations supplied by resuable nuclear transfer stages from earth orbit, or, ultimately, by deployment of lunar surface bases for extended surface operations.

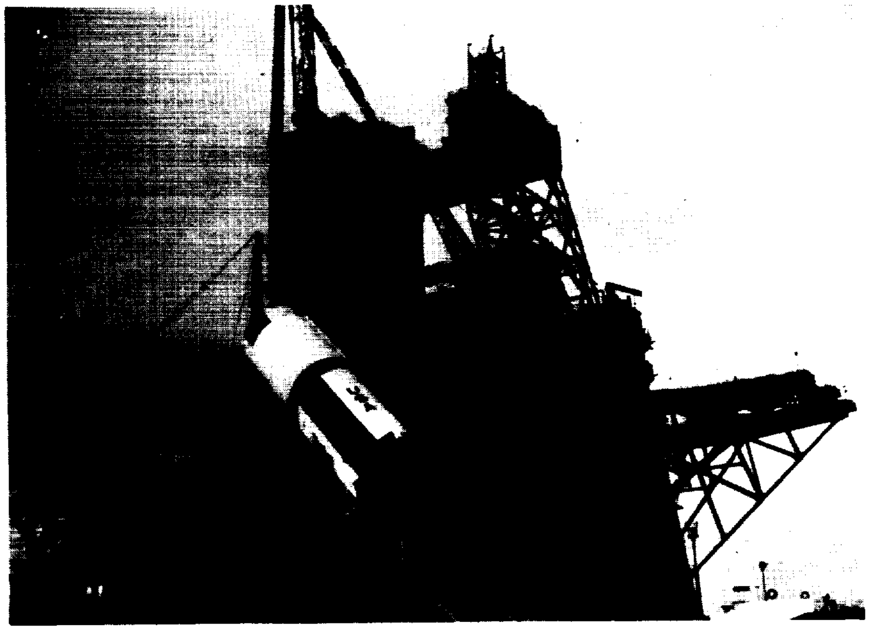


MISSISSIPPI TEST FACILITY

The Mississippi Test Facility, located 50 miles northeast of New Orleans, is where the first and second stages of the SaturnV launch vehicle are tested prior to shipment to Cape Kennedy.

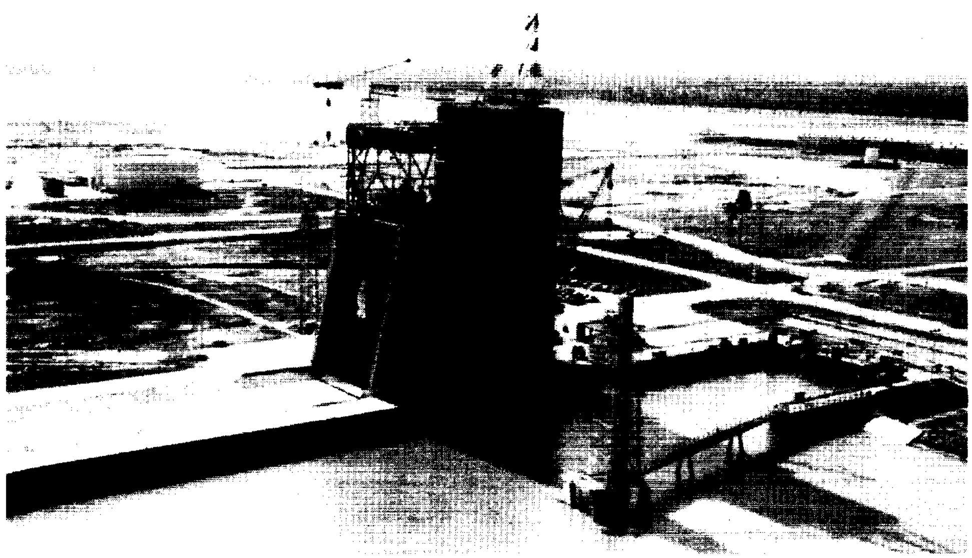
The current flight schedule following the initial Apollo landing as supported by the FY 1970 amended budget is:

1969 - 1 flight	1970 - 3 flights	1971 - 2 flights	1972 - 2 flights



MISSISSIPPI TEST FACILITY

The first stage of a Saturn V launch vehicle being hoisted into place at the Saturn V first stage test stand.

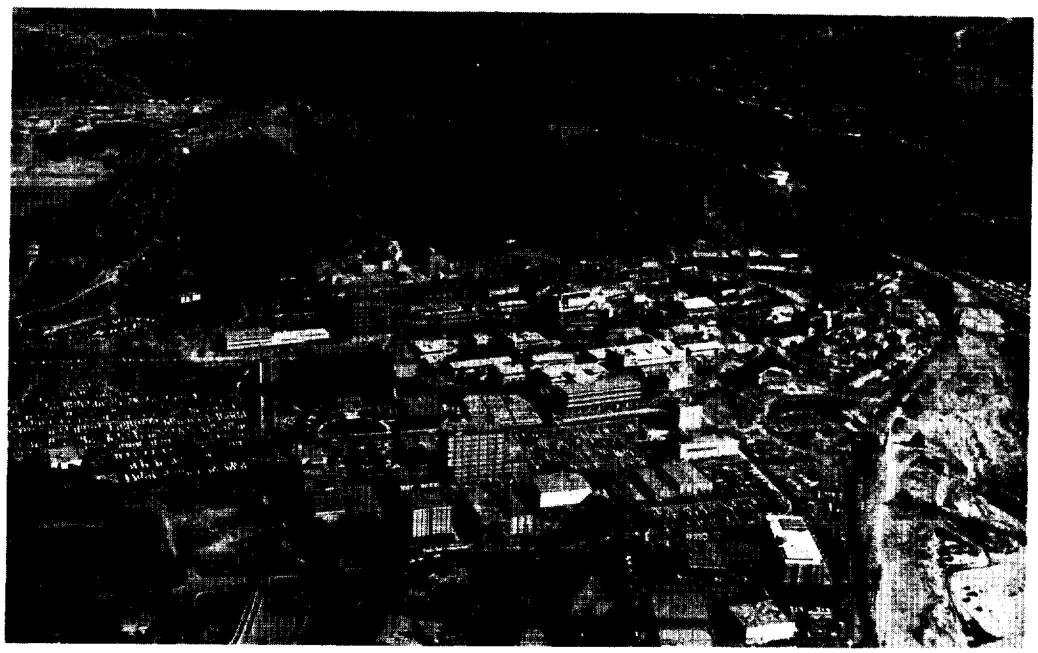


MISSISSIPPI TEST FACILITY

The second stage of the Saturn V launch vehicle is tested on this stand.

Planetary exploration. Of great importance in the investigation of our solar system is our ability to study not just planet earth, but many planets, not just earth's atmosphere but planetary atmospheres, and not only sun-earth relationships, but sun-planetary relationships. The broader perspective so afforded gives us a better insight into our own earth and into how we might go about tackling some of the problems of our environment and the wise management and use of earth's resources.

Most exciting of all is the possibility that life may be found on the planet Mars. Should extraterrestrial life be found on the Red Planet, this would be one of the most profound results from the space program, and would probably rate as the most significant scientific discovery of the century. But, even if life does not exist on other planets, the study of their chemical evolution should be helpful in the continuing investigation of the origin of life on earth.



JET PROPULSION LABORATORY, PASADENA, CALIFORNIA

The Jet Propulsion Laboratory consists of advanced facilities for propulsion research, research on the lunar, planetary and interplanetary sciences, management of the Mariner/Mars spacecraft, and operation of the Space Flight Operations Facility for the tracking of deep space missions.

Over the past decade in a partnership between the Mariner space probes and ground-based studies, we have shown that Venus, which is almost a twin to Earth in size, has about 100 times the amount of atmosphere that the Earth does. Soviet probes have established that the Venus atmosphere is composed mostly of carbon dioxide, with a little oxygen and water vapor. The surface of the planet is 800 to 900 degrees Fahrenheit, well above the melting point of lead. The planet has a very slow rotation rate (243 days) in the opposite direction to that of the earth, and no appreciable magnetic field. As a consequence Venus does not have a magnetosphere, and the cavity created in the solar wind, being generated by the planet itself and its atmosphere, is different in character from the magnetosphere of the earth. Thus Sun-Venus relationships are decidedly different from Sun-Earth relationships in which the magnetosphere plays a significant role.

Mars has also been observed by Mariner spacecraft. The planet, which is decidedly smaller than either Earth or Venus, also has no appreciable magnetic field and hence no magnetosphere. Its atmosphere is very thin, with a surface pressure of about one percent of that of the earth's sea level atmosphere. Solar radiations create an ionosphere on Mars as they do on Earth. With no magnetosphere, and a very thin atmosphere, most of the effect of Mars on the solar winds is due to the planet body itself, although some effect comes from the thin atmosphere.

The current planetary program is concentrated on Mars flights, two Pioneer missions (Jupiter flyby flights) and a Mariner-sized Venus-Mercury flyby. In 1969, Mariners VI and VII returned excellent pictures of Mars' equatorial and south polar regions, revealing numerous craters and the structure of the south polar cap. Other instruments on these flights have indicated that the polar cap is mostly frozen carbon dioxide, probably with some water ice. In the flights to Mars, there are approved plans for Mars orbiters in 1971 and Mars lander/orbiter (Viking) missions in 1973. The 1971 Mars orbiters will be our first spacecraft to orbit a planet and to obtain visual and infrared mapping of the surface. The 1973 Mars lander will present our first opportunity to discover life, if it exists, on the planet Mars. In addition, it will be able to obtain in situ measurements of the atmosphere and surface environment. The results of these missions will be correlated with the results from ground and space observatories in a comprehensive study of the planet Mars.

The Pioneer flights will be launched into trajectories permitting the exploration of interplanetary space to distances five times as far from the Sun as is the Earth, including the Asteroid Belt and the magnetosphere of Jupiter. Additional Jovian measurements will include the properties of changed particles, magnetic fields, and radio frequency emissions.

GODDARD SPACE FLIGHT CENTER, GREENBELT, MARYLAND

The Goddard Space Flight Center, located 15 miles northeast of Washington, D. C., is responsible for the management of scientific and applications satellite programs and for the operation of the manned space flight and satellite tracking networks.

The Mariner-sized Venus-Mercury flyby will use a single spacecraft to observe both Venus and Mercury. The spacecraft will have provisions for obtaining ultraviolet and visual television pictures, atmospheric and ionospheric data, and thermal maps from both planets.

The flight schedule supported by the FY 1970 amended budget is:

	1969	1970	1971	1972	1973	1974
Mariner	Mars Flyby		Mars Orbiter (2)		Venus-Mercury Flyby	
Viking					Mars Lander Orbiter (2)	
Pioneer				Jupiter Flyby	Jupiter Flyby	

Astronomy. On the ground we live beneath an atmosphere that blankets out most of the electromagnetic radiations that come to us from the sun, stars, and other galaxies. Our theories tell us that the information that comes to us through that atmosphere in the visible and some radio wavelengths, exciting though it is, is very limited, and that much more information will be found in the ultraviolet, and infrared radiations. Thus telescopes and associated instruments have been sent above the atmosphere, first in sounding rockets and the Orbiting Solar Observatory, and now in the Orbiting Astronomical Observatory, the most complex and intricate unmanned satellite yet launched by man, to observe the universe in the hitherto hidden wavelengths. Already results are spectacular. The sounding rockets have revealed X-ray sources over the sky which are yet to be explained. The observatory measurements have shown some of the stars to be much brighter in the ultraviolet than had been supposed. One explanation of this may turn out to be that the known universe is twice as large as it had been thought to be.

The currently approved programs include missions to survey the sun with increasing resolution, and to investigate high energy X-rays, gamma rays, and cosmic rays, from stellar and galactic sources. Of particular importance will be the study of the nature of the physical processes giving rise to and modifying these radiations.

The program envisions the use of both automated and manned systems in the early seventies. The results of these missions would complement the results of ground-based observatories. The basic systems to be used are:

- The Orbiting Solar Observatory, a spin-stabilized satellite which consists of a sail section that points at the sun, and a wheel section that rotates beneath the sail to provide stability. Mounted in the sail section are solar-pointing and solar-scanning scientific instruments which measure the ultraviolet, X-ray and gamma-ray emissions of the sun, and observe other solar phenomena. The wheel section houses instruments for full sun or sky-mapping purposes; these instruments scan the sun once every two seconds, owing to rotation of the wheel.

- The Orbiting Astronomical Observatory (OAO), a spacecraft instrumented with telescopes and a variety of detectors to make astronomical observations from above the earth's atmosphere. Experiments carried on OAO missions will map the sky in the ultraviolet region, obtain moderate resolution spectrometer data of stars down to tenth magnitude, and carry out high-resolution ultraviolet spectral analyses of fainter objects.

- Small Explorer-sized spacecraft, to investigate specific phenomena such as radio emissions from space.

- The manned solar observatory -- discussed earlier as part of the Apollo Applications Program under Earth orbital manned space flight.

The flight schedule supported by the FY 1970 amended budget is:

	1969	1970	1971	1972	1973	1974	1975
Orbiting Solar Observatory	X		X	X		X	X
Orbiting Astronomical Observatory		X	X				
Radio Astronomy Satellite		X					
Small Astronomy Satellite		X	X		X	X	
Manned Solar Observatory (ATM)							

Space physics. Sounding rockets, Explorer and Orbiting Geophysical Observatory satellites, Pioneer and other spacecraft, have provided a wealth of information about the earth's upper atmosphere and ionosphere, and interplanetary space. One of the most exciting discoveries of space research has been that of the earth's magnetosphere, which occupies a huge cavity carved out of the solar wind by the earth's magnetic field. The solar wind, which also was first observed by space-borne instruments, consists of only a few particles per cubic centimeter, primarily electrons and hydrogen nuclei, with some helium nuclei, ejected into space by the sun. The solar wind sweeps by the earth at velocities of hundreds of kilometers per second. Being electrically charged, the solar wind particles are deflected by the earth's magnetic field, and an immense shock wave develops that sweeps around the earth in much the same way that an aerodynamic shock wave accompanies a supersonic aircraft. While the magnetosphere extends into space 10 to 20 earth radii from the sunlit side of the earth, in the direction away from the sun the earth's magnetic field lines are swept out by the solar wind to great distances, well beyond the orbit of the moon. Within the magnetosphere itself are the trapped radiations that comprise the Van Allen Radiation Belts which were discovered on the first U.S. Explorer satellites.

The existence of the magnetosphere was not known before it was revealed by satellite research, and even when the Van Allen Radiation Belts were discovered, its great complexity was still unsuspected. It is now known that the magnetosphere is connected in various ways with the aurora, magnetic storms, magnetic fluctuations, disturbances in communications, and even possibly with some weather anomalies. Its investigation is interwoven with studies of the earth's atmosphere on the one hand, and of the interplanetary medium and solar activities on the other.

Moreover, the regions of the magnetosphere and interplanetary space beyond comprise a vast laboratory in which fundamental physics researches may be carried out on relativity, the basic nature of gravity, and the interaction of extremely high energy particles with matter.

The current program is transitional in character, from the period of survey and discovery that characterized the first decade, to a period of investigating the underlying causes, mechanisms, and processes involved in solar influences on the interplanetary medium and planetary atmospheres, and to the conduct of controlled experiments in the environment of space.

The spacecraft to be used beyond 1969, except for the Helios project described below, will be small Explorer-class satellites which will perform a variety of missions. These spacecraft are launched on Scout and Delta class boosters. The Helios spacecraft, a solar probe to go closer to the Sun than the planet Mercury, will be designed and built by the German space agency; NASA will provide the Atlas-Centaur launch vehicle, launch and tracking support, and some of the onboard experiments.

The flight schedule supported by the FY 1970 amended budget is:

	1969	1970	1971	1972	1973	1974	1975
Pioneer	X						
Orbiting Geophysical Observatory	X						
Helios						X	X
Interplanetary Monitoring Platform	X	X	X	X			
Other Explorers	(3)	(4)	(2)	(2)	X		

Space applications--earth surveys. What began as simple experimenting with earth photography back in the 1940s has now blossomed into operational meteorological satellites, which provide daily pictures of the earth's cloud cover and infrared observations. These data are used routinely in improving one-day to two-day weather forecasts. Such weather pictures are given to trans-atlantic pilots to show them the weather to be encountered enroute. They have been used to save ships at sea by directing them out of the midst of storms into good weather conditions, and to manage field operations in construction and agriculture. They have made possible more accurate hurricane and storm warnings, with the resulting saving of lives and valuable property.

The current operational meteorological satellites, named ESSA for the Environmental Science Services Administration, stem from NASA's TIROS (Television Infrared Observational Satellite) research and development satellites. Now, to lay the groundwork for even more valuable meteorological applications, the Nimbus satellites in polar orbits of about 600 miles altitude, and Applications Technology Satellites in synchronous equatorial orbits at 22,300 miles altitude, are being used for advanced research and development. A recent breakthrough on the Nimbus III satellite, in which it was shown to be possible to obtain temperature profiles of the earth's atmosphere from satellite-borne instruments, gives encouragement to those who look forward to the day when a global meteorological satellite system will make long-range weather forecasting possible. The Applications Technology Satellites in synchronous orbit have shown that it is possible to keep watch on the development of hurricanes, typhoons, thunderstorms, tornado weather, and the whole range of weather conditions from large-scale long-term to small-scale short-term. The importance of this capability to improve weather forecasting is inestimable, but the ultimate value to agriculture, transportation, commerce, construction, etc., has been put at billions of dollars annually.

It has already been pointed out how various space photographs have emphasized the potential importance of earth observation to the survey and management of earth resources. Although use has already been made of such earth resource material, this is a field that is only now beginning to open up. NASA has a combined aircraft and Earth Resource Technology Satellite (ERTS) program designed to provide the basic information from which to determine which observations are best made in which manner, and especially to help evaluate the dollar returns that may be obtained from our investments in earth observations from space. The current program activity centers on the development of sensors and instrumentation in ground-based laboratories, aircraft, and earth orbiting satellites, to develop systems and techniques for collecting data on the earth's environment and resources, particularly in the areas of meteorology, oceanography, hydrology, and geology.

In addition to the instrumented aircraft, the basic systems to be used in this program are:

- Nimbus, an orbiting spacecraft designed to test advanced concepts and sensors for gathering weather data.

- The Synchronous Meteorological Satellite, designed to demonstrate the continuous observation of major weather systems and the dissemination of weather data to local meteorologists.

- The Cooperative Applications Satellite, designed and built by the French Centre National d'Etudes Spatiales to be launched by the Scout vehicle will test the use of instrumented balloons in conjunction with earth orbiting satellites for obtaining meteorological data.

- The Geodetic Satellite, designed to improve our understanding of the dynamics of the earth.

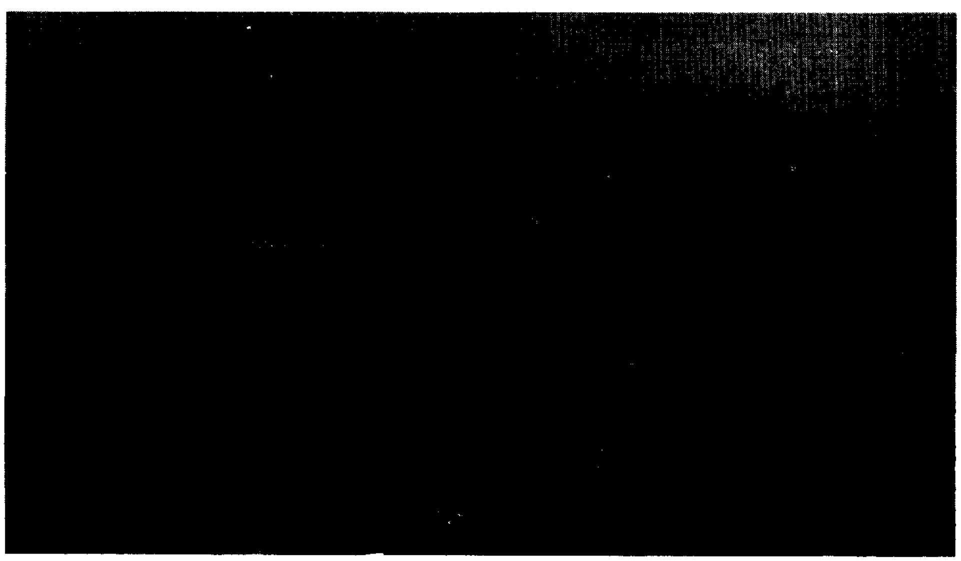
- The Earth Resources Technology Satellite, which will be designed to demonstrate the capability of various sensors. The initial spacecraft will be in the 1000- to 1200-pound range, with an experiment payload of 450 pounds, including a high resolution TV camera and a multispectral point scanner.

The flight schedule supported by the FY 1970 budget is:

	1969	1970	1971	1972	1973
TIROS	X				
Nimbus	X	X		X	X
Synchronous Meteorological Satellite			X	X	
Cooperative Applications Satellite		X			
Geodetic Satellite		X			
Earth Resources Technology Satellite			X	X	

Space applications--communications and navigation. Intelsat communications satellites in synchronous earth orbit now provide point-to-point communications services from continent to continent. Using them, major occurrences of international significance, such as political events, space missions, and sports competitions, can be seen around the world while they are actually happening. These communications satellites grew out of a wide range of satellite experiments, including those with Telstar, Relay, Syncom, and the large Echo balloon satellites which, looking like a bright moving star, have been seen by millions of people around the world.

The Intelsat spacecraft are bought and operated by the Communications Satellite Corporation, for which NASA provides launching services. The Comsat Corporation is the chosen manager for Intelsat, an international communications satellite consortium consisting of 68 countries. At the present time 17 countries have 26 ground stations in operation with the satellite system. By early 1970, 45 ground stations should have been installed around the world to operate in a total of 31 countries with the satellite portion of the network, and to interface with the ground-based communications lines that are necessary to complete the total net.



WALLOPS STATION, VIRGINIA

Wallops Station, located on the Atlantic Ocean about 100 miles southeast of Washington, D. C., consists of two major areas. The above is the main base which includes the range control center, administrative and support facilities, and the main telemetry buildings.

One can think of a wide variety of uses for a satellite communication capability. The Navy has developed and is using a navigation satellite system. NASA has been doing research on how such a satellite navigation capability may be made available to aircraft and private marine interests, including the very small user. For all these purposes the user's equipment must be small, lightweight, and inexpensive. Of particular importance in this connection is the matter of air traffic control. As is well known the problem in this area increases as traffic congestion grows day by day. NASA has been experimenting with its communications and applications technology satellites on continuous communications with transcontinental and transoceanic aircraft. The results of these experiments lead one to expect that space systems will be able to help in this important area.

WALLOPS ISLAND, VIRGINIA

The Wallops Station launch facilities for the Scout launch vehicle and for sounding rockets are located seven miles southeast of the main base on the ocean's edge.

With observations made on a variety of the artificial satellites that have been put into orbit, scientists have been able to improve our knowledge of the earth's gravitational field by many orders of magnitude. It has been possible to greatly improve the accuracy of positioning on the earth's surface, so that now the distance between continents is known to within approximately 25 meters. NASA's GEOS satellites with flashing lights and radio beacons have been of particular value in this area. These measurements will be of considerable practical value as we work to improve our charts of earth's natural and cultural resources.

The current program includes satellites to develop technology for communication, broadcasting, data relay, navigation and traffic control from space. The primary mechanism is the Applications Technology Satellite (ATS) in synchronous orbit. The program includes investigating newer frequency bands and means for reducing interference.

Current discussions may lead to an international program to develop a prototype Air Traffic Control and Navigation satellite on a cooperative basis with ESRO and the involved user agencies.

One ATS flight in synchronous orbit is scheduled in each year of 1969, 1972, and 1974, to conduct experiments, advance technology, and test developmental hardware pertinent to communications, navigation, and data collection.

Space biology. Space medicine, life support systems, and man-machine relationships, are all an integral and essential part of the development and use of manned space flight, and are included under the manned space flight and technology programs, particularly those concerned with the development of earth orbital manned space flight. The search for extraterrestrial life, one of the most exciting quests of the Space Age, is included under planetary exploration. But there are other aspects of the biological sciences to which the space program can contribute. Space experiments have shown that plants, insects, and other biological material are importantly affected by space conditions. Under weightlessness, radiation has markedly greater effects on some living matter than it does at the surface of the earth. Further work will be needed to understand fully the meaning of these results. Moreover, the importance of time as a factor in life processes may become clearer from experiments conducted in space away from the normal rhythms and periodicities of conditions at the earth's surface.

AMES RESEARCH CENTER, MOFFETT FIELD, CALIFORNIA

The advanced research facilities at the Ames Research Center, located about 40 miles south of San Francisco on the San Francisco Bay include large low speed and very high speed wind tunnels, guidance and control research apparatus, and life science research facilities.

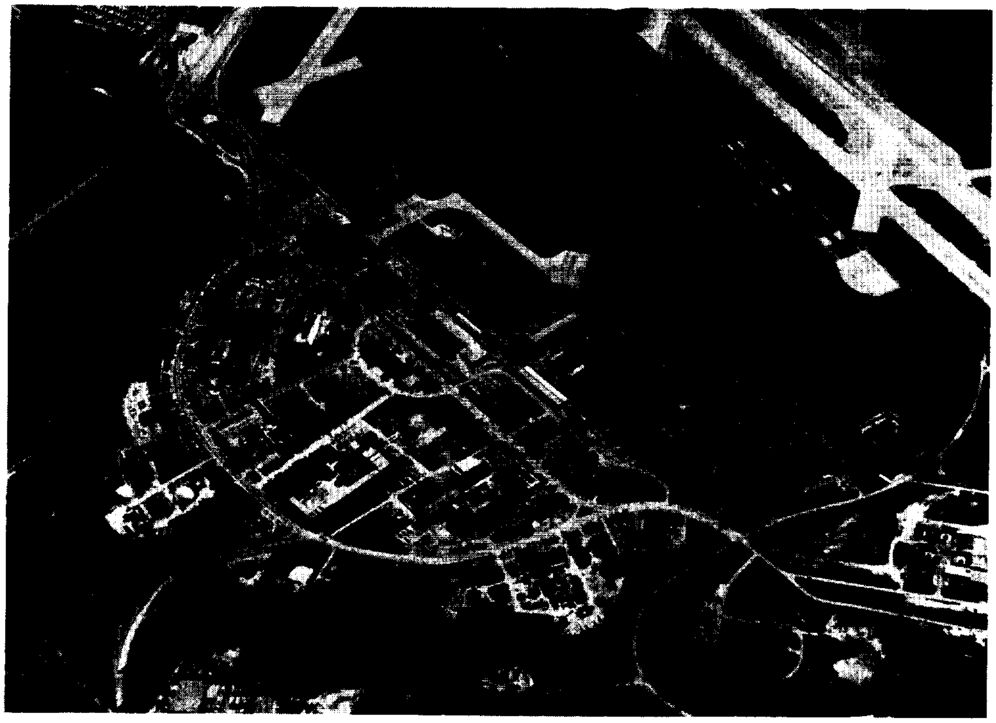
The current space biology program includes laboratory research on the ground, and the Biosatellite program. Biosatellite is a recoverable spacecraft designed for biological experiments in earth orbital space. It was in the first mission, flown in September 1967, that the results quoted above were obtained. The second Biosatellite mission, launched in June 1969, carried an elaborately instrumented monkey as the experimental subject. The primate's performance and reactions under space conditions are expected to give important information on the central nervous system and the cardiovascular, metabolic, and hemodynamic systems during weightlessnes. The results of this mission are being assessed.

The Fiscal Year 1970 Budget does not provide for any manor flight program beyond Biosatellite III. Current activities are directed toward studying future possible space biology programs, especially those that might be conducted in a space station.

Space technology. All NASA programs depend on the research and development base created in the space technology program. The strength of this program resides in approximately 12,000 people in NASA Centers, the unique in-house facilities available to them, and the industrial contractors and universities who work with NASA.

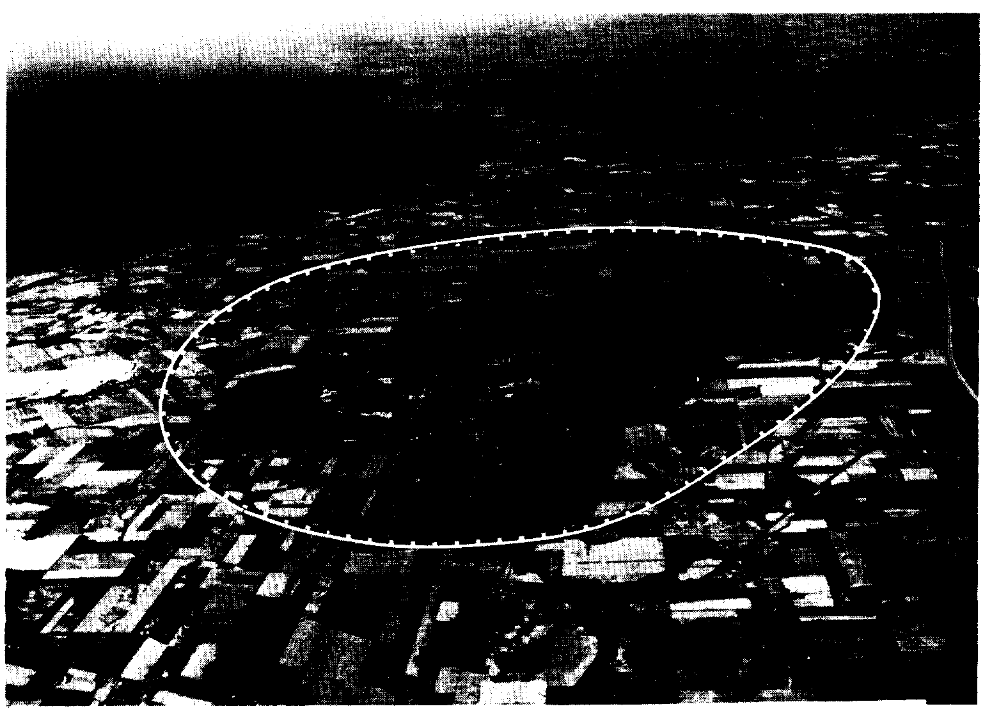
LANGLEY RESEARCH CENTER, VIRGINIA

The Langley Research Center, located near Norfolk, Virginia, is the oldest of the NASA Laboratories. The Center conducts advanced aeronautical and space research and has managed the successful Lunar Orbiter project.



LEWIS RESEARCH CENTER, CLEVELAND, OHIO

The Lewis Research Center, located in the southwestern corner of Cleveland, Ohio, contains many advanced and unique facilities for propulsion research.

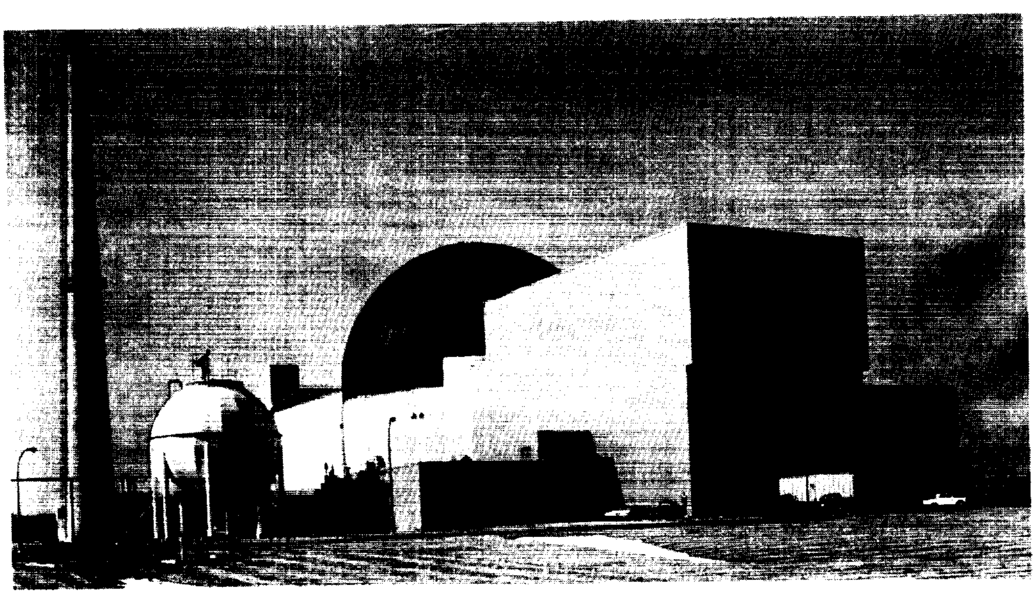


PLUM BROOK STATION, SANDUSKY, OHIO

The Plum Brook Station of NASA's Lewis Research Center is located 50 miles west of Cleveland and contains a nuclear research reactor, rocket test stands, the Space Power Facility, and support facilities.

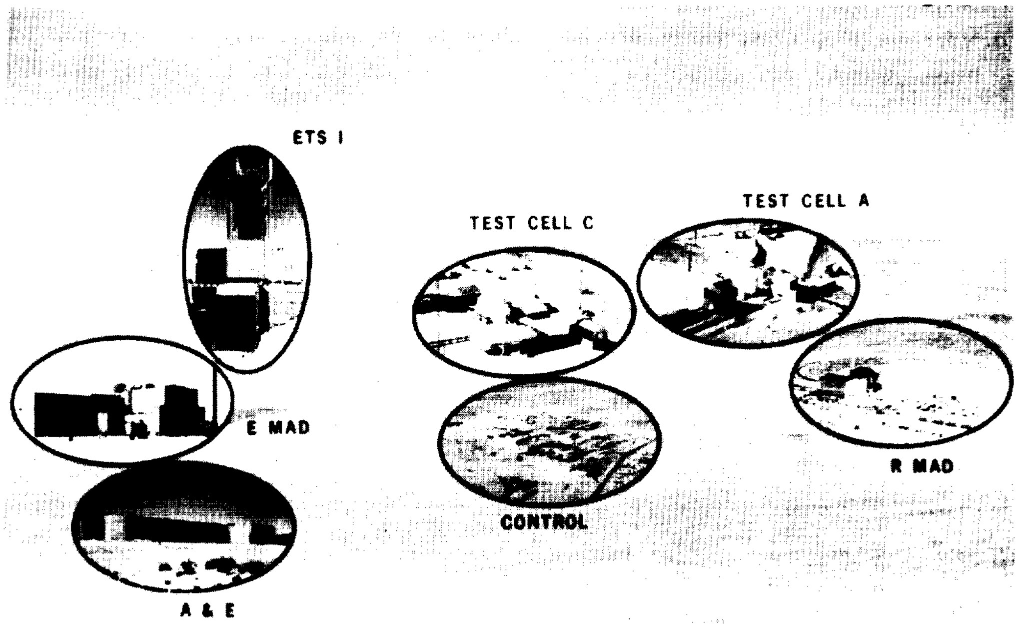
Space technology is conducted in seven major areas:

- Basic research - Fundamental research in the physical and mathematical sciences.
- Space vehicle systems - Applied research and technology covering entry vehicle and space vehicle aerothermodynamics, launch vehicle and spacecraft structures, spacecraft environmental protection, and design criteria.
- Electronics systems - Basic and applied research in electronics and the development of techniques and components for future application.
- Human factor systems - Development of technology for men in space. Areas of specialization are human research and performance, life support and protective systems, and man-systems integration.
- Space power and electric propulsion - Development of space-borne electrical power systems for advanced missions and thruster technology for electric propulsion; includes considerations of solar, nuclear, and chemical power supplies.
- Nuclear propulsion - Development of a flight-qualified 75,000-pound thrust NERVA nuclear-liquid hydrogen engine; development of nuclear rocket technology and systems for advanced orbital, lunar, and planetary missions.
- Chemical propulsion - Development of advanced liquid and solid propellant chemical rockets, fundamental research into propulsion concepts and design parameters, and test of experimental motors.



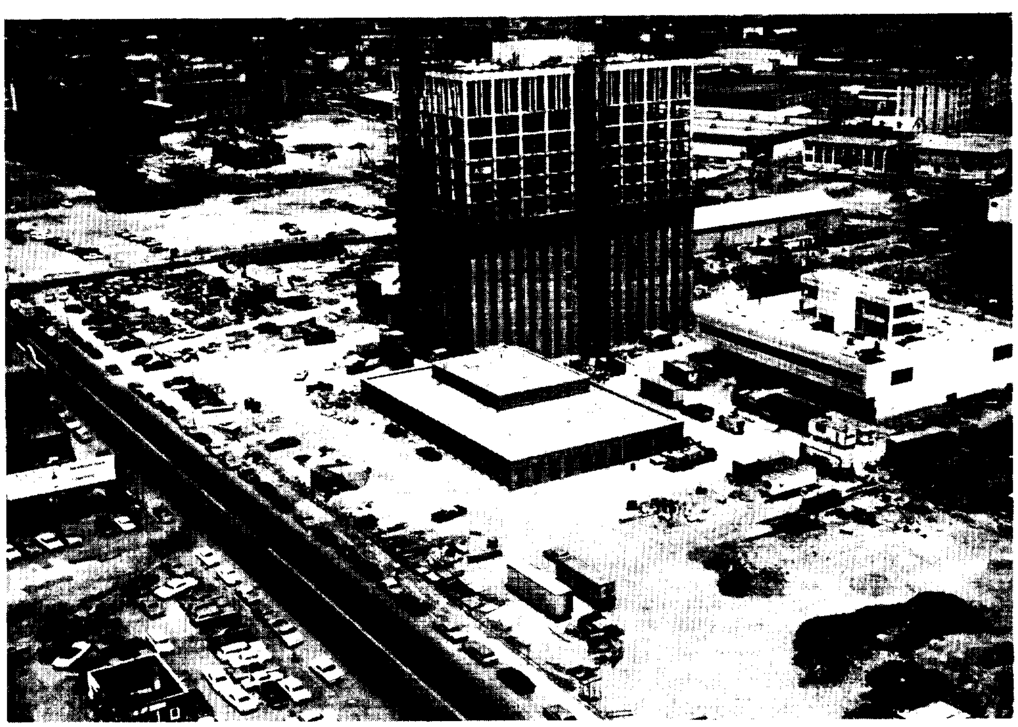
PLUM BROOK STATION

The Space Power Facility located at the Plum Brook Station used to test large non-nuclear components, vehicles, and spacecraft in a space environment, contains a test chamber 72 feet in diameter and 100 feet high, with capability of a vacuum of 1×10^{-8} torr.



NUCLEAR ROCKET DEVELOPMENT STATION, NEVADA

The Nuclear Rocket Development Station located about 90 miles northwest of Las Vegas, Nevada, is the site where nuclear rocket engines, components and vehicles will be tested.



ELECTRONICS RESEARCH CENTER, BOSTON, MASSACHUSETTS

The facilities for the Electronics Research Center, located in Boston, are in the construction phase. The large building above is one of the major laboratories to be built on the site.

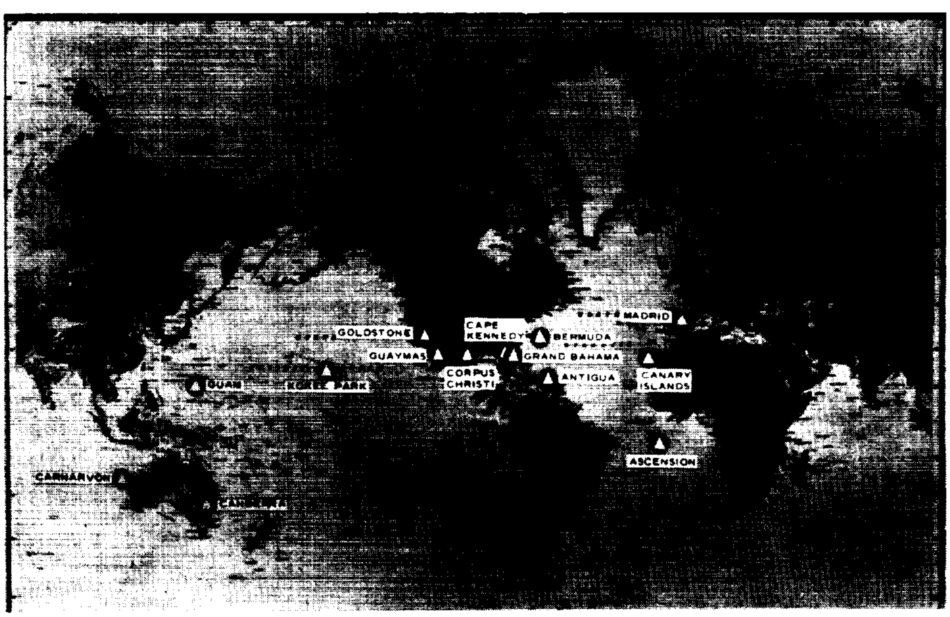
Supporting Activities

To support the various programs, there are numerous supporting activities, the most important of which are the management and operation of NASA's centers and installations, and the Agency's Tracking and Data Acquisition program. The latter supports all NASA space flight projects. It outfits, maintains, and operates three major functionally oriented networks: the Manned Space Flight Network; the Satellite Network; and the Deep Space Network. These provide tracking data, telemetry, and communications for all NASA space flight operations. In addition, there is a NASA Communications Network which provides worldwide communications links for the entire NASA activity.

FLIGHT RESEARCH CENTER

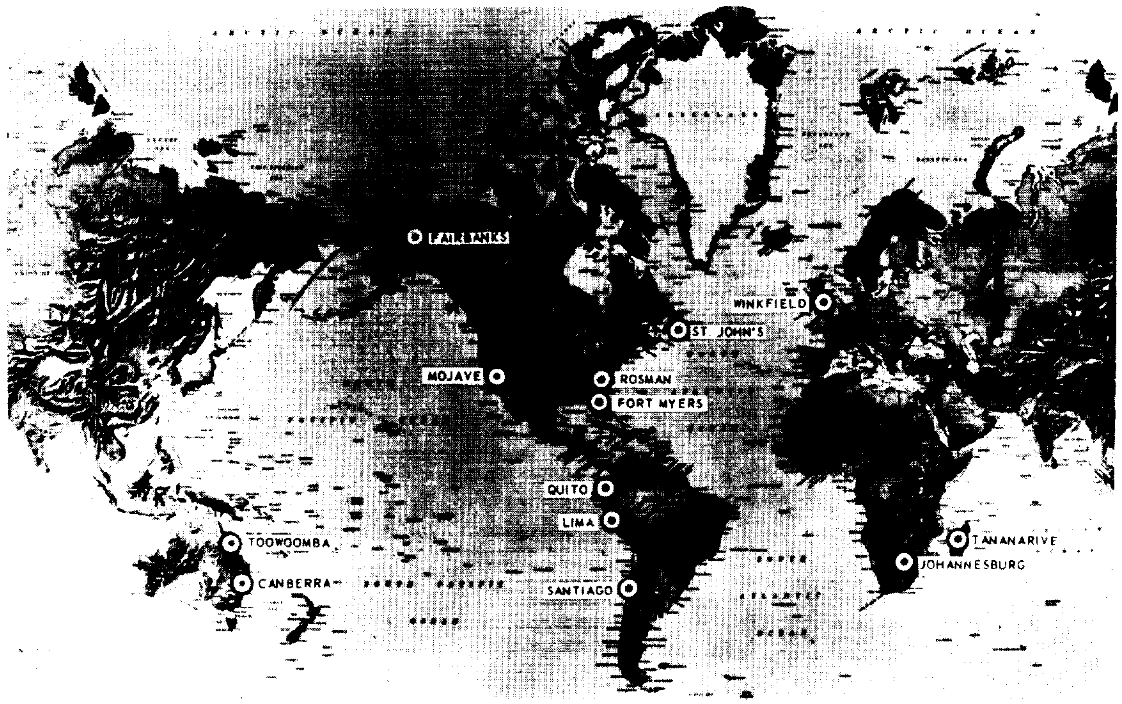
EDWARDS, CALIFORNIA

The Flight Research Center, located in the Mojave Desert, is responsible for research operations involving high speed aircraft, such as the X-15.



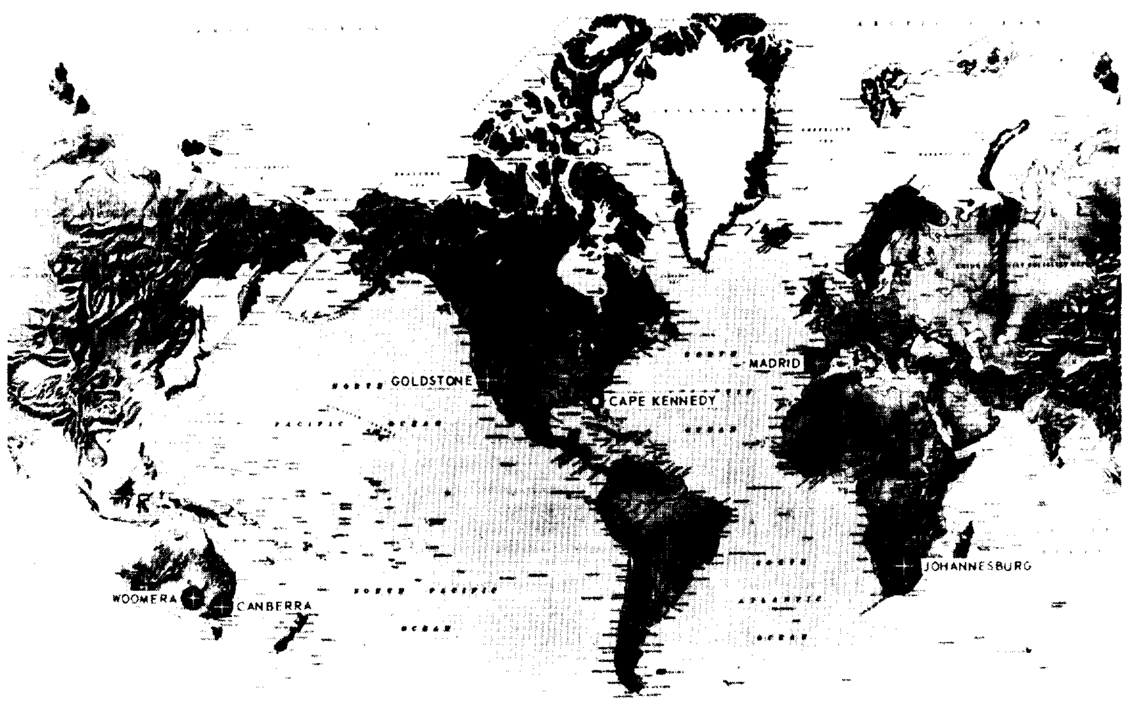
MANNED SPACE FLIGHT NETWORK

This network, which is responsible for tracking, command, and data acquisition for U.S. manned space flights, consists of fourteen ground stations, four tracking ships and eight aircraft.



SPACE TRACKING AND DATA ACQUISITION NETWORK

This network, which is responsible for tracking, command, and data acquisition for unmanned earth orbital space flights, **consists of thirteen ground stations.**



DEEP SPACE NETWORK

This network, which is responsible for tracking, command, and data acquisition for lunar, planetary and interplanetary space flight, consists of **five** stations, in addition to facilities located at the Cape Kennedy launch site.

SPACE COMMUNICATIONS COMPLEX, GOLDSTONE, CALIFORNIA

The above 210-foot diameter tracking and communications antenna forms the heart of the Goldstone Tracking Station which is part of both the manned space flight and deep space tracking networks.

IV GOALS AND OBJECTIVES

The decade of the 1970's can be the decade of U.S. pre-eminence in space exploration and application. During the next decade we can open up earth-moon space to permanent occupation and use by man. In the same period we can lay the necessary groundwork to send man to the planets. We can provide a continuing increase in scientific and technological returns, and we can bring into being new space systems that contribute to the Nation's security and well-being. We may learn whether life exists elsewhere in the solar system; and we can explore the moon, maintain men in space for long and useful periods, and capitalize upon our leadership in the peaceful uses of outer space for the benefit of all mankind.

Such a space program would serve a broad range of national purposes; scientific, technical, economic, social, and political, and would further the goals and objectives set forth in the National Aeronautics and Space Act of 1958:

"The Congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind."

"The aeronautical and space activities of the United States shall be conducted so as to contribute materially to one or more of the following objectives:

(1) The expansion of human knowledge of phenomena in the atmosphere and space;

(2) The improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles;

(3) The development and operation of vehicles capable of carrying instruments, equipment, supplies, and living organisms through space;

(4) The establishment of long-range studies of the potential benefits to be gained from the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes;

(5) The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere;

(6) The making available to agencies directly concerned with national defense of discoveries that have military value or significance, and the furnishing by such agencies, to the civilian agency established to direct and control nonmilitary aeronautical and space activities, of information as to discoveries which have value or significance to that agency;

(7) Cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results thereof; and

(8) The most effective utilization of the scientific and engineering resources of the United States, with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities, and equipment."

The Act itself and its legislative history also made perfectly clear the strong intent of the Congress that the core of the U.S. space effort would be an open civilian program that all the world could see was indeed "devoted to peaceful purposes for the benefit of all mankind," a decision that has time and again proven of great value to us on the international scene.

These goals and purposes, which were established at the beginning of the Space Age, are as valid and worthwhile today as they were when first enunciated. They continue today as the general expression of our aims in space, and just as they underlay our decisions and program choices during the past decade, so must they underlie our decisions and choices for the next decade.

In order to formulate a specific national program, the national goals set forth in the National Aeronautics and Space Act must be converted into various levels of goals and objectives that are specific to different areas of space research and development, and that correspond to current capabilities and explicit needs and opportunities. This chapter sets forth such goals and objectives, that both further the broad national aims of the Aeronautics and Space Act, and are timely and appropriate to use in driving our planning for more than a decade in space.

Exploration of the solar system is a natural objective of activities in space, and for the long term must be a major goal of the U.S. space program. Such an objective gives focus to our broad aim of opening up space to permanent occupancy and use by man, the development and use of new space technology, and the expansion of knowledge of our earth and space.

A properly balanced program must also seek (1) a continuing, steady output of returns in science, applications, and technology from utilization of existing space capability, and (2) a steady improvement and advancement in space capability, including the development of new capabilities that will be required for effective and profitable exploration and utilization of space in the future.

There are many exciting scientific investigations and valuable practical applications of space that can be undertaken now with existing capabilities, and it would indeed be possible to construct a full program of just these. Such a program could be of excellent quality and quite respectable in the short-term, but in the long-term would prove to have been shortsighted, for the time would inevitably come in both science and applications when new capabilities are required in order to take the next logical steps.

On the other hand, a program which is over-concentrated on the development of new capability would also be shortsighted. In that case one would be always investing in the future but not securing a wise return on such investments in the present.

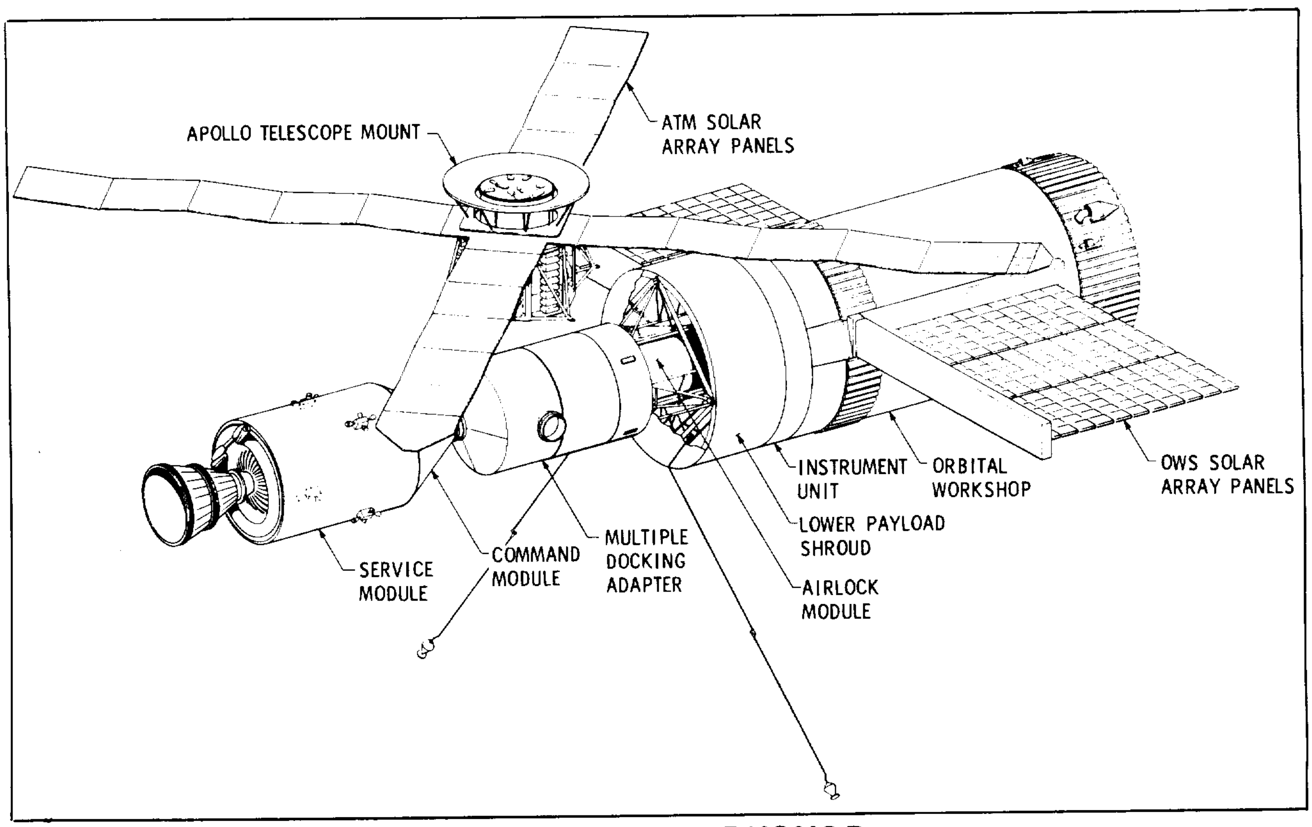
Our experience of the past eleven years has convinced us that we must develop new and more efficient ways of operating in space. Although they have sufficed for the initial claim to this new domain, our techniques and hardware in the past have been experimental and costly. As a consequence, the Nation should adopt a goal of reducing the costs of space hardware, and of establishing an economic, flexible, versatile space transportation capability. A specific aim in this endeavor will be to make space more broadly available both nationally and internationally.

In addition to the general objectives discussed above, there is a list of goals for major specific areas of the space program that were used to guide the selection of program elements and in combining them into an integrated total program plan. These goals are given without extended discussion in the following pages of this section.

EARTH ORBITAL MANNED SPACE FLIGHT

To extend and utilize the unique capabilities of manned space flight in earth orbit for the development of the capability to utilize and explore space, for the enhancement of our scientific and technological knowledge, and for beneficial applications.

The next logical step toward meeting this goal is to provide a permanent manned space station in earth orbit, to develop a flexible low-cost transportation system to support and sustain extended operations in space, and to develop and begin the use of this extended capability for technology, science, and earth-oriented applications



SATURN V WORKSHOP

The space station and low-cost space transportation systems are of major importance, and are critical interrelated elements of the space program proposed for the country. They will be used for the conduct of engineering, science, and applications experiments and sustaining operations; for simplifying and reducing the costs of space launches and operations; for developing the capability for long-duration space flight and gaining the experience and data needed for design, preparation, and conduct of manned missions to the planets; and for making space more easily, economically and broadly available to the nation and to the rest of the world.

A central reason for constructing a space station or space base in earth orbit is to provide a facility for research that cannot be conducted here on earth. Like laboratories on earth, the space facility would be outfitted with advanced equipment and instruments, and staffed with research and engineering personnel. One use for such a laboratory would be to conduct fundamental physics research. For example, using cosmic ray particles that are thousands of times more energetic than any that can be produced in the largest particle accelerators on the ground, fundamental experiments would be conducted on the constitution of elementary nuclear particles. The laboratory would also be used for experiments on processes that, when taking place on the ground, normally depend on gravity gradients for particle diffusion. Such activities would lead to use of the laboratory for the growth and purification of crystals and materials for solid-state electronic devices.

One of the most fruitful areas of research is expected to be in the field of biomedicine. The opportunity to experiment on and observe men, animals, and other biological organisms under space conditions, which are fundamentally different from conditions on earth, will be a powerful supplement to ground-based research. Also, as we continue the use of unmanned satellites for observations of the earth for both science and applications, supplementary manned observations from an orbiting laboratory will greatly aid in sharpening and improving the effectiveness of the unmanned spacecraft approach.

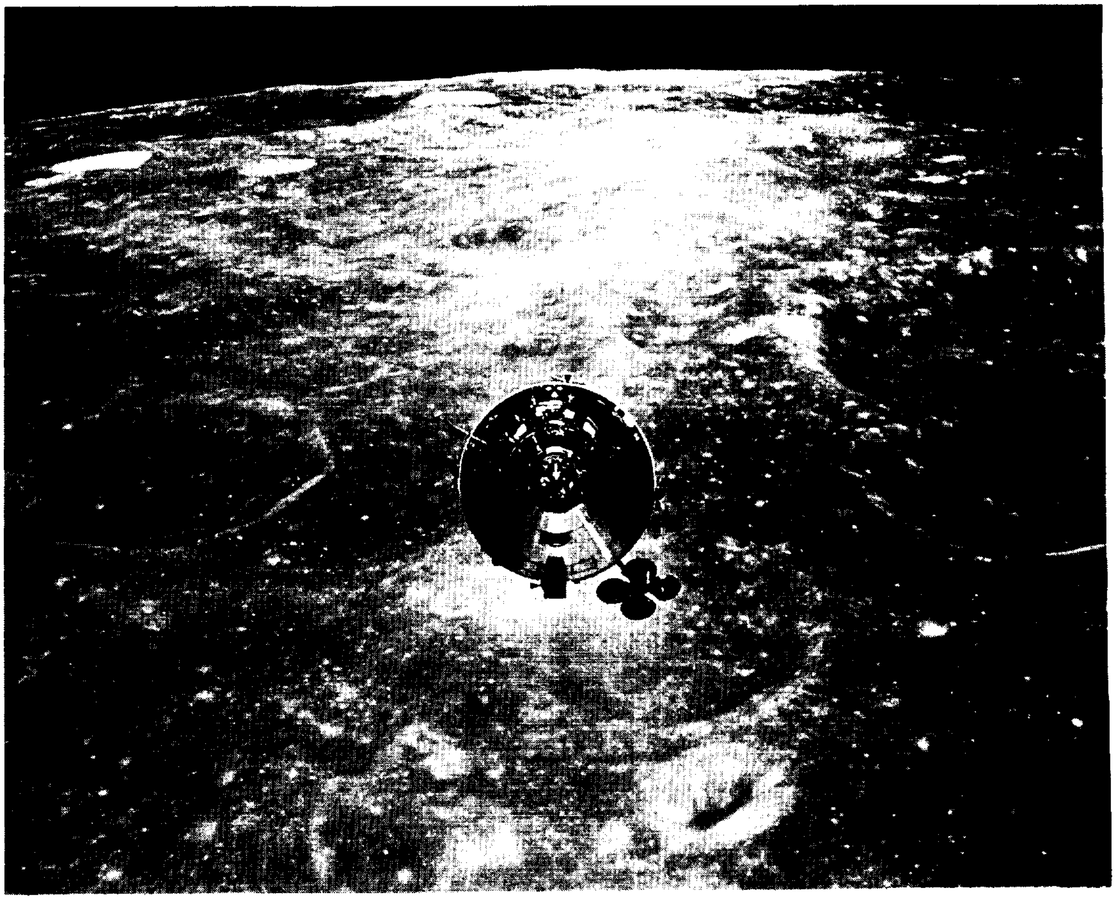
Astronomy is one area of science that has a very long term interest in a manned space station or base. Such an astronomical facility, orbiting above the atmosphere, will afford the astronomer a view of the universe in all electromagnetic wavelengths, including infrared, X-ray, gamma ray, and radio wavelengths that cannot penetrate the earth's atmosphere to reach telescopes on the ground. Such observations are needed to solve some of the puzzling mysteries of modern astronomy, such as radio galaxies, quasars, pulsars, and X-ray sources.

These classes of activity and the development and operational experience gained in establishing and manning these earth-orbital manned systems will enhance our technological and scientific capabilities as a nation, provide a base for extending our international cooperation, and develop our ability to undertake manned planetary exploration. The role and importance of space stations and economical space transportation systems are further discussed in Part V.

LUNAR EXPLORATION

To explore the moon; to understand the moon in terms of its origin and evolution; to search its surface for evidence related to the origin of life; to apply new data on the differences and similarities between the earth and moon to the reasonable explanation of dynamic processes that shaped our planet. To develop the technology essential for a continued lunar exploration program which will permit effective utilization of the moon, laying the foundation for future lunar bases. To extend man's domain to include the moon.

The moon is the first extraterrestrial body which man will be able to study in detail. The exploration effort is directed toward developing information which will allow us to understand the history of how the moon was formed and how it reached its current state. By integrating this new knowledge with what we currently know about the earth and the solar system, we will improve our understanding of their origins, histories, and current states.



APOLLO SPACECRAFT IN LUNAR ORBIT

To carry out the exploration of the moon, man's capability to operate near and on the moon in a routine manner for extended periods of time will be developed. Key to the development of this capability will be manned stations in lunar orbit and on the surface, a reusable nuclear stage to provide economical transportation between earth orbit and lunar orbit, and a reusable stage that would operate between lunar orbit and the surface to transport men and equipment.

Utilizing these systems, technology and manufacturing experiments that need or can effectively utilize the low gravity, vacuum environment of the lunar surface will be conducted. In addition, the moon will be used as a site for making scientific observations that take advantage of its remoteness from the earth, such as radio astronomy observations from the lunar far side.

The technology, knowledge and experience resulting from these extraterrestrial operations on the moon will be applicable to future manned planetary exploration.

PLANETARY EXPLORATION

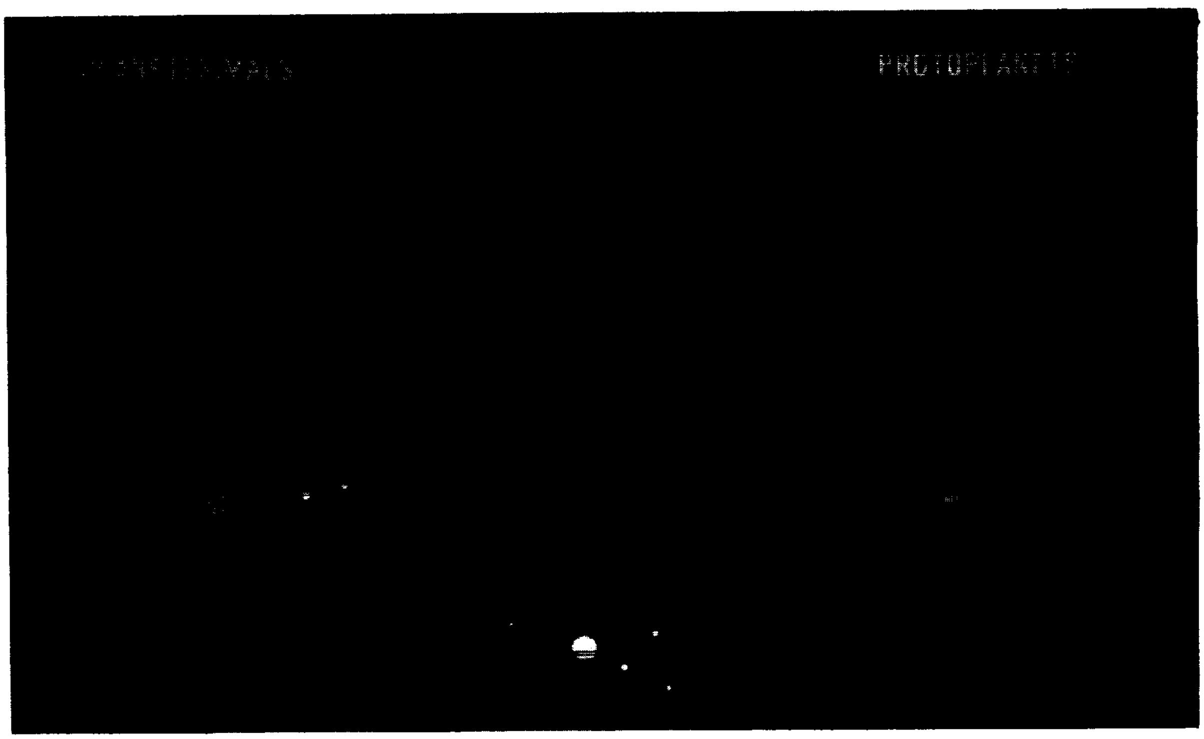
To explore the planets of our solar system; to understand the origin and evolution of the solar system, the origin and evolution of life, and the dynamic processes that shape man's terrestrial environment.

The possibility that man may extend his domain to encompass the solar system stands as the greatest challenge yet presented to the venturesome spirit of man. By its very nature, planetary exploration provides an outlet for man's inherent desires to explore the unknown and to achieve. Moreover, planetary exploration can thrill all mankind as the program, including the search for extraterrestrial life, progresses from planet to planet. The expanse of the solar system will be viewed in detail when the photographs and other data are returned to Earth from the surface of Mars, the vicinity of Jupiter, Saturn, Neptune, and even far-off Pluto. Sending man himself beyond the moon to the planets will open the thinking of man and make him aware of the full extent of his solar system.

The question for us to ponder is not whether man will go to the planets, for surely he will, but when this will take place and whether the United States will take the lead.

ASTRONOMY AND SPACE PHYSICS

To increase man's knowledge of the fundamental laws and principles of physics; to provide him with an understanding of the nature of the space environment and its contents; to identify the forces that shape the terrestrial environment; and to add to his understanding of the origin and evolution of the cosmic environment.



FORMATION OF PLANETS FROM A SOLAR NEBULA

The opportunity to observe across the entire spectrum of electro-magnetic radiations gives special impetus to the science of astronomy by transforming astronomy from a data gathering activity to one of problem solving. In the past, observations made in the optical and radio wavelengths that can penetrate the earth's atmosphere to telescopes on the ground, have led to theories about fundamental processes in the universe that could not be tested by observation because of lack of ability to see in the ultraviolet, infrared, and other wavelengths obscured by the earth's atmosphere. Moreover, the difficult questions raised by radio galaxies, quasars, pulsars, and X-ray sources as to their nature, tremendous rates of energy emission, distances, etc., require observations in all wavelengths. An astronomical observatory with increased capability is needed above the atmosphere for this purpose, where a 120-inch mirror can look 10 times farther into space and see objects 100 times fainter than can the 200-inch Mt. Palomar mirror beneath the atmosphere on the surface of the earth, and where in the absence of atmospheric distortions much greater angular precision can be obtained.

Similarly, the vast laboratory of outer space should prove useful for the discipline of physics. Here cosmic ray particles thousands of times more energetic than those obtainable in the biggest accelerators on the earth can be used to investigate the fundamental nature of elementary nuclear particles. It will also be possible to conduct controlled experiments on general relativity, and by searching for gravity waves in space seek a better understanding of the fundamental nature of gravity.

LIFE SCIENCES

The Life Sciences program includes two related areas of activity, Space Medicine and Space Biology. The former is concerned with understanding man and safeguarding his well-being while providing for his utilization in space operations and exploration. The latter deals with using the unique environment of space to increase our knowledge and understanding of life and the mechanisms of living organisms.

Space Medicine. To use the space environment for medical research; to develop an understanding of man and his supporting equipment which will allow the establishment of design criteria for optimal use of man-in-space operations, particularly for long-duration space flight; to apply the results of this activity as appropriate to the fields of medicine and public health.

A strong space medicine program is fundamental to the continued development of a manned space flight capability, particularly with regard to long-duration space operations in earth orbit, at the moon and for planetary exploration. Flights to the near-by planets will require years of operation in space traveling to the planets and returning to earth. An important element of the program will be the development and operation of a space station biomedical laboratory. This facility will also provide a capability for basic research in medicine.

Space Biology. To use the space environment for biological research; to contribute to the development of a unifying theory for biology, by increasing our basic understanding of life processes and structures, especially with respect to the influence of gravity and time; to apply the results of space biology as appropriate to such fields as medicine, public health, and agriculture.

Critical to the program is the flight of biological specimens in the unique environment of space -- weightlessness, radiation, and altered physiological rhythms -- to develop an understanding of biological reactions to the environment of space and their behavioral manifestations. Automated spacecraft and the manned biomedical laboratory noted above will play important roles in the development of this knowledge.

The activity related to the search for an understanding of extraterrestrial life is discussed under Planetary Exploration.

SPACE APPLICATIONS

The perspective afforded by observations of the earth from orbit contribute powerfully to a number of important application areas.

Meteorology. To understand the physics of the atmosphere, to bring about improved prediction of weather, and to establish a basis for eventual weather modification and climate control.

The Environmental Science Services Administration has the responsibility to meet requirements of the public, the Departments of Defense, Interior, Transportation, and others for weather information and predictions. NASA's responsibility is to advance instrumentation and systems technology, to prove out operational systems concepts, and to support ESSA in meeting its mission responsibilities. Potential annual returns from this area of space applications have been estimated at billions of dollars.

Earth Resources. To establish a capability for responsible management of the earth's resources and human environment.

Potentially one of the most productive areas of space applications, earth resource surveys are of interest to the Departments of Interior, Agriculture, Commerce, and those agencies concerned with marine sciences. As in the field of meteorology, NASA's responsibility is to advance technology, develop appropriate instrumentation, and develop and operate experimental systems to support user needs in this area. An early requirement is to collect observational data needed to assess the feasibility, usefulness, and value of the space observations in different areas. Various study groups have already assessed returns in the earth resources area at hundreds of millions of dollars annually.

Earth Physics. To define the earth's gravitational field, geometry, surface characteristics, and dynamic body properties.

Results in this field will be of particular importance in various fields of space applications: earth resource mapping, improving the accuracy of space flight trajectory calculations, and in the scientific study of the earth. This area is of interest to those agencies concerned with earth resources, and of special interest to the Departments of Commerce and Defense.

Communications. To facilitate the application of satellite and space technology to communication needs, nationally and internationally, and to the need for data collection from earthborne, airborne, and spaceborne vehicles.

This is a particularly broad area of application in which space techniques should be able to contribute to radio and television broadcasting, community broadcasting, the support of special educational programs, navigation and air traffic communications, data collection and transmission, and the support of both earth-based and space operations. NASA's role is at least three-fold:

(1) to advance space communications technology, and to experiment with potential operational systems and components; (2) to support the Communications Satellite Corporation with reimbursable launchings and with advice and consultation; and (3) to serve as advisor and consultant to various agencies of the government on space communications matters. Here again, estimates indicate hundreds of millions of dollars of return annually. Some of this return is already being realized in the current Intelsat commercial operations.

Navigation and Traffic Control. To facilitate the application of satellite systems and space technology for the improvement of terrestrial, air, and space vehicle navigation, and traffic control.

One of the major needs of the country in support of the marine and aeronautical industries, is for an economical and effective system for navigation and the management of the flow of traffic. The Navy has already developed a satellite navigation system, which, however, is too expensive and specialized for general use. Working with the Department of Transportation, NASA is defining needs, requirements, and specifications for equipment and systems, and is working to advance technologies that will be needed in this area.

SPACE TECHNOLOGY

To reduce the cost and expand the versatility and usefulness of space operations and hardware, to advance fundamental knowledge pertinent to space flight, and to provide the technical capability for undertaking future missions.

The space technology program is fundamental to the development and advancement of the technological capability necessary to undertake the space exploration planned for the future. There are two interrelated elements of this program. One element is research on fundamental elements of the physical sciences that will provide a continuing source of new fundamental knowledge pertinent to space flight. The other element is the demonstration of how this knowledge can be applied to meet the needs of future space exploration activities.

In order to provide an expanding technological base advances must be made in a number of areas. These advances include: development of techniques for leaving and entering the planetary atmospheres and landing on planetary bodies, including the earth; improved methods for lightweight structures and the use of new materials; demonstration of the generation and distribution of electrical power for use in space propulsion systems with improved performance; development of electronic components and systems that have high reliability and long life characteristics; and increased knowledge in the physical and mathematical sciences basic to space flight.

V PROGRAM PLANS

CHAPTER 1

PROGRAM APPROACH

To achieve the recommended goals and objectives, it is important that:

1. The United States accept, for the long-term, the challenge of exploring the solar system.

2. As the next essential step toward our long-term objectives of exploring and using space, the United States undertake, during the next decade, the task of opening up earth-moon space to permanent occupancy and use by man.

3. The next decade be devoted to building an integrated, efficient, economical space capability consisting of permanent space station modules and a low unit-mission cost space transportation system that will make earth-moon space easily and economically accessible to man for his use for exploration, applications, science, and technology research.

4. The country maintain a steady return in applications, science, and technology on its space investments.

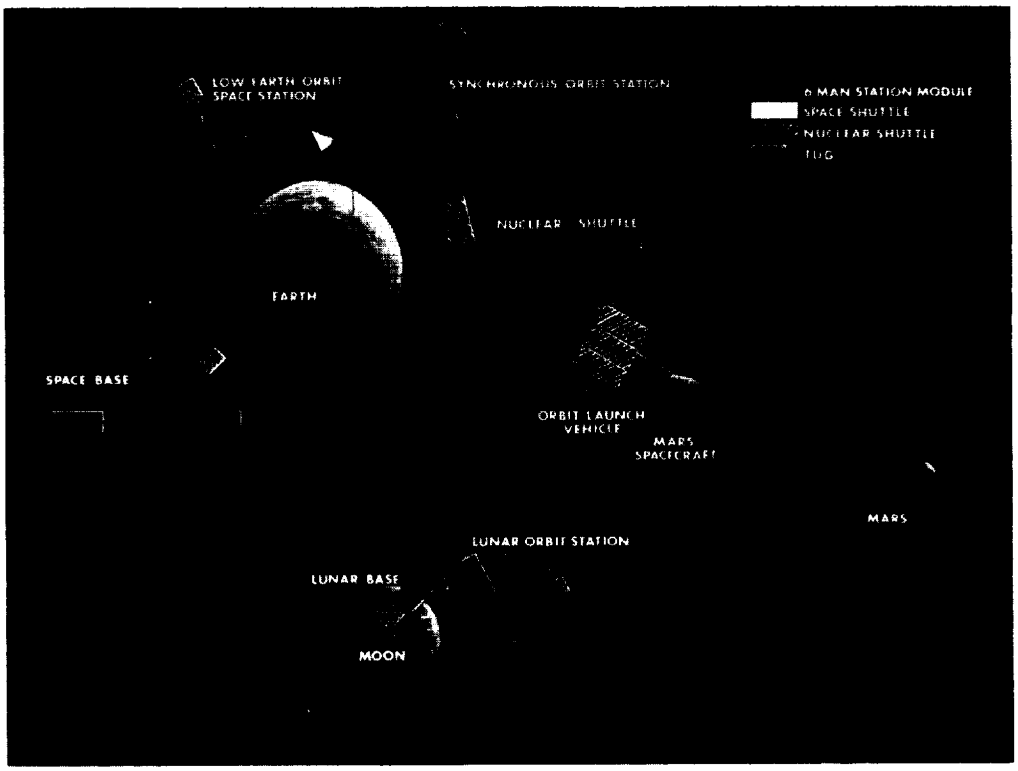
5. The country use the challenge of making both near- and far-space easily and economically accessible to man and machines as a means to stimulate and focus the development and use of space technology.

6. The United States use its improved space capability not only to extend the benefits of space to the rest of the world, but also to increase direct participation by the world community in both manned and unmanned exploration and use of space.

It is important that the next two decades of space activities embodying these aims be carried out with emphasis on economy. The critical factors that will make effective progress possible. are:

- Commonality - the use of a few major systems for a wide variety of missions.
- Reusability - the use of the same system over a long period for a number of missions.
- Economy - the reduction in the number of "throw away" elements in any mission; the reduction in the number of new developments required; the development of new program principles that capitalize on such capabilities as man-tending of space facilities; and the commitment to simplification of space hardware.

A space exploration program has been developed that emphasizes these factors of economy and embodies the aims stated above that are considered necessary to achieve the recommended goals and objectives. Central to this program is the continuing extension of man's abilities into space. This capability can be achieved through a sufficiently large, multi-manned, long-lived space station. In order to support the station and its subsequent additions, efficient transportation to and from earth is required. Low operating costs and high flexibility are necessary here to take full advantage of the manned orbital station's unique capabilities for scientific, engineering, and applications functions. Therefore, an earth-to-orbit chemical propellant shuttle is required that can meet these criteria; this envisages high reusability and, eventually, airline-type operations between space and the surface of the earth. Together, the space station and shuttle are the keystones to the next major accomplishments of the nation's space program.



INTEGRATED PROGRAM HARDWARE ELEMENT COMMONALITY

The space station and shuttle's relationship to future mission possibilities are of basic importance:

- By assembling a number of individual station modules together in orbit, a permanent space base of large size can be built up using existing Saturn launch vehicles. Shuttles would provide rapid easy service to crews, experimenters, and operators.

- Later, a space station in polar orbit around the moon using the same modules provides a flexible base from which to conduct sorties to the surface. The sortie vehicle would be a new resuable landing stage capable of long staytime on the lunar surface with 3- to 6-man teams.

- This same lunar landing stage could land complete space station modules on the moon as the building blocks of a permanent lunar surface base. Resupply from earth would be most economically achieved through use of a reusable earth-orbit-to-lunar-orbit transportation system using a restartable and reusable nuclear stage. Crews, payload, and propellants would be carried from the ground to earth orbit by the chemical shuttle. This system will greatly lower costs of establishing and supporting lunar bases.

- Eventual manned expeditions to Mars would employ the basic space station module as crew quarters and laboratory while in transit and as an orbital base while at the planet. The mission would use the same nuclear stages as would the lunar bases. A new excursion module to land men on Mars from orbit would be the only major new development required.

The following section of this report describes in further detail the content of the principal elements of the program that has been developed utilizing these concepts of program integration and commonality and reuse of major hardware systems.

CHAPTER 2

PROGRAM CONTENT

In the description of the program content in this Chapter, the program elements previously described in IV - Goals and Objectives have been grouped into the following five categories:

- Earth Orbital
- Lunar
- Planetary
- Aero/Space Technology
- Ground Based Activities

The Earth Orbital category deals with all of the Earth Orbital Manned Space Flight activity; Space Science, which includes Astronomy, Space Physics, and Life Sciences; and Space Applications. The manned lunar activity previously described is contained in the Lunar category. Both automated and manned planetary flight activity are contained in the Planetary category. Aeronautics and space research and technology activities are included in the Aero/Space Technology category.

The Ground Based Activities category contains many ground activities that support or augment various segments of the program in the other four categories. This category will be explained in greater detail at this point than the other categories since it will not be dealt with further in this report.

One element of this category is Tracking and Data Acquisition. This activity encompasses operation of NASA's ground based tracking and data acquisition stations, tracking ships, and communications networks around the world that support all space flight missions.

Another element is the common support for all manned space flight missions. Included here are the ground testing and checkout of spacecraft and launch vehicles prior to launch, the associated launch operations support activities at the three manned space flight centers, the operation of the Mission Control Center at the Manned Spacecraft Center in Houston, and astronaut training activities.

All of NASA's Research and Program Management is included. This activity provides the following: the personnel staff for in-house research and for planning, managing, and supporting the NASA R&D programs; operational capability to the laboratories and facilities for in-house research, development, and mission operations effort; general purpose computer capability and such necessary logistics support as travel and transportation; maintenance and operation of facilities; and technical and administrative support.

Three other areas of activity are also included. These are the Technology Utilization Program; the program of university research grants and student fellowships; and the engineering activities necessary to sustain and support the small and medium launch vehicles that are used to launch all of the automated spacecraft.

The remaining portion of this Chapter describes the content of the other four program categories.

EARTH ORBITAL

Earth Orbital Manned Space Flight

The pursuit of an aggressive program of manned space flight during the next decade will make it possible to place and sustain many men in earth orbit for extended periods of time and to provide them with the means for performing complex tasks in space. The achievement of this capability entails the development of: long-duration, multi-manned space stations with integral and interdependent operational systems and experimental modules; low-cost earth-to-orbit and orbit-to-orbit transportation systems for men and materials; and eventually a large earth orbiting space base, staffed by specialists who do not need to be highly trained astronauts but who are skilled in unique disciplines and collectively are capable of conducting a wide variety of activity in the fields of technology, science, and applications.

Initially a space station module capable of accommodating from 6 to 12 men with an operating life-time of several years will be developed. Such a space station, built up from specialized attached or dependent modules, will be used to obtain data on man and his supporting equipment, to conduct a wide range of experiments, and to test and develop operational systems. Utilizing the data and operational experience gained from these activities, additional space station modules will be launched into orbit where they will be assembled to form a 50-man permanent, earth orbital research, development, and operational space base capable of supporting a broad spectrum of scientific, technological and applications activity. Additional space station modules will be added later to expand the space base to a 100-man capacity. The space station and space base could service other government agencies, and function as instruments for international cooperation through the active use of these facilities by other nations.

Efficient utilization of this class of manned space flight capability requires a flexible, inexpensive space shuttle system for the routine transfer of men and materiel to and from Earth orbit. Thus, the earth-to-orbit shuttle would be brought into operational use at the same time as the space station, in order to provide economic logistics support. Such a shuttle system will be reusable, with a minimum of refurbishment, would have a short ground turn-around capability between flights, and would be designed to operate at low levels of acceleration during launch and reentry. It would be substantially less expensive to place payloads in orbit with the shuttle system than with the current non-reusable launch vehicles. Also, the shuttle would provide a much broader and more flexible operational capability than current launch vehicles. The space shuttle will be able to perform limited duration tasks in earth orbit, launch unmanned spacecraft, and service or return various satellites to the ground for maintenance, repair, or updating. Space shuttle payloads ranging up to 50,000 pounds could be placed in orbit or returned to earth and up to 12 men could be accommodated as passengers aboard the shuttle.

As manned activity in earth orbit and at the moon increase, the workload for the earth-to-orbit shuttle will likewise increase. A major increase in activity will occur with the introduction of the reusable nuclear transfer stage which will provide transportation for men and cargo between earth and lunar orbits and later become the propulsion system for manned planetary exploration. The nuclear transfer stage will be refueled and serviced in earth orbit with propellant transported by the shuttle from earth to an orbital propellant station, which can be regarded as an orbiting "filling station."

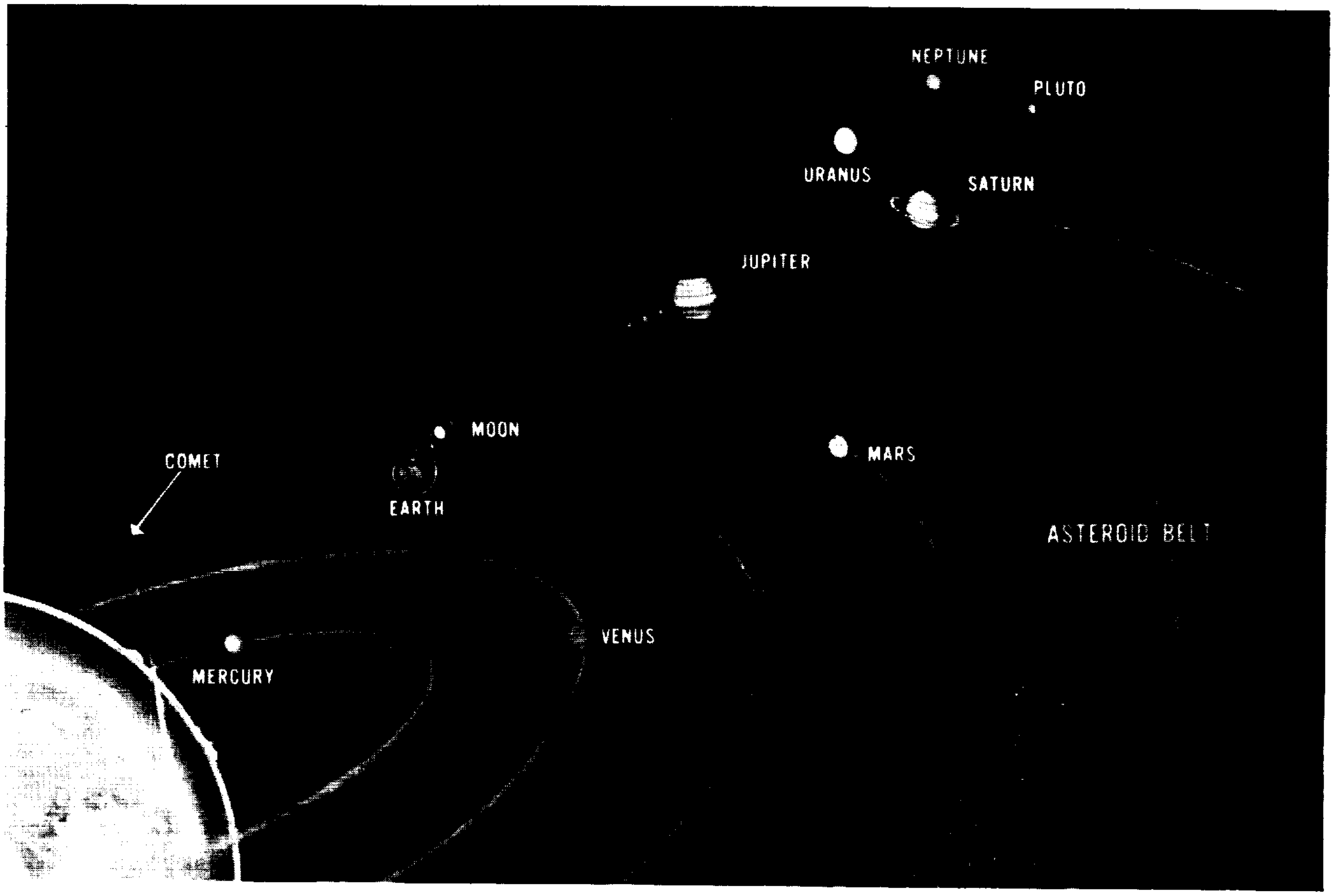
The space station module will also find use in manned lunar and planetary programs. A space station module will be used as the lunar orbiting base and also as the module in which the crew will be housed during the journey to Mars and the return to Earth.

Science

The Science activity is composed of the Astronomy, Space Physics, and Life Sciences programs. All of these programs will continue the use of automated flight systems, primarily for missions that require an orbit different than that of a space station. In each area these observations will be augmented by experiments conducted aboard the space station or in separate experiment modules receiving support and attention from the space station.

Astronomy and Space Physics. In the Astronomy program, which is directed toward learning about the origin, evolution, and structure of the universe, through observations with telescopes in space, special attention will be given to four major areas: solar astronomy, optical astronomy, high energy astronomy, and radio astronomy. The solar astronomy activity will provide for continued survey and study of the sun with automated spacecraft, followed by manned high resolution solar missions. In optical astronomy the program will continue to survey and to study the hot, the faint, and the very distant celestial objects particularly those of unusual character, like quasars and pulsars, and will provide for a future guest observatory, a large space man-tended telescope, and a National Astronomical Space Observatory. Work in the area of high energy astronomy will be initiated with the introduction of a large multi-ton high energy astronomy and space physics spacecraft that will investigate high energy X- and gamma-ray and ultra high energy cosmic ray sources, and study the nature of the physical processes occurring at these sources. In the area of radio astronomy there will be increased emphasis on the development and demonstration of higher resolution systems as precursors to a large radio telescope.

The Space Physics program is directed toward obtaining a better understanding of the physical phenomena in space by making in situ measurements in space using specialized satellites and probes. Activities will be pursued in three major areas: the environment near and around the earth in cislunar space, the environment in interplanetary space, and the use of space as a laboratory in which to conduct physics research.



A SCHEMATIC OF MAJOR POSSIBLE SOLAR SYSTEM EXPLORATION MISSIONS

MERCURY	VENUS	MOON	MARS
○ 73 & 78 Flybys	● 62 Flyby	● 64 Impacter	● 65 & 69 Flybys
○ 82 Orbiter	○ 77 Atmos. Probe	● 66 Orbiter	○ 71 Orbiter
	○ 78 Orbiter	● 66 Lander	○ 73 & 75 Landers
	○ 80 Lander	● 69 Manned Landing	○ 77 & 79 Landers/Rovers
	○ 82 Manned Flyby (Return from Mars)	○ 76 Orbiting Base	○ 81 Manned Expedition
		○ 78 Surface Base	

ASTEROID BELT	JUPITER	SATURN	GRAND TOUR
○ 75 Survey	○ 72, 73, & 74 Flybys	○ 81 Orbiter	○ 77 Flyby (J-S-P)
			○ 79 Flyby (J-U-N)

● Accomplished
○ Goals

In that portion of the Space Physics program dealing with the earth environment emphasis will be shifted from the exploration and mapping of the earth's environment to concentrate more heavily on understanding the mechanisms and processes which control this environment. In the area of interplanetary environment, space exploration will be extended to regions of the solar system not previously explored. Activities that will be initiated to make use of space for conducting physics experiments will include a manned space physics and chemistry laboratory in a space station to perform experiments not feasible on earth.

Life Sciences. The Life Sciences program is a continuum of activity in Space Biology and Space Medicine. The primary purposes of the program range from that of using space for gaining new insight into the nature of life itself through advancements in the field of biology, to the determination of the impact of space operations on man, and the support required in order that he may operate safely and effectively in space. Mutually supporting ground-based and flight mission activities are necessary in these programs.

In Space Biology, two kinds of flight experiments are involved, non-recoverable and recoverable. Small, non-recoverable satellites will be utilized for the study of biological rhythms in earth orbit, lunar orbit, and heliocentric orbit. For continuing investigations into the effects of weightlessness and radiation on plants and animals, it is necessary to examine the specimen after the experiment is completed. Such experiments will be conducted in a biolaboratory within a manned space station.

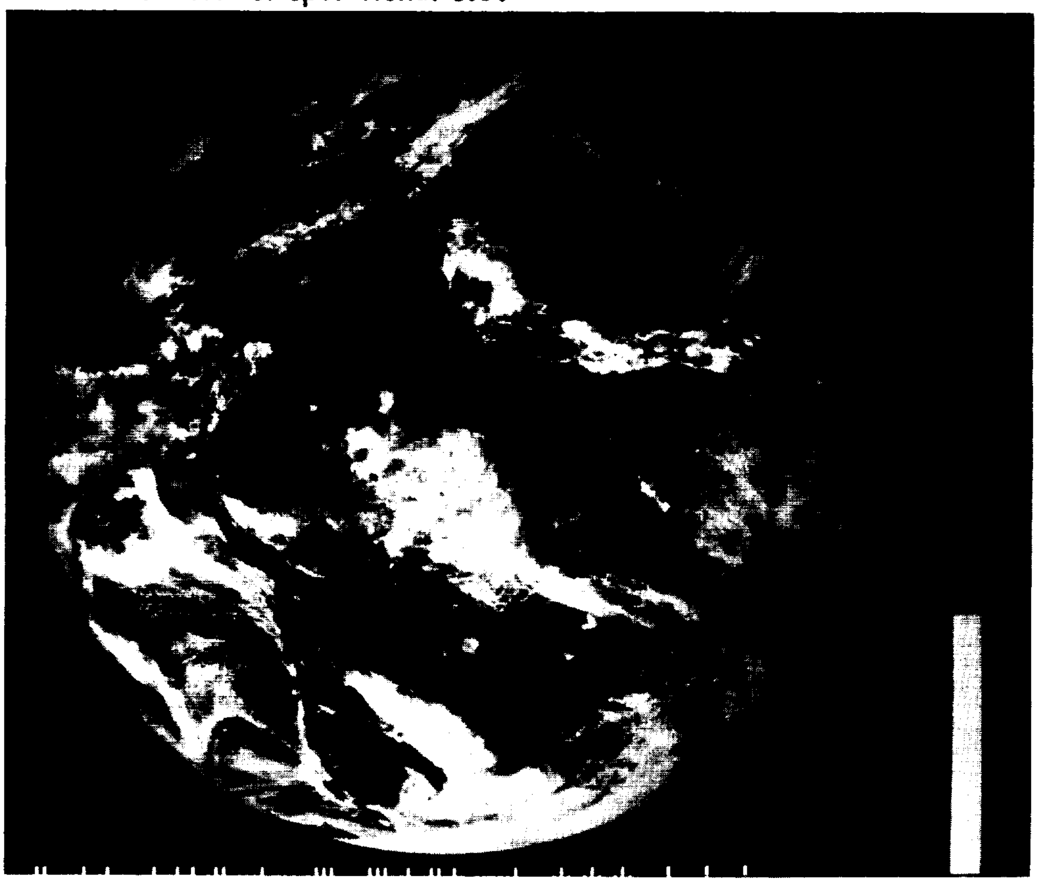
The Space Medicine activity deals with the investigation of man's reaction to space operations; with maintaining him in a healthy state, medically and psychologically, during long staytimes in space; and with providing the life support and protective systems and the operating equipments that allow him to be fully effective in space. A comprehensive and integrated program of observations, tests and experiments will be carried out in the biolaboratory of the space station. In conjunction with these experiments, the medical status of the crew members will be monitored for both operational and medical research purposes. To provide the necessary support and environment for the crew, ground-based research will be concentrated on developing technological improvements in environmental control, food and waste management, and crew equipment and operating procedures. Technological advancements in these areas will be demonstrated to facilitate their application to systems for the space base, the lunar base, and manned planetary exploration.

Applications

Our society—increasing in density, mobility, and complexity—is recognizing that many functions, as conducted today, are too cumbersome and inadequate. By applying aerospace technology and space systems, methods for meeting man's needs could be improved. The Applications program is divided into five subprograms: Meteorology, Earth Resources, Earth Physics, Communications, and Navigation and Traffic Control. The content of each subprogram is discussed in the following paragraphs.

Meteorology. It is technically feasible to reach by the mid-1980's a global observation capability to acquire information throughout the atmosphere, and to develop comprehensive atmospheric and weather models. Once developed, the models can be used to make 14-day weather forecasts and long-range climate estimates. The experimental data will supply the background and experience base for experimenting with weather modification and climate control on at least a hemispheric scale.

The Meteorology objectives that have been established to achieve these capabilities are to observe on a global scale the composition, structure and energetics of the atmosphere so as to understand atmospheric interactions: (1) within the atmosphere; (2) in response to solar inputs; and (3) at the air-earth surface interface; and to establish a basis for experiments in control of the weather. The end sought is a working knowledge of how the weather is affected by external and internal forces so that an accurate model can be developed. Continuing refinement of the level of understanding based on increased precision and sophistication of observation and measurement techniques is necessary. Not until an acceptable world weather model has been developed can the first basic experiments in large-scale weather modification and climate control be considered. This work will be closely coordinated with the Environmental Science Services Administration to assure that the final products can be provided as quickly as is reasonable for operational use.



VIEW OF EARTH FROM APPLICATIONS TECHNOLOGY SATELLITE

To accomplish these objectives, further improvements in operational satellites will be demonstrated using advanced versions of the TIROS satellite series. Development of advanced earth orbiting sensors will also continue utilizing additional Nimbus spacecraft. This activity will be complemented by a new Application Technology Satellite specifically designated for Meteorology to develop meteorological sensors and technology at synchronous altitude. A series of four spacecraft will be provided to support data gathering experiments in the international Global

Atmospheric Research Program (GARP), sponsored by the United Nations' World Meteorological Organization and the Committee on Space Research of the International Council of Scientific Unions.

Earth Resources. It is possible by the mid-1980's to develop space systems which could gather data to help solve the problems of an ever-decreasing supply of mineral resources, potable water, food, energy sources, and fresh air to meet the needs of an increasing population.

The objectives of the Earth Resources Program are to determine the performance of remote sensors in identifying earth resources and to establish signature recognition criteria. Along with the sensor development, experimental spacecraft for application to future operational satellite systems must be developed. In addition, the concept for a complete operational user-oriented earth resources survey system must be demonstrated, including ground, airborne, and space components as well as data reduction and handling techniques.

An alternate approach to that of transmitting data by telemetry, which is used in the experimental Earth Resources Technology Satellites of the ongoing program will be investigated. This approach will use film recovery from a satellite for obtaining higher resolution data. In addition, Small Applications Technology Satellites will be used for testing sensors or critical subsystems prior to commitment to the large experimental satellites. The results from these initial developments will provide the basis for selecting the direction that should be taken in the next phase of the Earth Resources program.

Earth Physics. It is feasible during the next 15 years to substantially increase our understanding of the movement of the earth land masses, crustal motion such as earthquakes, the gravitational field, the tides, and the ice masses. From this information, a dynamic earth model can be developed from which predictions of disturbances such as earthquakes could be made.

In Earth Physics, the objectives are to provide a precise and accurate geometric description of the earth's surface; provide a precise and accurate mathematical description of earth's gravitational field; and determine the time variations of the geometry of the ocean surface, the solid earth, the gravity field, and other geophysical parameters. To meet these objectives, it will be necessary to develop a unified world datum; a first-order static model of the earth; and an extension from the static, or time invariant, earth model so as to arrive at a model of the active earth. This will require measurements of land masses, ocean surface, and deep ocean areas. The active model of the earth will require measurements over time of "highs" and "lows" in the earth's figure, and solid mass movements.

In Earth Physics, in addition to the data and analysis from GEOS I and II, a third GEOS satellite will be used to complete development of the unified world datum. Drag-free satellite flights give promise of being able to measure the earth's gravity field with high spatial and time resolution. Variations in sea-surface altitude will be measured using a satellite with a radar altimeter capable of measuring heights to 1-meter accuracy from orbit. It is estimated that the model of the active earth will require continuous and very accurate satellite tracking data. Such data will be obtained using satellite-to-satellite tracking with a series of satellites over a period of several years.

Communications. It is technically feasible by the mid-1980's to achieve widespread routine use of satellites to provide good quality, dependable, flexible communications from anywhere on land, at sea, in air, or in space to any other part of the world. Included will be the capability to communicate with entire populations of large areas for educational, informational, cultural and other national purposes. The capability can be developed to efficiently collect data and track earth-based, airborne, or spaceborne vehicles.

Two important objectives of this program are to conduct research leading to increased capacity in the presently used bandwidths and to investigate possible utilization of other bandwidths. In other areas, the communications program must meet the needs of space broadcasting for fulfilling special educational and information needs; providing a data relay and tracking function for other space missions; and applying satellites to collect data from fixed and moving sensory platforms.

Advanced versions of the current series of Applications Technology Satellites will be used in continuing the communications activity to investigate transmission characteristics in bandwidths used today and to explore other potential bandwidths that might be utilized. To develop and demonstrate the technology of space broadcasting, investigations will be conducted with a series of spacecraft that cover the three frequency ranges needed for all broadcasting applications. A Data Relay Satellite, capable of providing a continuous communications link between the space station and the ground, will be developed and flown to demonstrate the concept and its utility as a forerunner to an operational satellite system.

Data collection experiments will be conducted on both synchronous and low altitude spacecraft as precursors to a prototype operational data collection satellite system. The satellite is to be capable of collecting data from fixed and mobile platforms on the earth's surface.

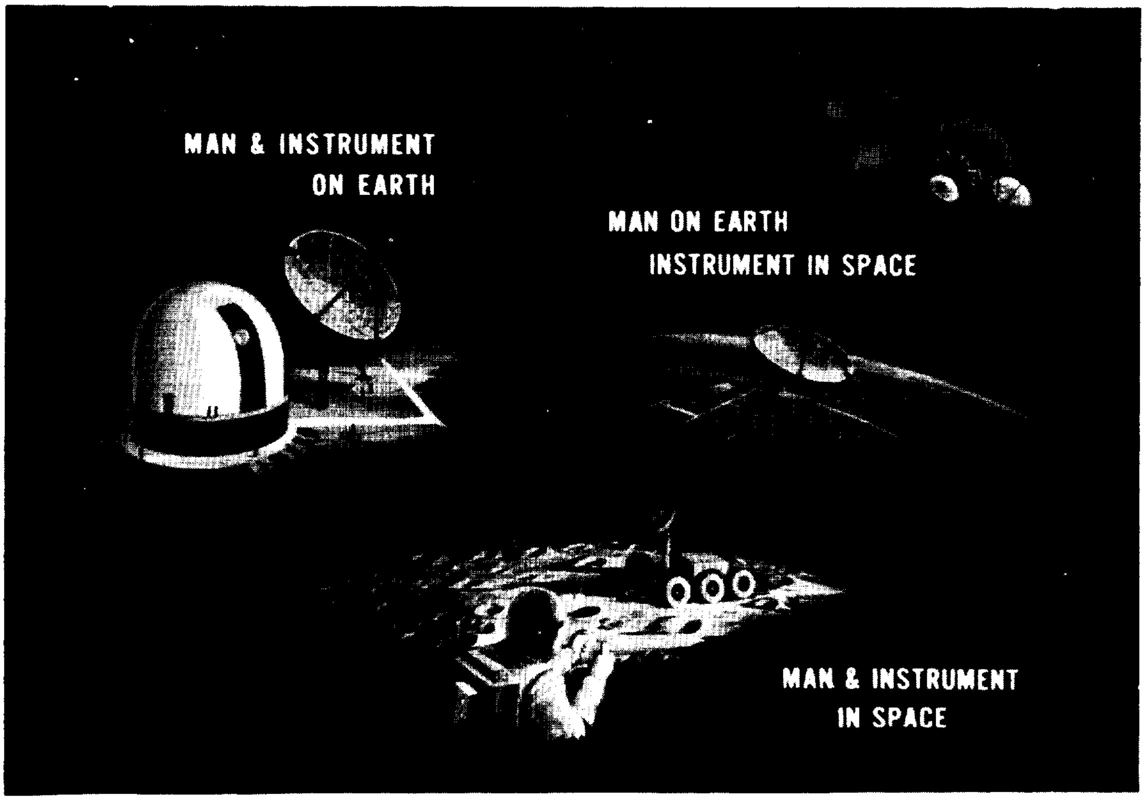
Navigation and Traffic Control. It is feasible to achieve, within the next 15 years, safer and more comfortable air and sea travel by providing an improved navigation and traffic surveillance capability, along with the ability to communicate environmental information and forecasts enroute.

The objective of this program is to determine the utility of satellite systems to meet the over-ocean aircraft and ship navigation and traffic control needs. A position fix within 0.5 nautical mile is desired. Satellite-aided aircraft and ship collision avoidance concepts will be studied and demonstrated using experimental spacecraft. Since there is a large number of aircraft and ships, low cost on-board equipment will be considered in the design of the overall system.

LUNAR EXPLORATION

In order to achieve the goals and objectives of the lunar exploration program, it will be necessary to expand the limited landing-site accessibility, staytime, payload and mobility capabilities developed by the Apollo program. Essentially, the entire lunar surface must be made accessible as landing sites, the staytime must be extended from days to weeks, astronaut mobility must be improved to the extent that sorties of at least 10 kilometers radius with science payloads of several hundred pounds can be made, automated Rover traverses up to 1000 kilometers are required, increased payloads to support the longer staytime and provide adequate scientific equipment are necessary, the ability to return larger payloads of lunar material for laboratory examination on earth is needed, and finally, the capability to conduct a broader spectrum of in situ experiments must developed.

The lunar program is structured to meet the above requirements by adding to and expanding the Apollo capabilities in three phases. The first phase, Apollo follow-on, will use basic Apollo equipment modified to increase payloads and provide greater mobility. The second phase begins with the establishment of a base in lunar polar orbit from which it will be possible to descend to any portion of the lunar surface for stays of up to 14 days. The third phase is initiated with the start of the build-up of a permanent lunar surface base.



TECHNIQUES OF EXTRATERRESTRIAL EXPLORATION

Apollo follow-on missions will use a slightly modified Saturn V with increased payload capability, but will continue to be of three-day staytime. Better mobility will be provided by improved suits and life support systems for the astronauts and a dual mode Rover, which will increase the radius of operations at the landing sites. The Rover will also be used for earth-controlled traverses after astronaut departure.

With this equipment, broader scale exploration of lunar highlands and major craters will be initiated. In addition to sample return, automated instrumentation will be emplaced, automated Rover traverses of key areas will be made, and remote sensing and mapping of the surface will be carried out from the orbiting command module.

The second phase, involving a lunar orbit base, has three key elements: the lunar orbit base, a reusable nuclear powered transfer stage, and a reusable lunar landing system. A space station module of the type developed for use in earth orbit will be used for the lunar orbit base. It will accommodate a six-man crew and will be placed in a polar orbit where it will serve as a base of operations for 14-day sorties to the lunar surface by three-man crews. The nuclear stage will be developed to transfer payloads from earth orbit to lunar orbit and return in support of the lunar orbit base, the new lunar landing system, and surface operations. The new reusable lunar landing system will transfer crews and large payloads between the lunar orbit base and lunar surface and will serve as quarters for the astronauts during surface operations.

The nuclear transfer stage will also be used for operations in earth orbit for transportation between low earth orbit and geosynchronous orbit and as the main propulsion system for manned planetary exploration. The lunar landing system will be used as a "tug" in earth orbit to move large modules into the desired location after they have been placed in orbit. It will also serve as the fourth stage of an uprated Saturn V for direct delivery of heavy payloads from earth to lunar orbit.

Important new capabilities developed by this second phase are: accessibility of the entire lunar surface for orbital sensing and surface operations, surface staytime extended to 14 days, increased payloads to and from the lunar surface, a laboratory in lunar orbit to analyze surface samples and conduct experiments, and the ability to perform sensitive radio-telescope astronomical measurements from the space station when in the area of radio silence behind the moon.

In the third phase of the program the buildup of a lunar surface base will be initiated. This will be possible due to the capability which was developed to deliver heavy payloads to the moon and the experience gained in orbital and surface operations. The initial surface base will be progressively expanded to accommodate larger and more complex surface operations. Additional bases at key locations on the moon will also be established as appropriate. As a result, staytimes of several months will be available and a broad spectrum of in situ experiments and observations will be initiated.

PLANETARY EXPLORATION

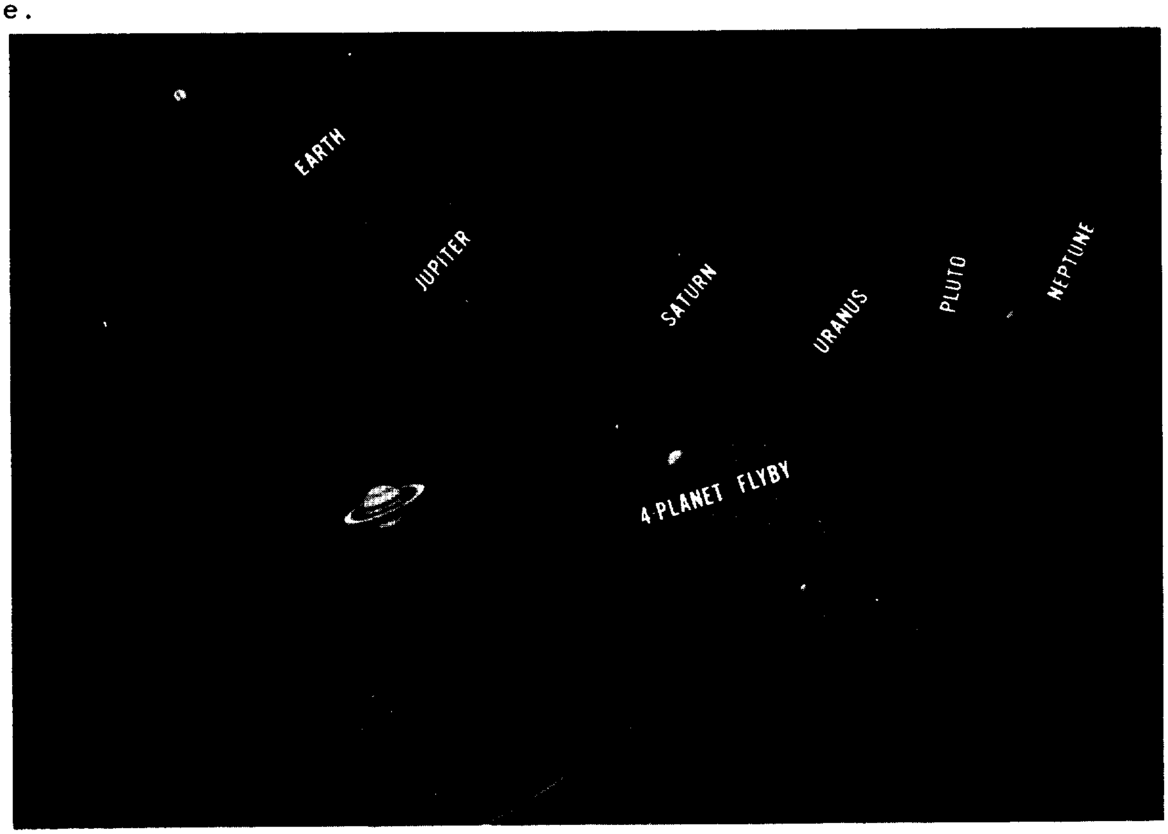
We have already emphasized the tremendous challenge to mankind represented by the opening up of the solar system to human exploration and use. Exploration of the planets must be a major part of any such enterprise, and as stated earlier the principal objectives would be to gather data on each planet, search for extraterrestrial life, and compare the various results among the planets, but especially with Planet Earth.

Near Planets: The most effective way to proceed with the exploration of the nearby planets Mars and Venus is with an integrated exploration program utilizing both automated and manned systems. The manned missions will be preceded by automated precursor missions to Mars and Venus. The automated precursor missions to Mars will provide data on atmospheric and surface characteristics necessary to design and develop mission-peculiar manned systems and to aid in selecting a manned landing site. The approach of the automated Mars exploration program is to proceed from the recent flyby missions to orbiters and then to orbiters with surface landers. The present program would be extended by adding surface roving vehicles to the landers, in conjunction with orbiters that have a capability of high-resolution mapping.

The data obtained from the automated Mars missions will be used, as it becomes available, in the design and development of the manned system. The manned Mars landing system will make maximum use of manned Earth orbital and lunar operating experience. Also, as part of the integrated program, it will utilize the space station module to house the crew during their journey to Mars and on the return flight to Earth; the nuclear transfer stage, developed initially for Earth-to-lunar-orbit transportation, will be used for boost out of Earth orbit, entering and leaving Mars orbit, and reentering Earth orbit upon return. The earth orbital program will qualify both man and systems for long-life duration in space while the lunar program will provide techniques and experience for extraterrestrial surface operations.

Exploration of Venus will continue with automated flybys and orbiters, some with atmospheric probes. These flights will gather data on the space environment near Venus, atmospheric data by remote observation, and in situ measurements from the probes. At certain Mars launch opportunities, Venus exploration will be enhanced by incorporating a Venus flyby in the manned Mars mission profile during the return trip back from Mars. Thus, man-tended instruments could gather remote sensing data, such as radar mapping measurements, and probes could be launched to penetrate the atmosphere for in situ environmental data on the surface. Automated flyby and orbiter spacecraft, some with probes, will continue observations of Venus between the manned flyby missions.

Because of Mercury's closeness to the Sun and the fact that it has little or no atmosphere, only an occasional opportunity will be utilized to fly spacecraft by the planet to obtain data on the near space environment and remote measurements of the surface. The particular opportunities for launch will be selected, in most cases, to take advantage of the relative position of Venus to permit a gravity boost for flyby missions to Mercury, thereby requiring a smaller launch vehicle.



GRAND TOUR EXPLORES FOUR OUTER PLANETS

Outer Planets: A look will be taken further back in the history of the solar system when we investigate the outer planets (Jupiter, Saturn, Uranus, Neptune, and Pluto), for it is believed that the materials of these planets are representative of the solar system material at the time planets were formed.

Jupiter, the largest and nearest of the major planets, is the first of the outer planets to explore. With its huge mass Jupiter can be used to provide a substantial gravity boost to spacecraft headed for the far out planets. In the late 1970's, the outer planets are so uniquely positioned that multiple planet flyby missions, referred to as "Grand Tours," are feasible with a single spacecraft. The next such opportunity is the Jupiter-Saturn-Pluto swingby in 1977. This is followed by a Jupiter-Uranus-Neptune swingby opportunity in 1979. Utilization will be made of both of these Grand Tour opportunities. In addition, these missions will be augmented by occasional flyby or orbiter flights to Jupiter and Saturn for remote measurements of the atmospheric and surface characteristics. Probes are included in some flights for in situ atmosphere and surface measurements.

Comets and Asteroids: The comets may consist of the primordial material out of which the solar cloud was formed, and hence be representative of a very early development stage of the solar system. Thus, studies of the comets may give us an insight into the origin and evolution of the solar system including the planets, and the dynamic processes which continue to affect planet earth. The initial mission to observe a comet's composition will be a flyby mission past the comet D'Arrest.

The asteroids are fragments of material which exist largely in a belt between Mars and Jupiter. They may be the result of collisions and breakup of planets, or they may be debris that was left when the terrestrial planets were formed. A survey flight will be made through the asteroid belt to provide a better definition of total number and general characteristics of these fragments. Later a flyby past the asteroid Eros will be made to give specific information on the environment and characteristics of one particular asteroid.

AERO/SPACE TECHNOLOGY

Underlying the flight programs described in the preceding sections of this Chapter is a vigorous effort in all the pertinent areas of technology: propulsion, including the nuclear rocket; life support systems; materials and structures; optics and electronics; guidance and control; power systems; data handling and analysis; and aeronautical technology. Although this report treats only the space portion of the NASA program, it should be noted that the aeronautics program is not only important for its own sake, but both contributes to and benefits from the space effort.

As described earlier, the Space Technology activity is composed of two elements, research to develop new fundamental knowledge of the physical sciences and supporting technology to demonstrate the applicability of this new knowledge to future space flight systems. The research activity, which usually is categorized by disciplines, cuts across the entire space flight spectrum. For instance, research in the mathematical sciences contributes to the field of machine intelligence; work on lasers contributes to communication and magneto-hydrodynamic power and propulsion systems; high temperature material work contributes to rocket combustion chambers and nozzles and to entry heat shields and structures, which are basic to achieving an earth orbital shuttle or a planetary entry spacecraft; structure research in composite materials contributes to reducing costs of spacecraft, launch vehicles, and the earth orbital shuttle.

In supporting technology, flight experiments and proof-of-concept projects are configured for timely support of the Earth Orbital, Lunar, and Planetary programs. In support of manned earth orbital and lunar missions, major technology efforts will include demonstration of systems applicable to low cost solid boosters, development and demonstration of advanced hydrogen-oxygen engines and lifting bodies applicable to flexible and economic space shuttle systems, development of techniques to permit long term storage of hydrogen in space, and demonstration of advanced power systems for long-duration missions. Effort will also be continued toward the development of a nuclear rocket engine for subsequent use in the nuclear transfer stage having application to both the lunar base and manned planetary exploration.

The technology activity associated with Science and Applications includes flight projects for radio (large deployable parabolic) and optical (reflective 2-meter) telescopes, demonstration of communication and tracking techniques employing high-power lasers, a gravity gradient experiment for stabilization purposes, and an earth horizon measurement experiment employing infrared techniques to improve vertical pointing accuracy.

In support of planetary exploration, activity will include demonstration of advanced electric propulsion concepts; development of techniques for entry and landing on the planets and for earth entry upon return; initiation of a flight experiment for an interplanetary meteoroid mission; and demonstration of prototype propulsion systems employing promising propellant combinations.

CHAPTER 3

PROGRAM RATES

Three representative approaches for carrying out the program described above over the next twenty years have been developed, each of which maintains the integrity of the following basic concepts:

- Increasing returns in science, engineering, and applications commensurate with investment costs.
- Pursuit of the principles of commonality, reusability, and economy through the efficient development, management, and operation of manned space systems.
- Continued exploration of the solar system, including manned expeditions to the planets, beginning with Mars.

The three programs include the same principal elements of activity but the accomplishments are differently phased in time with a corresponding shift in annual resource requirements.

COMPARATIVE PROGRAM ACCOMPLISHMENTS

MILESTONES	MAXIMUM RATE	PROGRAM I	PROGRAMS II, III
Manned Systems			
Space Station (Earth Orbit)	1975	1976	1977
50-Man Space Base (Earth Orbit)	1980	1980	1984
100-Man Space Base (Earth Orbit)	1985	1985	1989
Lunar Orbiting Station	1976	1978	1981
Lunar Surface Base	1978	1980	1983
Initial Mars Expedition	1981	1983	II - 1986 III - Open
Space Transportation System			
Earth-to-Orbit	1975	1976	1977
Nuclear Orbit Transfer Stage	1978	1978	1981
Space Tug	1976	1978	1981
Scientific			
Large Orbiting Observatory	1979	1979	1980
High Energy Astronomy Capability	1973	1973	1981
Out-of-Ecliptic Survey	1975	1975	1978
Mars-High Resolution Mapping	1977	1977	1981
Venus-Atmospheric Probes	1976	1976	Mid-80's
Multiple Outer Planet "Tours"	1977-79	1977-79	1977-79
Asteroid Belt Survey	1975	1975	1981
Applications			
Earliest Operational Earth Resource System	1975	1975	1976
Demonstration of Direct Broadcast	1978	1978	Mid-80's
Demonstration of Navigation/Traffic Control	1974	1974	1976

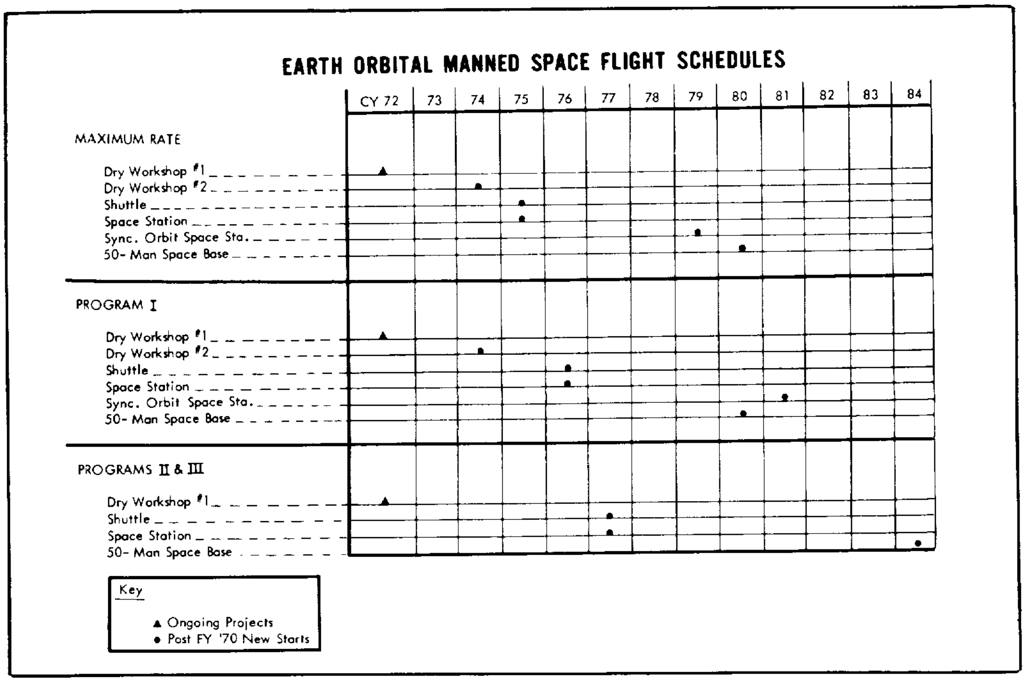
Program I represents a vigorous build-up of activity aimed toward early achievement of our space potentials. Program II is constrained by a hypothetical FY 1971 ceiling of $4 billion and represents a much lower and slower level of accomplishment in all areas over the full period. Program III is identical with Program II except without a commitment to manned planetary exploration; it illustrates the severability of such a decision from the rest of the recommended program elements. These three representative programs are described more fully below and are illustrated by accompanying expenditure charts, representative flight schedules, and program accomplishments. For purposes of comparison, these figures also include the estimates of expenditures, the schedules, and program accomplishments that would reflect the earliest possible technically feasible achievement of all major program milestones.

PROGRAM I

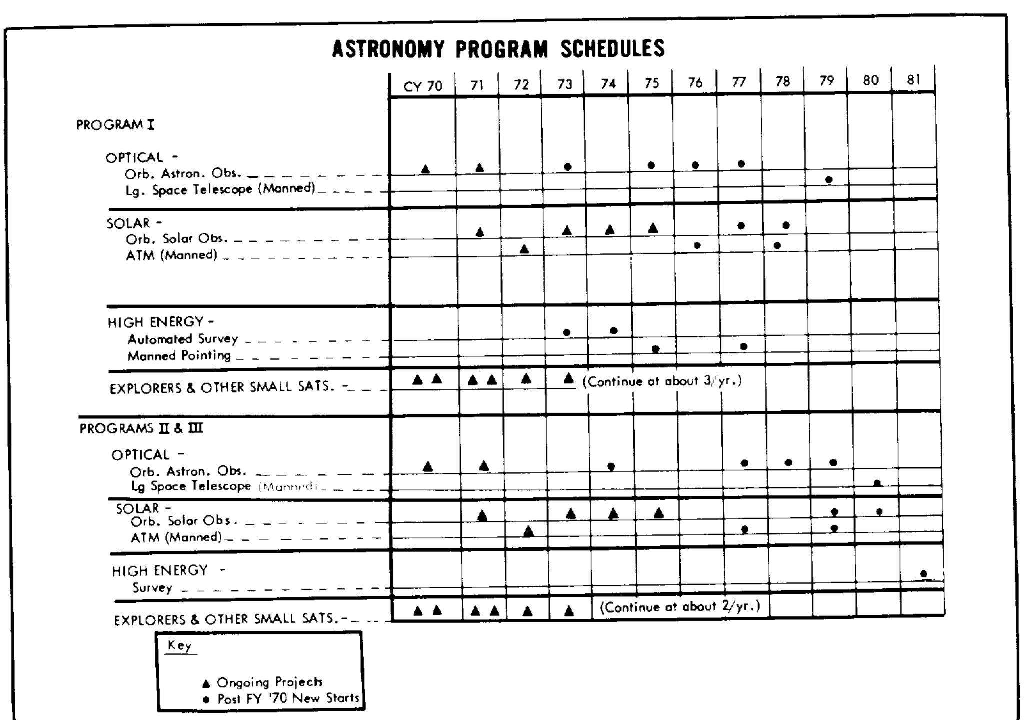
Earth Orbit

The major emphasis for earth-orbital activity is the early and rapid development of the interrelated space station module and earth-to-orbit reusable shuttle. A 12-man station would be operating in 1976 supported by the space shuttle. By 1980, this initial capability would be steadily expanded to a 50-man space base, and further expanded by 1985 to house 100 people. A 12-man geosynchronous station would be launched in 1981 and later expanded to a 50-man base.

The basic launch vehicle for the space station modules would be a 2-stage derivative of the Saturn V. The standardized space station module would also serve for later use as lunar orbit and surface modules (see below) and a planetary mission module in the 1980's.



In Astronomy, the main focus would be on developing large (100-inch) telescope systems for use with the manned systems as well as aggressive development of high energy experiments that could lead to an eventual manned laboratory. Explorer and OSO-class automated satellites would be continued.



In Space Physics, the major developments would include relativity experiments, space weather probes, out-of-the-ecliptic probes, and a cluster of magnetosphere satellites. The Explorer class satellites would also continue. In the Life Sciences would be included space station laboratory work, non-recoverable biological satellites and probes, and a major emphasis on both ground- and space-based research on terrestrial life in space, including man.

SPACE PHYSICS SCHEDULES

	CY 70	71	72	73	74	75	76	77	78	79	80	81
PROGRAM I												
ISIS	▲		▲		●							
Atmosphere Explorers		▲	▲				●●			●		
Small St'd. Satellites	▲	▲	▲	▲	●●	●	●	●	●	●	●	
Interplan. Monitor Probes	▲	▲	▲		●●	●●		●●	●	●●	●	
Helios					▲	▲						
Small Interplan. Sats.			▲	▲	▲	▲	▲					
Space Weather Probe				●				●			●	
Cluster Satellites						●			●		●	
Cooperative Satellites				●	●							
Out-of-Ecliptic Pioneer						●	●					
PROGRAMS II & III												
ISIS	▲		▲		●							
Atmosphere Explorers		▲	▲									●●
Small St'd. Satellites	▲	▲	▲	▲	●	●	●	●	●	●	●	
Interplan. Monitor Probes	▲	▲	▲			●●	●●		●●			●
Helios					▲	▲						
Small Interplan. Sats.			▲	▲	▲	▲	▲					
Space Weather Probe						●						
Cluster Satellites								●			●	
Out-of-Ecliptic Pioneer									●	●		

Key

▲ Ongoing Projects
● Post FY '70 New Starts

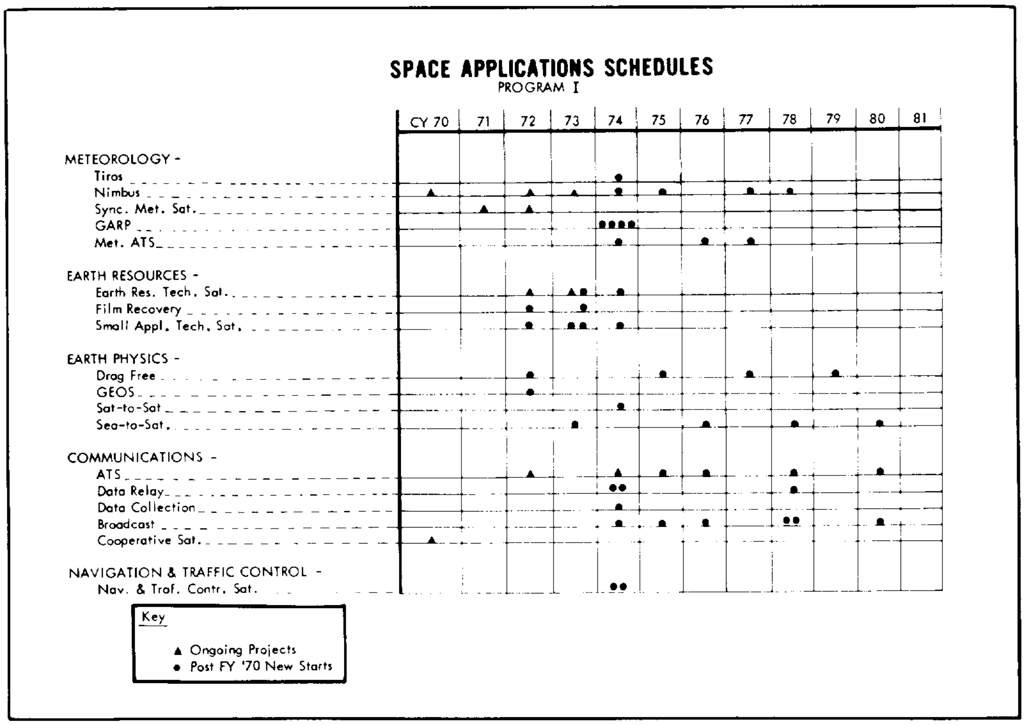
LIFE SCIENCE PROGRAMS

	CY 70	71	72	73	74	75	76	77	78	79	80	81
PROGRAM I												
AUTOMATED-												
Bioexplorer			●●	●●	●●	●●	●	●	●	●	●	
Biopioneer					●	●	●	●				
MANNED-												
Biotechnology Lab.							●					
Variable G Exper.							●					
PROGRAMS II & III												
AUTOMATED-												
Bioexplorer				●	●	●	●		●		●	
Biopioneer						●		●		●		
MANNED-												
Biotechnology Lab.								●				
Variable G Exper.								●				

Key

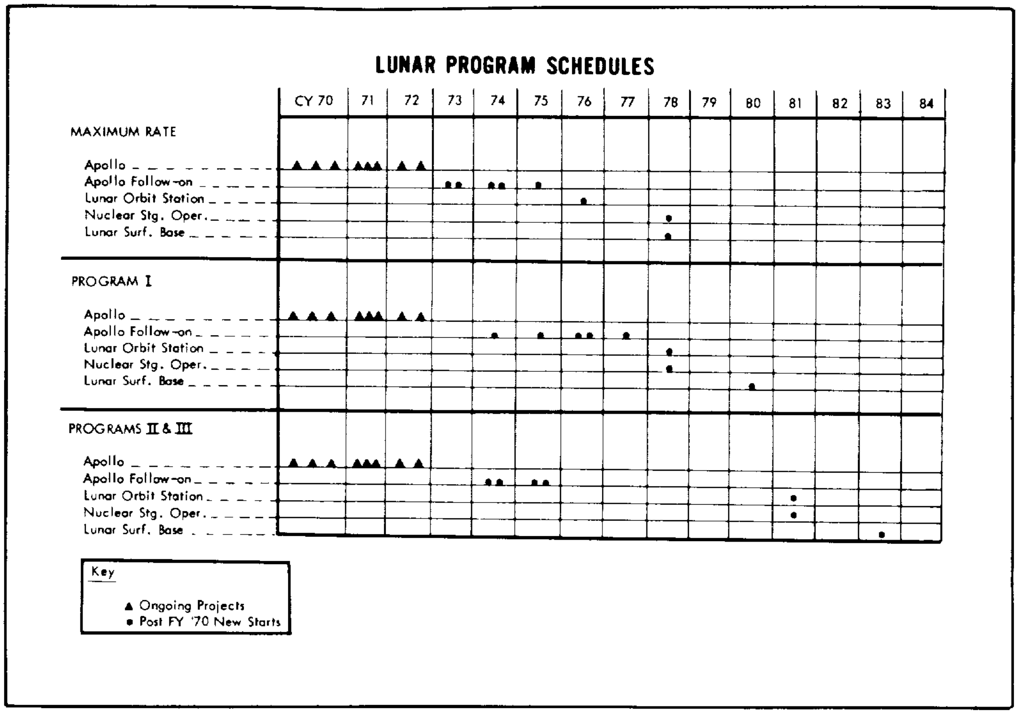
▲ Ongoing Projects
● Post FY '70 New Starts

In Applications, a vigorous effort would be focused on bringing into operation as quickly as possible new and improved space systems for earth resources surveys, advanced meteorology, oceanography, data collection and relay, navigation and traffic control, and direct broadcasting.



Lunar

Following the runout of the current Apollo missions in 1972 would come extended Apollo missions having a 3-day surface mission duration. In 1978, a space station module would be placed in lunar polar orbit by a reusable nuclear stage. A new landing vehicle, the space tug, would permit continuing manned sorties to any part of the lunar surface for mission durations of up to 14 days with an emergency capability for an additional 14 days on the lunar surface. This would make possible our first rescue capability. Resupply and crew rotation from earth would be accomplished by using the space shuttle for transportation between the earth and earth orbit and using the nuclear shuttle to transport the space tug between earth orbit and lunar orbit. In 1980, a space station module would be landed as part of the first permanent lunar base. By 1984, there would be a 25-man lunar orbital base in operation and by 1986, a 50-man surface base. The nuclear stage, the space tug, and the earth-to-orbit shuttle would provide low cost logistics support to both orbital and surface lunar activities.



Planetary

A strong automated program of solar system exploration would be complemented by a manned planetary expedition at an early opportunity. Mars would be visited by automated orbiters and landers in 1975, 1977, 1979, and 1981; dual manned expeditions would be launched in 1983, 1986, and 1988, using space station modules as crew quarters, nuclear stages developed in the lunar program, and a new manned Mars excursion module. These voyages would be made on reusable deep-space ships. The first mission would swing by Venus on the return trajectory from Mars, providing an opportunity to probe the Venus atmosphere and surface with remote controlled equipment. At almost each Venus opportunity, automated spacecraft including probes, orbiters, and buoyant stations would be launched. Automated exploration of the outer planets would include a Jupiter-Saturn-Pluto Grand Tour in 1977 and another in 1979 to Jupiter, Uranus, and Neptune.

PLANETARY PROGRAM SCHEDULES

		CY 70	71	72	73	74	75	76	77	78	79	80	81	82
PROGRAM I MARS	- Orbiter		▲▲											
	Viking Orb/L				▲▲		●●							
	High Data Rate Orbiter								●				●	
	Lander/Rover								●●		●		●	
	Explorers						●		●				●	
VENUS	- Mercury/Venus Swingby				▲					●				
	Flyby with Probes								●●					
	Orbiter									●			●●	
	Explorers				●		●	●		●				
OUTER PLAN.	- Jupiter Flyby			▲	▲					● (Orbiter)				
	Jup-Sat-Pluto Swingby								●●					
	Jup-Uran-Nept. Swingby										●●			
	Jupiter Flyby with Probes											●		
	Saturn Orbiter with Probes												●	
COMETS	- D'Arrest Flyby							●						
ASTEROIDS	- Asteroid Belt Survey						●							
	EROS Flyby												●	
PROGRAMS II & III MARS	- Orbiter		▲▲											
	Viking Orb/LDR				▲▲		●●		●					
	High Data Rate Orbiter												●	
	Explorers										●		●	
VENUS	- Explorers									●		●	●	
OUTER PLAN.	- Jupiter Flyby			▲	▲									
	Jup-Sat-Pluto Swingby								●●					
	Jup-Uran-Nept. Swingby										●●			
ASTEROIDS	- Asteroid Belt Survey												●	

Key
▲ Ongoing Projects
● Post FY '70 New Starts

MANNED PLANETARY FLIGHT SCHEDULES

	CY 80	81	82	83	84	85	86	87	88	89	90
MANNED PLANETARY EXPEDITIONS											
MAXIMUM RATE		●		●			●		●		●
PROGRAM I				●			●		●		●
PROGRAM II							●		●		●
PROGRAM III				(Left Open)							

Key
▲ Ongoing Projects
● Post FY '70 New Starts

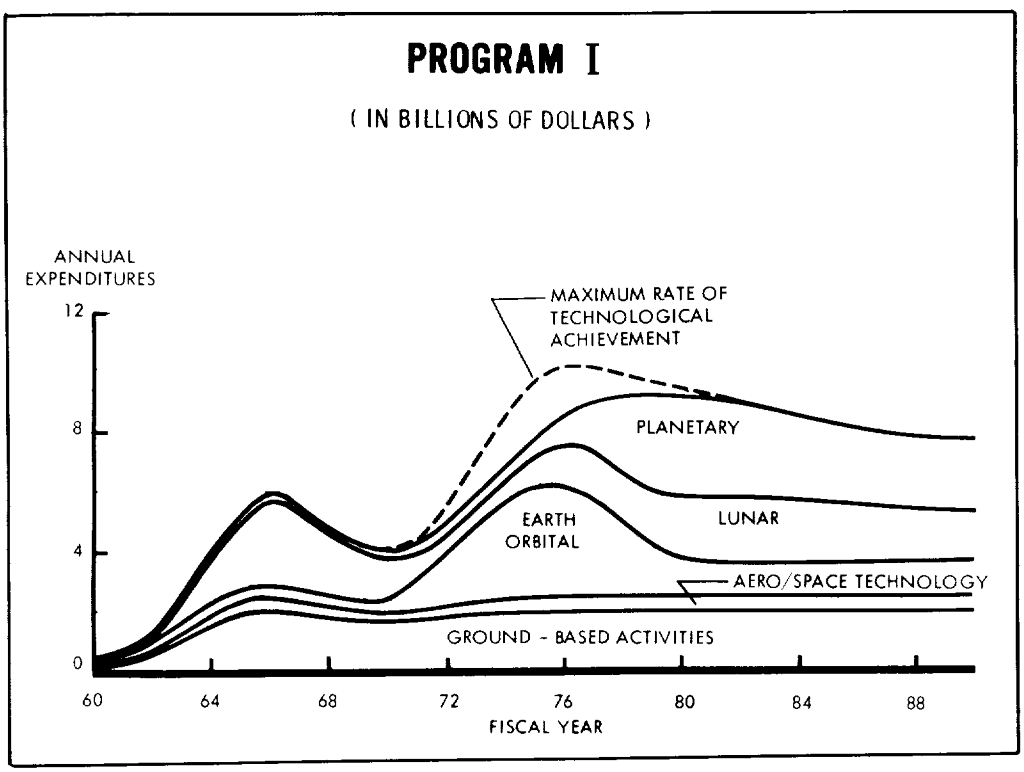
Aero/Space Technology

The Aeronautics program would provide for a vigorous research program to advance the technological base, continued intensive support to other agencies, and some selected activity in proof-of-concept and flight test applications.

The Space Technology program effort would continue to advance fundamental knowledge pertinent to flight and to provide the technology base geared to the requirements of the flight programs and objectives outlined above.

Ground-based Activities

Ground-based Activities comprise the necessary personnel and facilities support for the R&D flight program, as well as the University and Technology Utilization programs. This category of effort would reflect the program vigor described above. An increase over present levels in in-house personnel, tracking and data acquisition operations, and university research grants and fellowships would be indicated.



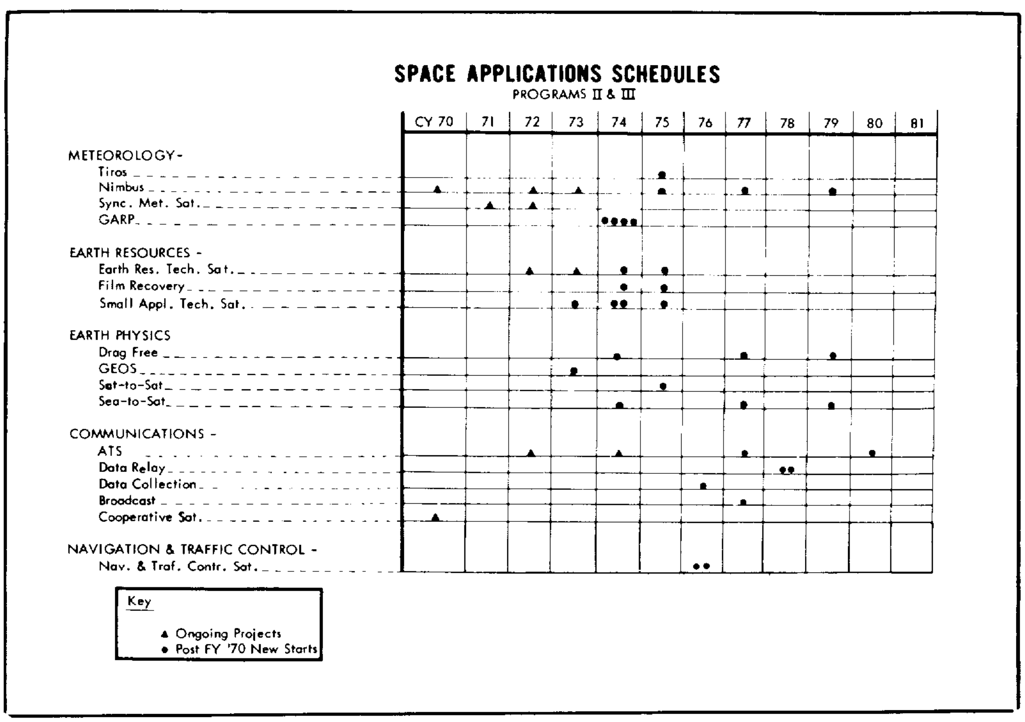
PROGRAMS II AND III

Earth Orbit

The space station and shuttle described above would become operational in 1977; expansion to the 50-man base would be in 1984 and to 100 men by the end of that decade.

The Astronomy program would include additional OAO-class observatory satellites in 1974 through 1979; additional ATM solar instruments in 1977 and 1979 and a large manned telescope by 1980. High energy missions would begin in 1981. In Space Physics the Explorer and IMP class satellites would be continued, with a space weather probe in 1975 and the first magnetosphere cluster satellite in 1977. In the Life Sciences, Bioexplorer missions would begin in 1973 and Biopioneer in 1975. A continuing level of supporting research and technology would be maintained in the area of Space Medicine. In Applications, there would be continuing investigations in areas of interest at a rate permitting some new starts after 1971.

The level of science and applications investment, while higher than the present, would be 30% below that of Program I.



Lunar

After the Apollo runout in 1972, there would be a 4-flight program extension of three-day surface missions in 1974 and 1975. In 1981, a lunar orbit station would be launched, followed by the first surface station in 1983. Both stations would be gradually expanded through the rest of the decade, utilizing nuclear shuttle capability.

Planetary

The automated program would focus on Mars prior to eventual manned exploration, with automated missions to Mars at each opportunity through 1983. This would be followed by the first manned expedition in 1986 or 1988. The 1977 and 1979 Grand Tours would be included, and automated Venus missions would be resumed in the late 1970's.

In Program III, the manned planetary decision is left open.

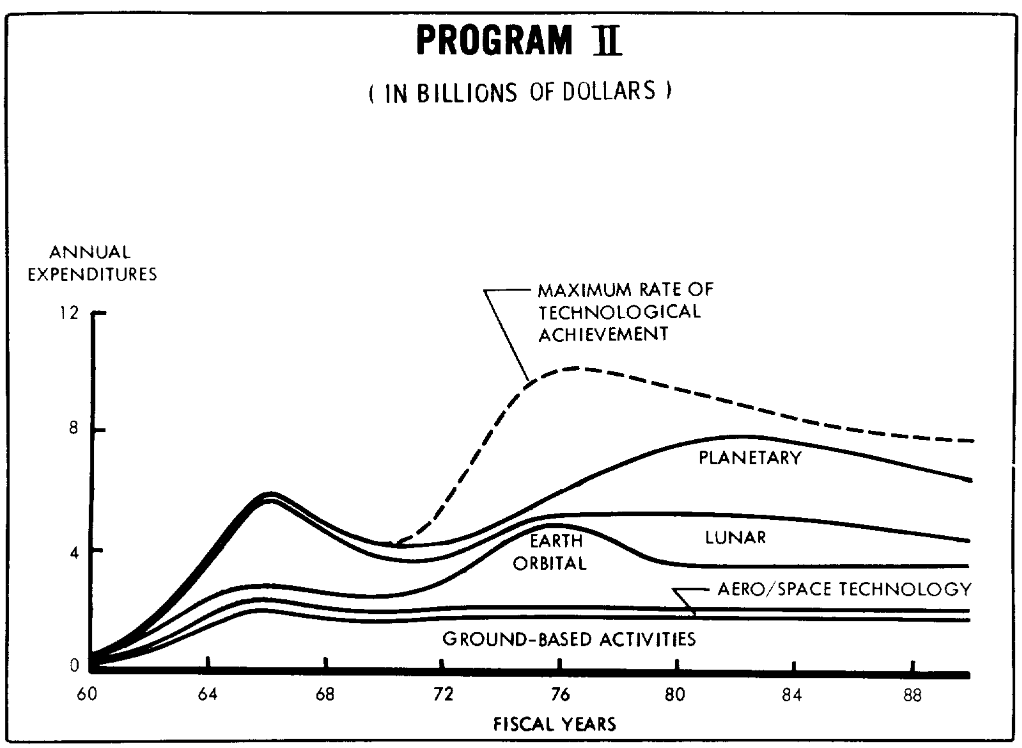
Aero/Space Technology

In Aeronautics, the program supports continuation of research activity at approximately current levels.

The Space Technology program effort will continue to advance fundamental knowledge pertinent to flight and to provide the technology base geared to the requirements of the flight programs and objectives outlined above.

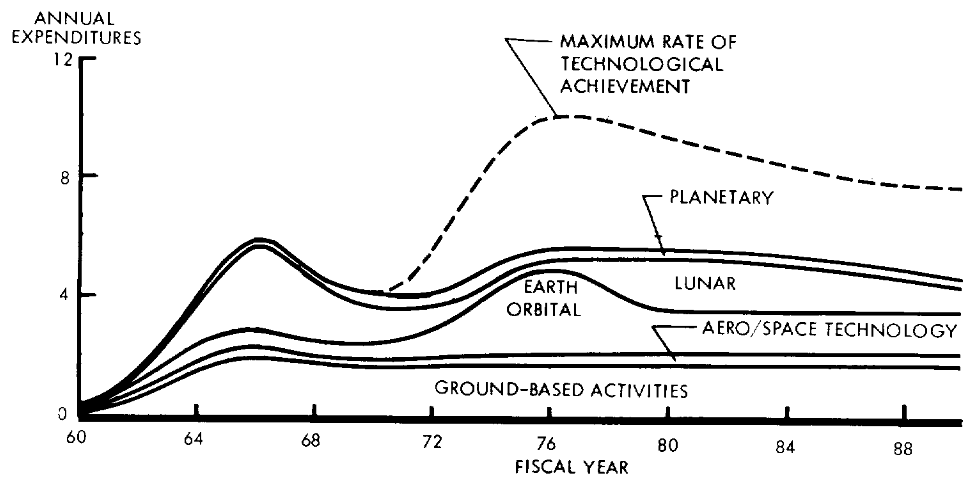
Ground-based Activities

It is assumed that no buildup in capabilities will be required beyond 1971.



PROGRAM III

(IN BILLIONS OF DOLLARS)



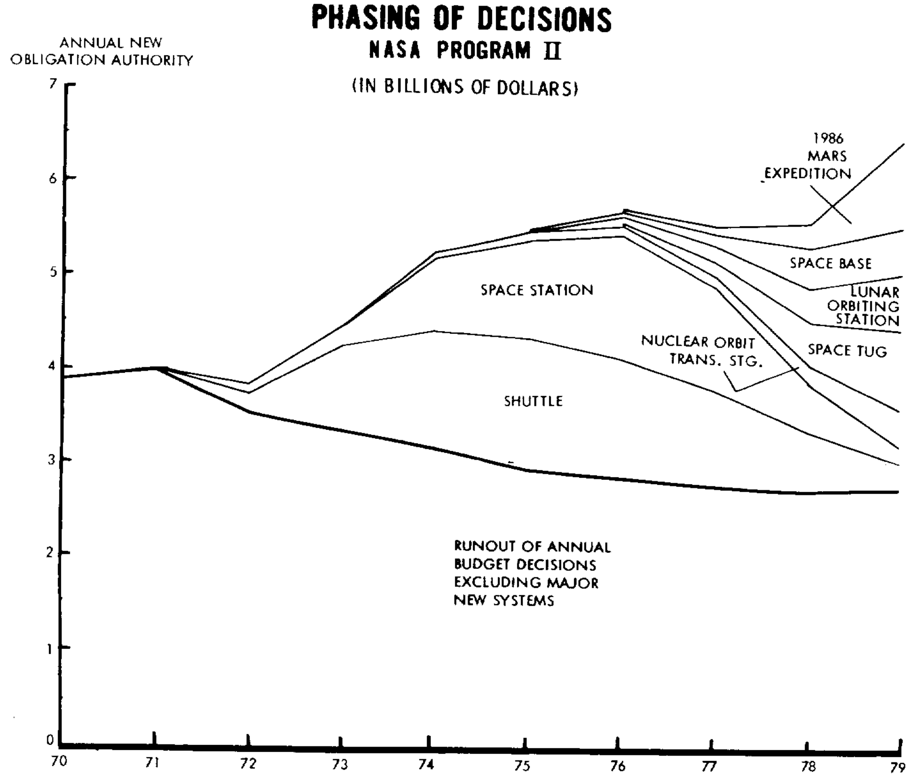
PROGRAM FLEXIBILITY

The expenditures for the several programs are envelopes resulting from the cumulative effect of many detailed project decisions to be made over time. Each program illustrates a particular combination of decisions necessary for a specific time-phased achievement plan. Many of these decisions can be made independently; others are interdependent in character, particularly those involving the sequential phasing of the development and use of the major space station module and space transportation system elements. Within limits, therefore, the three representative programs can be bracketed by other potential program combinations reflecting different feasible sequences of future decisions that would still be consonant with the overall goals and objectives sought for the next decades in space.

PHASING OF DECISIONS

NASA PROGRAM II

(IN BILLIONS OF DOLLARS)



VI VALUES OF THE SPACE PROGRAM

The values of the space program are many and varied, and a proper assessment of the worth of the space investment to the Nation requires a look at the total picture. In this total picture there are both direct and indirect, tangible and intangible, values to assess.

Science and Applications

Among the direct, tangible benefits are the utilization of space for practical applications and scientific research. The values of weather forecasting, communications and its applications, navigation and traffic control, and earth resource observations can be stated to some extent in terms of dollar returns, and this is discussed further below.

One of the most valuable contributions of the space program is to provide the means for estimating the feasibility of potentially valuable space applications, and this is a legitimate and important element to include in the space applications program. In an arena where estimates by various study groups place the total returns at many billions of dollars annually, this general advanced technology and experimental development provides the basis for selecting those specific applications with the greatest payoff.

The value in the scientific area lies in the ability to attack important problems on the frontiers of science that cannot be investigated with effectiveness or even at all by other techniques. Geophysics, now encompassing the many bodies of the solar system, has become a broader, more illuminating, more powerful science than ever before. Because of the practical importance of geophysics to us in understanding and wisely managing our environment and natural resources, the value is very great. From this field we derive an understanding of those atmospheric processes that we will have to deal with in tackling problems of air pollution, weather modification, and eventual climate control. Study of the earth also aids in the search for new mineral resources, a growing need in our technological era.

With spaceborne instruments, astronomers can observe in ultraviolet, X-ray, gamma ray, infrared, and radio wavelengths denied to them at the surface of the earth by the blanketing effects of the earth's atmosphere. Moreover, even in the optical wavelengths, the sharpness and precision of observations should ultimately be improved because the distortion of the earth's atmosphere has been eliminated. A 100-inch telescope in space, above the distorting atmosphere, could see 10 times as far as, and detect objects 100 times fainter than can the 200-inch Palomar telescope, and would afford significantly greater precision in angular measurements. Moreover, such a telescope would for the first time in the history of astronomy permit the development of theory and adequate test by observation across the whole spectrum. Coming at a time when quasars, pulsars, and X-ray sources have been discovered, and are yet to be explained, space techniques will be a most powerful aid to modern astronomy. The X-ray sources, which were discovered by rocket instruments, were not predicted by previous theory. Moreover, the ultraviolet emissions of hot stars have been found to depart widely from what had been expected, and may imply that previous estimates of distances in the universe were much too small.

It should also be recalled that the attempt to explain how the sun and stars continue to radiate for billions of years, led to opening up the field of nuclear energy. Now astronomers are wrestling with a question of explaining how quasars are able to emit energy at prodigious rates far beyond anything known hitherto. Space observations will provide data to help answer such questions.

Interplanetary space is a valuable laboratory in which the physics of plasmas, high energy particles, and magnetic fields can be studied free of many of the limitations experienced in our orbital space laboratories. Fundamental experiments, requiring the scale of the solar system, can be conducted on relativity and the fundamental nature of gravity. For the former, precise clocks or very high precision quantized magnetic flux gyroscopes can be used to check velocity and gravity red shifts and orbital precessions to provide more precise checks on the predictions of general relativity than have hitherto been possible. The earth-moon system itself may be used as a detector to look for the passage of gravitational waves in the universe, such as might be created in supernova explosions. Gravity, the weakest of the fundamental forces of nature, still defies explanation, and experiments to learn more about it have, therefore, a special importance.

The discovery of extraterrestrial life would likely rank as the greatest scientific discovery of the century. Its study should prove most illuminating in investigations of the origin and nature of life. A variety of instruments on Mars landers will measure the chemistry and environment of the planet, and look for evidence of biological activity. Even if life is not found on Mars or any of the other planets, the progress of their chemistry toward life will be important in understanding the chemical evolution of life. Eventually, after we have studied these planets, we may well want to experiment with the interaction of terrestrial life with their atmospheres and surface environments.

Biological experiments can be conducted in space under conditions of weightlessness and removal of the normal periodicities of the earth environment. Such research will give fundamental information on the basic role of time and gravity in life processes. So far unmanned satellites have been used for this purpose, but eventually a manned space laboratory will be important for such researches. Various tests have been and will be made to study behavior of plants, animals, insects, and other specimens under prolonged weightlessness, where possible through several generations. Deep space probes, which will remove specimens completely from earth periodicities will be especially important in studying the fundamental role of time in life processes.

Thus the space program contributes in a significant way to the advancement of science, which makes possible in turn the advancement of our modern scientific and technological society. A more direct contribution of space science is to the understanding of our space environment which is required in the design and utilization of space hardware, and in the planning of the exploration and use of space. A future important contribution of space science will be to understanding and solving the problems of making it possible for terrestrial plants and animals, including man, to exist self sufficiently on other worlds.

National Capability

One of America's most important accomplishments to date in the space program has been the establishment of a broad national capability to plan and carry out a forward-looking space program. This capability permits us to operate as we choose in space, to make use of the advantages we choose, and to prevent any other power from denying us the utilization of space in our interests. Thus, the existence of this space capability contributes to our national security, and maintains our prestige and standing in the world. Moreover, a visibly strong America is important in maintaining stability within the world. Our space capability, and the use we have made of it, for example, in the Apollo visits to the moon, make Americans stand taller in their own eyes, as well as in the eyes of the rest of the world. It gives Americans a sense of achievement, and of the ability to achieve. It stands as a challenge to the vexing problems of the day to tackle those with equal vigor and success, and gives reassurance that we can succeed if only we determine to do so.

The continuing development and utilization of this national space capability will help to maintain our standing in the eyes of the world, and is a powerful hedge against technological surprise in an area of importance to national security, as well as to civilian applications, science, and exploration.

This national capability provides the various agencies of government, -- Defense, Interior, Agriculture, Commerce, Transportation, etc., -- with new and powerful approaches to meeting some of their requirements. Because of this capability, space techniques can now contribute substantially to long range weather forecasting, and ultimately to weather modification, and climate control. We can foresee expanded communications capabilities, effective air traffic control and safety systems and programs, and better earth resource survey and management.

Expanding Horizons

Peering into the future, it is likely that the greatest value of all in the space program will be the introduction of a new era of exploration, in which the solar system will be opened to mankind. How long it will take for this to become a self sustaining venture no one can truly foresee. But we are privileged to have the opportunity to exercise leadership in this high human adventure. If this is indeed to be the greatest value of all in the long sweep of history, it certainly behooves America to move out in the years ahead with a boldness and determination equalling that which led us to undertake the Apollo project in the early 1960's.

Past Results

The projects set in train by the civil space program have been so advanced in character and their public visibility has been so high that the program has inevitably been associated with a range of broader values and implications. Among them are the retrieval and advancement of U. S. prestige, the enlargement of scientific knowledge and intellectual horizons, the interest and excitement of high adventure, the innovation of practical benefits on a global scale, such as space communications and weather systems, the stimulation of the national economy in general and advanced technology in particular, the demonstration that our society can effectively mobilize to achieve pre-set goals and solve complex problems, the provision of new opportunities for international cooperation, and significant contributions to national security.

To the extent that these values and implications are substantial, they enhance the returns from the national space program, broaden the consideration it should have in national planning, and deepen its contribution to the national interest. A selection of factual and quantitative data is provided below to suggest the reality and extent of the broader values and implications of the space program. Its significance is not in the precise weight of each item or in the simplistic addition of items but rather in the degree to which, taken together, they suggest the greater breadth and depth of the forces and attractions set in motion by the nation's space program.

Economic impact. To put NASA's outlays in perspective, it should be noted that the U. S. civilian space effort accounts for less than one-half of one percent of the Gross National Product, three percent of the federal budget, and only fifteen percent of aerospace industry sales. A bold and vigorous space program would build up to a level of 1% minimum. All but 17 of the top 100 American corporations now employ more people than NASA which is only half the size of a large corporation like General Electric. Americans spend three times NASA's annual budget on alcohol, over twice as much on tobacco, more on foreign travel and more on parimutuel betting. Federal expenditures alone in FY 69 provided $92.6 billion for social purposes -- natural resources, commerce and transportation, housing and community development, education and manpower, health and welfare (including disbursements from trust funds), and federal aid to the poor. In the past decade, such expenditures have totaled $550 billion, with Asian wars consuming an equal sum. These two Federal ventures thus represent one trillion dollars in outlay, compared to $35 billion for space.

Space programs have already created at least one new growth industry -- commercial satellite communication -- which has multiplied the number of available commercial communications channels (Atlantic and Pacific) 2-1/2 times and introduced real-time intercontinental TV. Costs per circuit have been reduced below those provided by the latest submarine cables by about four-fifths. This new global industry can be measured already as a $168 million activity, but it is only in its infancy and the larger economic effects of vastly improved global communications can only be guessed at.

The economic impact of operational meteorological satellite systems is less tangible, but the early reporting of typhoons in vast areas which previously lacked warning systems is resulting in continuing savings in lives and property. The National Academy of Sciences puts the potential economic value in the U. S. alone at $2-1/2 billion anually. The cost of a global weather system based on satellites has been estimated to be $150 million a year less than a less-effective conventional system. Already, more than fifty nations are receiving direct daily weather data from U. S. satellites.

Impending earth resources survey programs by satellite promise further extensive direct economic returns.

Using the Bonneville Power Administration as a model, estimated 20-year benefits resulting from improvements in water management by satellite remote sensing would exceed $6 billion within the U. S. alone.

Prospective air-sea traffic control and navigation satellite systems will add additional sums to the economic contributions of space activity through direct increments in traffic efficiency and safety: A one-percent savings in fuel and manpower costs due to navigation improvement would save the shipping industry $150 million per year. Of course, these space systems create at the same time new needs and growing markets for high-technology equipment and skills.

As an earth-bound economic activity, the national civilian space effort has contributed $35 billion in goods and services to the U. S. economy in a decade, employing an average of 250,000 people per year for ten years. The space industry is highly labor-intensive, i.e., makes heavy use of manpower relative to cost of product, a characteristic associated with the most efficient flow of economic benefits. Over ninety percent of space funds has been spent in the private sector, impacting over 20,000 firms in the first levels of prime and sub-contracts. These contracts have gone to all states in the nation. Twenty states have received over $100 million each in prime contracts alone. The twenty-five largest contractors actually perform their contracts in 30 states and 177 cities. By February 1969, 802 cities has received 10,000 contracts and grants totalling $22.5 billion. Almost $2 billion in prime contracts went to 329 labor surplus cities. Space expenditures were further distributed by a small business program over the past five years which brought a third of prime contractors' subcontracts to small businesses. High-technology work and skills, previously lacking, were introduced intensively in Florida, Louisiana, Texas and Alabama, four of the six states which have received over $1 billion each in prime contract awards. Cutbacks in space would severely impact communities in these areas.

NASA and its contractors absorbed only twenty-five percent of the increased national requirement for scientists and engineers in the 1962-65 build-up period. We now employ only four percent to five percent of scientific and engineering manpower in the nation, yet work is being stimulated and advanced in over 100 specialized areas of science and engineering and many new specialities have been created.

In advancing management techniques NASA has extended and refined the PERT system, developed an advanced documentation system for very large projects in the Apollo program, and introduced advanced data retrieval systems and equipments for management purposes. NASA has extended the use of incentive fee and cost-plus-award provisions in billions of dollars of contracts and has extended and improved contractor selection techniques through Source Evaluation Board practices in all procurements over $1 million. More than 1000 technical personnel have participated in procurement training programs. Patent policy innovations have been introduced to stimulate the commercial practice of inventions. Government-owned facilities and equipment have been made available on a rental basis for commercial work and, in 250 separate cases in CY 1968 alone, they have been made available on a rent-free basis to support the work of other government agencies.

Most fundamental, NASA has managed its program in such fashion, despite the ambitious and complex character of its objectives, as to achieve those objectives with a high degree of success, within predicted timeframes, and within reasonable range of targeted program costs.

Technological stimulus. Space activity is a forcing function in each of nine broad areas of technological innovation which the Department of Labor expects will have the greatest impact on future society: computerization of data processing; advanced instrumentation and process control; increased mechanization; progress in communications; advances in metal-working operations; developments in energy and power; new materials, products, and processes; and managerial techniques. No one can yet assess just how great the impact of space programs has already been in these areas. That we are a forcing function, however, is clear. More than 3,000 items of new technology generated by the civilian space effort have been reported to the industrial, education and business communities through NASA's Technology Utilization Program. These communities purchased 500,000 Tech Briefs describing such innovations in 1968 alone. Nearly 500 fee-paying industrial clients use the search-and-retrieval services of the Technology Utilization Program's six dissemination centers. The Clearing-House for Federal Scientific and Technical Information has received purchase orders for more than 100,000 copies of TU surveys, reports and handbooks which review sixty-five fields of technology in which space programs have made significant technological contributions (45 more reports and surveys are in preparation). Seven hundred trade and professional journals routinely review NASA's TU program; 387 of them published over 900 articles in 1968 reporting the availability of space innovations to a circulation exceeding 55 million. The Denver Research Institute at an early stage in this program has documented more than 400 consummated and applied technology transfers from space work.

An interagency task group has been established to spread this technology identification and transfer program through all federal agencies, and the AEC has already implemented a duplicate program. NASA has pioneered arrangements for the exchange of data bank tapes permitting NASA, DOD, and Commerce to exchange tapes covering about 10,000 NASA items and a similar number of DOD items without reprocessing. NASA has established a Computer Software and Management Information Center (COSMIC) through which over 15,000 computer programs and related software information have been ordered by industry and other agencies. The average user of a COSMIC computer program saves 50-90% of the development cost. One widely-used structural analysis program has permitted savings conservatively estimated at over $100 million. Another program has been purchased by 170 different enterprises.

To bring space-generated technological innovations to small business, NASA and the Small Business Administration have collaborated in conferences reaching 1500 industry representatives and set up a pilot project to make the services of the TU dissemination centers available to small firms. Thirty percent of fee-paying clients of the dissemination centers are classified as small businesses.

Educational values and impact. The university has been centrally involved in shaping and implementing the scientific and applied content of the civil space program. NASA has grants and contracts with over 200 universities in areas of research, training or facilities. Fifty universities have participated directly in space flight experiments and another fifty in supporting ground-based research. The increase in engineering Ph.D.'s from 800 in 1960 to 2800 in 1968 must be attributed in significant part to the space program: NASA has funded support for 7600 predoctoral candidates at 152 universities, 1700 of whom have received Ph.D.'s. Of these, 8% entered government service, 60% remained to teach and 30% went to industry.

The space program has brought 37 new laboratories to 34 university campuses, plus a close association between government laboratories and universities (e.g., over 1000 faculty fellowships for summer research at NASA centers and 500 post-doctoral residencies; degree program for government laboratory employees; and the use of NASA facilities by universities). Closer university-industry relationships have been developed through programs for university administration of satellite projects and graduate programs in systems design and management.

Space satellites and sounding rockets have contributed fundamental new tools for university research in the sciences and engineering, including the physics of the atmosphere and ionosphere; cosmic rays; solar, planetary, and stellar astronomy; cosmogony; meteorology; celestial mechanics; biology, ecological systems; X-ray optics; metallurgy of rare metals; extreme UV spectroscopy; and medical instrumentation.

At college and school levels, available data indicate strong teacher-student interest in the space program and its exploitation for the advancement of science teaching. NASA's spacemobile program has brought 73,000 live lecture-demonstrations to 22 million students and teachers in eight years. The Council of State Science Supervisors reports that this program affected the career/course choices of 20% of college students polled and that 45% of high school and 42% of college students polled reported an increased use of libraries and needs for reference material. Abroad, the program has reached over seven million students and teachers in 63 countries which have hired and paid NASA-trained lecturers and maintained spacemobiles. Eleven of these countries have requested repeat tours of schools and colleges at their own expense.

Florida, Georgia, Puerto Rico, California, Ohio, Michigan, Pennsylvania, and New York have used a NASA curriculum supplement to reorient and update their industrial arts curricula. The Council of State Science Supervisors is using another NASA review of resources for science teachers to modernize biology courses in 50 states, and purchase orders for this publication are coming in to the Government Printing Office at the rate of 1000 per week. Other school programs are being shaped in Nebraska, New York, and Massachusetts as a consequence of joint programs with NASA. The Air Force is using NASA materials in all Junior ROTC High School programs, and the Boy Scouts have established a merit badge in Space Exploration which has been studied for and won by 8,000 Boy Scouts.

Public impact. Intense interest by the media and public in the national space program has produced unprecedented coverage and record response. Public mail to NASA in 1968 exceeded 266,000 pieces. Foreign mail exceeded 19,900 in 1968. The rate of both almost doubled in the first quarter of 1969. Over 1,311,000 persons visited NASA installations in 1968, and the rate was up to 48% in the first quarter of 1969. Entirely in response to requests, NASA distributed to the public, including schools and other organizations, 4.5 million publication items in 1968. Over 17,000 film prints were loaned in the first quarter of 1969 for an audience of 1.5 million. A wide variety of public groups requested and obtained 1585 speeches on space activities in 1968, an average of 4.3 per day, and this rate doubled in the first quarter of 1969. Almost 500 exhibits were provided for 25.7 million people in 1968.

NASA received 85,993 mail and telephone inquiries from news media during 1968. TV stations are borrowing film prints at a rate of 8,500 for 1969 and reached an audience in the first quarter estimated at over 82 million. Media accreditations for the Apollo 10 flight reached 1824.

Foreign interest was equally intense and suggested strong attention to the space program as a showcase of U. S. technology and achievement. Hundreds of thousands of people in each of a dozen capitals in Europe witnessed astronaut appearances, foreign mail and visit data attest to deep and widespread interest, and foreign TV and theater coverage was as great or greater than in the United States. One Dutch TV program alone, covering the Apollo 8 flight for the Low Countries until 4:00 a.m. on Christmas Eve, stimulated 12,000 letters to the network. Air reservations from South Africa to London were completely booked prior to Apollo 11 by passengers flying to witness the mission on BBC-TV. The proportion of USIA's total effort expended on U. S. space activity in the last six months was 32%. The Voice of America carried 1200 features in 36 languages for 1/3 billion space program listeners. A record world-wide audience received VOA's Apollo 8 and 9 coverage. Eighty countries requested prints of the Apollo 8 film for theater use. Foreign requests for other films are up 50%. Almost 24,000 letters were received from abroad in response to the Apollo 8 coverage, and mail from Communist countries increased six-fold.

Contributions to other government objectives. The space program has contributed to quantum advances in weather research and analysis within ESSA's mission and to international commercial communications within the missions of the FCC and ComSat. In the field of foreign affairs, it has contributed a compelling positive element to the national image and U. S. influence abroad during an otherwise adverse period. It has contributed to the mission of HEW by inspiring and assisting in a revitalization of school and university curricula and programs. It is making experimental advances in the field of air traffic control and navigation in collaboration with FAA; and it promises significant aid to a long list of user agencies in the earth resources satellite field (Agriculture, Interior, Commerce, Navy, etc.). Its contributions in the defense field are implicit in the programs and plans of the Department of Defense.

International impact. Something has already been said of the international impact of the space program as expressed in correspondence, visits, film requests, TV exposure and response to Voice of America programming. These facts suggest that the national space program does project to the world an image of high technological achievement, managerial excellence and national purpose.

In addition, civil space activity has generated new international institutions in the United Nations Outer Space Committee, in the 68-nation space telecommunications consortium -- Intelsat -- and in the two European regional space organizations (ESRO and ELDO). The Outer Space Treaty and related conventions on astronaut return and on liability extend the pattern and practice of arms control and international law.

The operational requirements of the civil space effort have extended constructive U. S. international relationships through tracking station agreements with 21 countries. Two thousand foreign nationals are employed in the stations and operate them wholly or partially, receiving technical training while doing so.

The space program has generated a world-wide fabric of constructive cooperative relationships with agencies and scientists of over 70 countries, in a mode of international cooperation which provides for substantial inputs from both sides with no exchange of funds. Agreements currently call for U. S. launching of 22 foreign satellites and probes (12 already launched) for 12 nations including the European Space Research Organization. Other agreements cover extensive sounding rocket experimentation and the contribution of foreign experiments for flight on U. S. satellites. Over 50 countries are equipped to receive weather data daily and directly from U. S. satellites. The cooperative program extends also to such projects as a dramatic and pioneering experiment with India which will bring TV instructional broadcasting by satellite directly to 5000 Indian villages. Contact has been maintained with the Soviet Union in cooperative projects and personnel exchanges which have been restricted in scope only by the policies of the Soviet Union.

The international program has brought political, economic, scientific and technological benefit to the U. S. The political values are implicit in the wide participation of foreign nations in open and peaceful cooperative projects, even overriding political coolness, as in a uniquely rewarding cooperative program with France. Economic benefits have been realized, e.g., in Canadian contributions of an entire series of satellites to NASA's ionospheric research program, in contributions to the creation of a $20-$30 million annual market abroad, and in extensive foreign range support for U. S. sounding rocket projects. Scientific values are exemplified by the preferential selection on their merits of outstanding foreign experiments for NASA satellites, by wholly new data obtained from the Canadian top-side sounder satellites and the Italian atmospheric density satellites, by such new techniques as the German barium cloud procedure for visualizing lines of force of the earth's magnetic field in space, and by the global observations of foreign cooperators in radio propagation and geodetic programs. Technological gains are illustrated by Canadian pioneering of extensible spacecraft booms and by French advances in balloon technology, remote sensors, and aircraft hazard testing.

The fundamental intellectual and technological implications of the space age are international in character and will become increasingly evident through improvements in communications, weather forecasting, earth resource surveying, advances in knowledge of solar-terrestrial mechanisms, and the high example set for achieving human aspirations.

Impact on national security. The fundamental contributions to the economy in general, and to scientific knowledge and advanced technology in particular, which have been encouraged or generated by the civil space effort are in fact contributions to national security. Department of Defense space programs make this clear. In addition, the participation of several hundred military personnel in NASA programs has contributed an additional training ground and base of experience for defense program and project management.

Specific space programs have provided assistance to the Department of Defense in the fields of communications and meteorology (particularly in Southeast Asia and the Antarctic) and have contributed technically to military support systems in these fields. Substantial contributions were made to the now-cancelled Defense MOL program through major NASA Gemini systems, various Apollo hardware, space suit technology, operating procedures, and the acquisition and demonstration of basic experience in manned flight. With the cancellation of MOL, NASA's continuing manned flight program assumes more importance as the only national activity in an area whose full future significance and implications cannot yet be foreseen.

In a number of specific applications, NASA has worked with DOD agencies to bring expertise and technology to bear on current combat area problems. A sound-locating system has been developed for the detection of mortars and is being pursued by the Army. A cheap device has been provided to isolate a parachute in which a survival radio is inadvertently activated, obviating the need to unpack all parachutes in the location to find the radio. Unique solid state elements have been substituted for tubes in Special Forces field radios, cutting their weight from 75 to 35 pounds and extending battery life to days rather than hours. A special purpose radio relay for a critical, one-time theater application was delivered within five days of the request for it. Other similar contributions are in process.

The Soviet View

Whatever its intrinsic merits, the Soviet view of the broader values of space programs is important to an understanding of the motivations and objectives of the Soviet Union in the field of technology in general and space in particular. Soviet officials are currently engaged in a major discussion of their support of science and exploitation of advanced technology. Those whose comments have been noted include the Party's Central Committee, its Secretary, Premier Kosygin, officials of the Soviet State Committee on Science and Technology, the President of the Academy of Sciences of the USSR, the scientist Peter Kapitsa, and the influential journal Voprosy Filosofii. Their views have been gathered from Russian language sources. Taken together, they establish a clear line of argumentation which runs as follows:

> Technology is a decisive factor in the competition between systems. Science is the main source of technological achievement. The future of the USSR lies in science. "Our scientific achievements find their concentrated expression in the study and conquest of the cosmos." That is, space activity is among the highest expressions of science and technology. However, scientific productivity in the USSR is only half that in the U.S.; this must be corrected. Investment in science is 3.5 times more productive than in production capital and 6 times greater than capital investment which does not include technological development. The conclusion is that expenditures on research and development for civilian branches of the Soviet economy must grow annually at not less than 18-20% per year in the next 10-12 years.

To begin to give concrete meaning to these premises, extensive reorganization of research and development in the Soviet Union was initiated last October to encourage competition in research and development, to foster composite science-technology project teams, and to establish incentives and sanctions for individuals and institutions in the application of science and technology.

VII INTERNATIONAL CONSIDERATIONS

The global impact of Apollo offers a new opportunity to increase international participation in space exploration and utilization during the next decades. Ten years of extensive and successful United States cooperation with over 70 countries offers a substantial base for this increase.

In the past two decades NASA's international space projects have included the launching of a dozen foreign satellites, the flight of 19 outstanding foreign experiments on NASA spacecraft, more than 500 cooperative scientific rocket soundings from sites all over the world, widespread distribution to foreign scientists of lunar surface samples, direct daily reception of data from United States weather satellites by some 50 countries, and the construction and operation of major communications satellite ground stations in a dozen countries. A computerized scientific and technical information exchange program has been established by NASA and the European Space Research Organization which is unparalleled in extent and sophistication. These and other programs have been carried out without the export of dollars. The wide range of additional commitments already negotiated will continue this cooperation well into the next decade, but substantial increases could be made if full advantage is taken of the unique post-Apollo climate.

Western European and Other Space Programs

The principal space programs which offer opportunities for increased cooperation with the United States are those of Europe, Canada, Japan, and Australia. Significant opportunities also exist in the developing nations and the Soviet Union.

In Europe, space activities are currently funded at little more than $300 million per year, of which about a third goes to the regional agencies, the European Space Research Organization (ESRO), and the European Launcher Development Organization (ELDO). Much of the remaining activities of these countries is undertaken in bilateral cooperation with NASA through the development of satellites launched on a cooperative basis. Current commitments cover half-a-dozen future cooperative satellite projects, the most ambitious being a major German solar probe. We also have in good prospect seven or eight additional cooperative satellites with individual European countries and ESRO. These include a major contribution by ESRO to a future North Atlantic air traffic control system and by France to the Global Atmospheric Research Program. Prospective scientific satellites include a Dutch ultraviolet and X-ray stellar astronomy satellite, a United Kingdom satellite to identify new stellar X-ray sources, a German galactic cosmic ray satellite, and a Spanish gamma ray satellite. Additionally, reimbursable satellite launchings have been requested by Italy and ESRO.

The challenge we now face with our collaborators overseas is to develop significantly greater international participation in the next decade of space, which will require more advanced technology and increased investment in space activities in Europe and the other advanced countries. This raising of sights is fundamental to increasing international participation in future space progress. To accomplish this several actions must be taken:

- We must fully inform prospective collaborators of the future direction and scope of United States programs.

- These collaborators must become involved in the detailed definition of space objectives and in the conceptual and design studies required to achieve them.

- We must approach future decision points for United States and other nation commitments to new space programs within a framework of common knowledge, experience, and close association so that every nation's space interests may find focus in the development of new capabilities for space exploration and utilization.

- Domestic policies and procedures in the United States and other participating nations will have to be reviewed to facilitate cooperative activities.

- New international mechanisms for developing and managing major multinational space ventures must be brought into being.

Many specific projects have been identified and are available for joint consideration if basic decisions are made in Europe or other countries to explore increased international participation in space.

The Developing Countries

Among the developing countries, India and Brazil have particularly significant programs, very largely developed through cooperative projects with NASA. These afford excellent opportunities for increased collaboration with the United States in practical applications of space work. This area of space activity -- communications (particularly direct broadcasting), meteorology, navigation, and earth resource surveys -- holds great promise for increasing international participation. We must first develop practical space systems which demonstrate the early promise of these areas. We must also define attractive new institutional arrangements for the organization and conduct of future space applications of benefit to people in developing areas of the world. Prime opportunities include:

- Earth resource satellites, which have captured the imagination of leaders in the developing countries well in advance of their practical realization. The United States, Brazil, and Mexico have undertaken early cooperative projects in earth resource aircraft surveys to foster international acceptance, to clarify the possibilities and limitations, and to provide useful experience and data.

- An extremely exciting pilot program for direct broadcasting of educational television from satellites is in prospect under a projected agreement with India. Under the agreement, the United States would make available an ATS satellite to relay to 5,000 villages TV instruction emphasizing agricultural productivity and population control. India would be responsible for the ground facilities, the TV program content, and evaluation of the results. Judgments of the long-range potential of direct educational broadcasting for developing countries depend heavily on the results of this experiment.

- United States participation in the Global Atmospheric Research Program to improve weather prediction capabilities will greatly strengthen our base for assisting developing countries to further engage constructively in worldwide weather data collection and use. An excellent example is a current United States-Mexico joint project to develop a system approach to the collection, dissemination, and use of Automatic Picture Transmission (APT) satellites for cloud cover analyses.

With respect to defining attractive new institutional arrangements, particularly in the earth resources field, a three-phase approach can be visualized once the practicality of these techniques is proved: (1) The United States would make data available on a duplication cost basis to interested parties; (2) On an interim basis, a special United Nations facility might be established to serve those UN specialized agencies which are already dealing with resource data; (3) The special UN facility could later assume the principal function of data duplication and dissemination at its own cost, drawing on operative satellites of all nations which are gathering resource data in space.

To maximize chances for success in space cooperation affecting the developing countries, we require a strong United States applications program, the preservation of an international environment encouraging experimentation, and the initiative and commitment that the developing countries themselves are able to bring to bear. The prospects for this are excellent.

The Soviet Union

Soviet space activities present major opportunities both for healthy competition and constructive cooperation. The character and dimensions of the Soviet space program should in no sense dominate United States space planning, but United States planning should not proceed without an appreciation of Soviet efforts. In gross terms, the Russian and American space programs are comparable. About 170 of the Soviet launchings in the past decade have been identified by public sources in the United States as civil in character, compared to NASA's 174 in the same period. Since the Soviet gross national product is only about half that of the United States, a space program similar to ours must require about double the percentage of the Soviet gross national product (2% in the Soviet Union as against well under 1% in the United States).

The Soviet program is roughly comparable to that of the United States in the major categories of space activity, although the United States has given considerably more attention to practical applications and has conducted more manned flights. However, the number of

Soviet planetary probe attempts has been nearly double that of the United States. Current and developing Soviet launch capabilities, as well as demonstrated space flight capabilities, strongly suggest that future Soviet space objectives go well beyond their current efforts.

The magnitude of Soviet space activity has been steadily upward; successful flights for the years from 1960 through 1968 number 3, 6, 20, 17, 30, 48, 44, 66, 74. There is no sign of retrenchment. A host of official Soviet statements forecast manned flight throughout the solar system and eventual colonization of the moon and planets.

Efforts to increase cooperation with the Soviet Union in the past ten years clearly indicate that the meager results are due to political obstacles, rather than any lack of technical opportunity. Many specific proposals have been made to the Soviet Union in various forms with disappointingly little success.

Progress would only be possible if the Soviets were to accept the principle of cooperation in space despite the presence of abiding political issues in other areas. They would have to be convinced at the highest level of government that substantive cooperation in space is a desirable path to detente and the establishment of broader mutual confidence. A series of graduated steps to this end could easily be formulated. The lowest level could consist simply of full and frank exchanges of detailed space project results. The next level might involve prearranged complementary activities, for example, mutual support of tracking requirements or coordinated satellite missions for specific tasks in space. A third level would reach fully integrated projects in which subsystems provided by each side would contribute to an agreed, coherent space mission. Such a graduated approach need not be a precondition to cooperation, but might contribute to a growing base of confidence and an increasing level of future cooperative ventures.