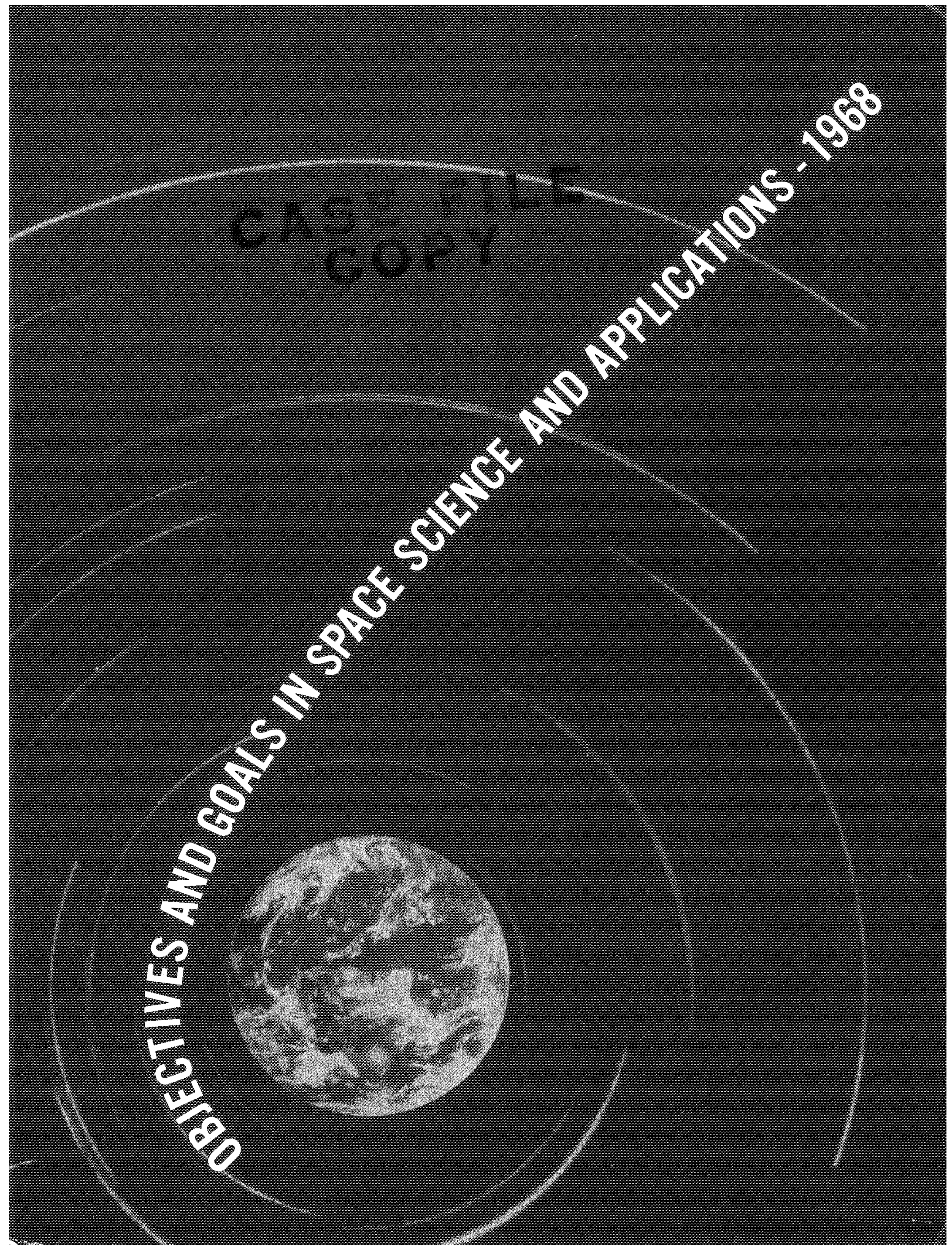

OBJECTIVES AND GOALS IN SPACE SCIENCE AND APPLICATIONS - 1968

NASA SP-162

OBJECTIVES AND GOALS IN SPACE SCIENCE AND APPLICATIONS 1968

Prepared by the
Office of Space Science and Applications

Scientific and Technical Information Division
OFFICE OF TECHNOLOGY UTILIZATION 1968
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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foreword

Planning on a program basis is carried on almost continuously throughout NASA. During 1968, NASA-wide planning efforts integrated program activities through the use of discipline oriented working groups. This document provides a glimpse of the objectives, current programs, and future mission options developed during this effort which relate to the Office of Space Science and Applications. It is written in a synoptic, non-technical format, with a view toward making it useful to officials and their advisers concerned with broad decisions affecting the future space program.

It should be recognized that portions of this document will become outdated in varying degrees with the passage of time. The early sections dealing with history and objectives for science and applications space missions will probably enjoy the greatest longevity. The sections dealing with relative emphasis on objectives, strategies for exploration, and current programs are more temporal in nature. Perhaps even more subject to obsolescence are the portions of this document related to future mission options, for they are sharply influenced by advances in our knowledge and changes in technology as we progress.

It is sincerely hoped that this document will serve a useful purpose and that it may be successively improved by response from its users. If additional information is desired on its contents or if helpful suggestions can be made for future improvements, they should be addressed to Mr. Pitt G. Thome, Director of Advanced Programs, Office of Space Science and Applications, NASA Headquarters.

John E. Naugle
Associate Administrator for
Space Science and Applications
National Aeronautics and Space
Administration
Washington, D. C. 20546

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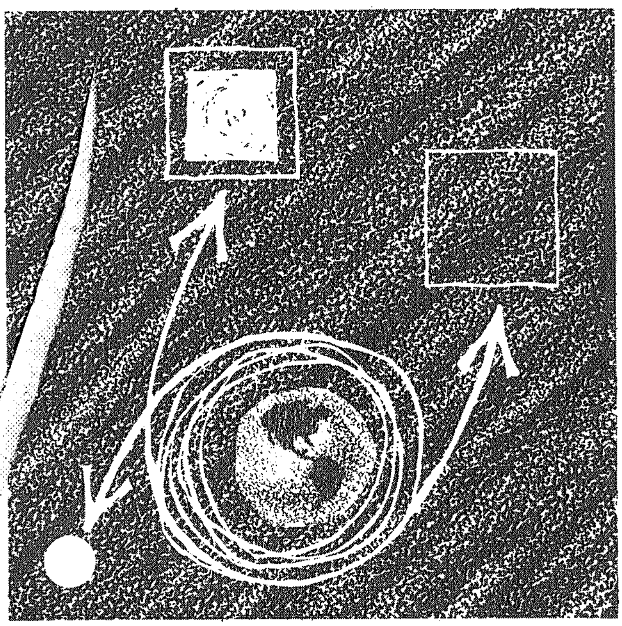

In the ten years since the first beeps of Sputnik I, man has broken free from the earth, and has expanded many fold the volume of space he can reach. Daily communications across oceans are accomplished by satellites, the Earth cloud cover is routinely photographed for weather prediction, and, during this period, man has flown instruments past the planets and taken close-up pictures of the Moon and Mars.

Science has always looked impatiently at the boundaries of knowledge and of the universe: Where men can't go he sends his instruments: if he can't send instruments, he turns to the incoming radiations and particles—meteors, starlight, radio noise, cosmic rays.

There has been a logical continuity in man's quest of space. First were the millennia of observations made with the unaided eye. Then came telescopic observation. Next, film replaced the eye at the end of the telescope. After that, radio and radar astronomy turned to new regions of the spectrum.

The space program is a part of this sequence. The tools of space—rockets, satellites, and space probes—have already enabled man to lift instruments above the atmosphere to see the stars in their full spectrum, and to send instruments throughout the solar system. Ultimately, man himself will explore the solar system and perhaps other parts of the universe.

These tools of space have had practical applications, as in meteorology and communications. Soon navigation satellites will provide continuous all-weather guides to civilian ships and aircraft; geodetic satellites are already measuring the earth to heretofore unavailable accuracies.

The space program's intensive scientific and technological effort has resulted in advancements in knowledge. And stretching the state-of-the-art has demanded and produced the opening of new technological, and operational fields.

As part of the space program planning effort, the NASA Office of Space Science and Applications participated in the 1968 agency-wide planning activity. Rather than to identify the approved NASA program, the purpose of this activity was to detail the program objectives and the many options from which a program can be built. Presented here are some of the science and application possibilities that were identified.

It is important to note that many tools required for the future space program have already been developed and that many of the future ventures will require only modest improvements. This is not to suggest, however, that improvement in performance will be limited; spacecraft pointing accuracies and stability will improve and spacecraft lifetimes will steadily increase. More powerful transmitters will communicate data across ever-widening expanses. Spacecraft will increase in weight and man will have increasing capability to navigate and work in space. Advances in chemical propulsion and introduction of nuclear and electric propulsion along with new combinations of existing stages will permit growth of launch vehicle capability to meet the demands of these missions.

The next steps in this orderly conquest of space will follow from the program that is being supported in FY 1969. The segment of the continuing space program being supported in FY 1969 recognizes the need for austerity in this period of major needs for National Defense and other urgent national programs. The FY 1969 space program provides for continuing at an economical level the programs already underway, and for initiating only projects of great merit, including those where a unique opportunity might be lost—always with regard to preserving the national investment in space resources, facilities, technology, and, most important, skilled and proven teams of people of outstanding excellence.

In the years to come, the emphasis will be on expanding the applications of space and space technology for the direct benefit of man: developing the capability for surveying the resources of the earth, providing TV broadcast from the vantage point of space, and improving our ability to forecast the weather. Only a small but significant step has been taken in the exploration of our solar system. In coming years we will see an expansion in our knowledge of not only the planets Mars and Venus but also Mercury, Jupiter and the other outer planets. With the introduction of larger, more accurate telescopes into space, man will perhaps take his greatest step in understanding the nature of his universe.

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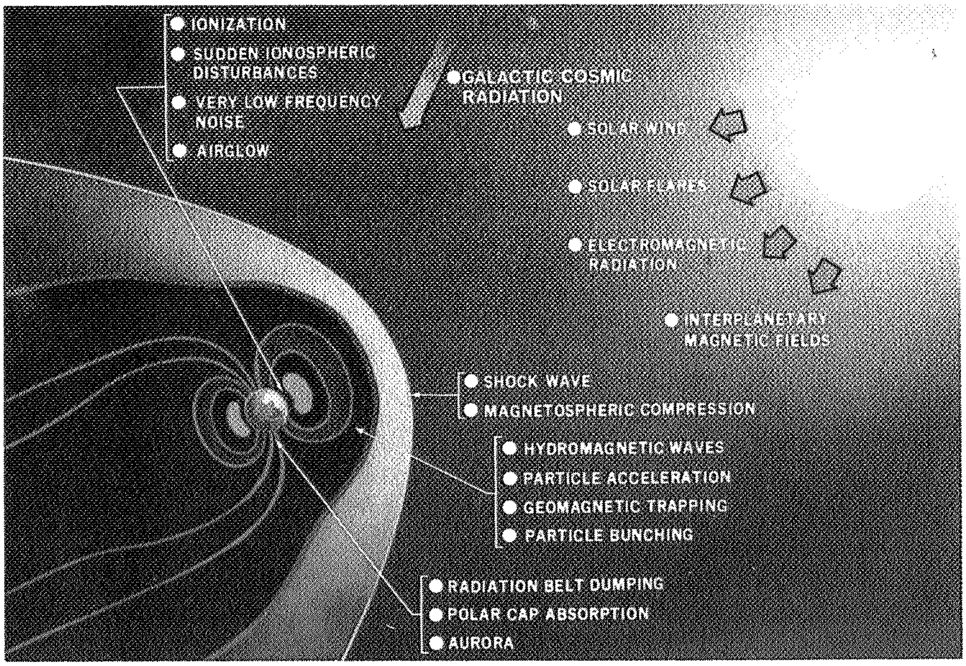
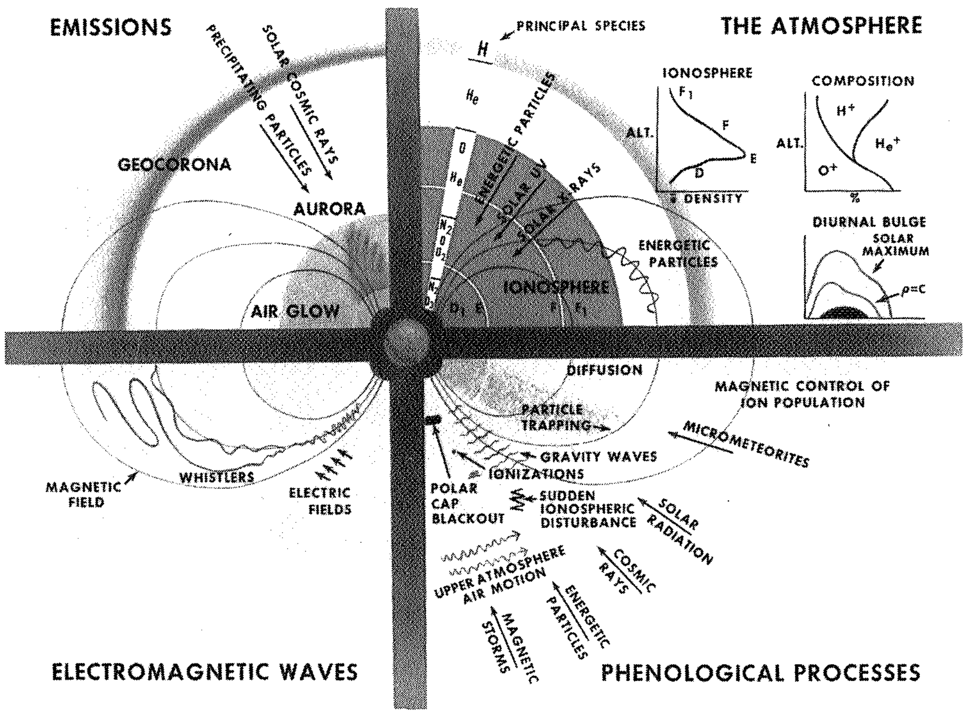
objectives of space exploration



CORRELATIVE ASPECTS OF EARTH-SUN RELATIONSHIP

THE NEAR-EARTH ENVIRONMENT



objectives in space physics

An understanding of our own Earth will inevitably entail a knowledge of its space environment and of the influence that the Sun exerts on that environment. Achieving this understanding represents a necessary first step towards the eventual use and exploitation of space for the benefit of mankind.

Satellites and sounding rockets have provided a wealth of new knowledge so that we can now state gross features of the Earth's environment even though in many cases the way in which these features are produced is not yet understood.

The Sun is of essential importance in controlling conditions on Earth. The energies in the visible, UV, IR, and x-ray parts of the spectrum as well as the particles in the solar wind react continuously with the Earth's atmosphere and magnetic field producing a variety of manifestations which we do not yet sufficiently understand. Understanding solar-terrestrial relationships is of both scientific interest and practical urgency, being essential to long-range weather forecasts, global communications, weather modifications, and reliable operation in space.

After a decade of space exploration in which we have learned to make physical measurements in space and have charted the phenomena to be found in the Earth's space environment we are ready to *explore* other regions of space, to *define* the detailed variations of space parameters with position and time in the regions explored, to *consolidate* our knowledge of the phenomena we have found, in regions already explored, by learning to understand the mechanisms responsible for them, and to *exploit* the use of space as a laboratory. The objectives of space physics may then be stated as follows:

- To obtain a detailed understanding of the physical interactions and dynamic processes which control the Earth's space environment
- To explore new regions of space in order to increase our understanding of the nature and evolution of the solar system and the universe
- To define the space environment and to assess the hazards to men and machines
- To exploit space as a laboratory for investigations and experiments not feasible on Earth.

NEAR-EARTH ENVIRONMENT

Near the Earth's surface the atmosphere is well mixed and of remarkably constant composition. At altitudes above 100 Km turbulence disappears and the gases tend to separate under the influence of gravity, the lighter ones going to the higher altitudes. Solar radiations is partially absorbed by the Earth's atmosphere: harmful x-rays and ultraviolet rays are thus prevented from reaching the surface. In the absorption process some of the atmosphere is dissociated into electrons and ions, forming the ionosphere which makes possible long distance radio communication. These electrons and ions recombine through complicated reactions and are moved both by winds and electrical forces.

The aurora of the polar regions has been observed but unexplained for many centuries. To produce the aurora engergetic particles over the magnetic poles impinge on the atmosphere and produce light. Auroral activity appears related to events in the distant tail regions of the magnetosphere and more strongly to solar storms.

Airglow and whistlers are among the phenomena of the near Earth environment. This airglow in the atmosphere has different characteristics at different altitudes and times. The existence of very low frequency electromagnetic noise and "whistlers" has been known for years, but so far there exists only speculation about the particle/wave interactions thought to be responsible for some types.

While much has been accomplished, much more remains to be learned. We want to know more about:

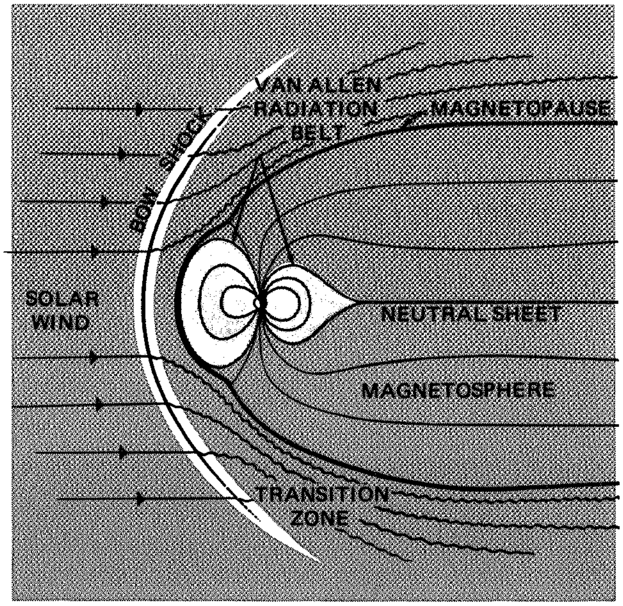
- Global distributions of atmospheric composition, temperature, and density and their variations with time, season, solar cycle and geomagnetic activity.
- Atmospheric motions and diffusion and their relationship to solar and geophysical events
- The coupling of the upper and lower atmospheres
- The processes that form the ionosphere and air glow emissions
- The production of the aurora
- The interaction between charged particles and electromagnetic waves

Measurements appropriate to these questions are shown at the bottom of this page.

MAGNETOSPHERE

The Earth's magnetic field has important interactions with the charged particles. These particles from the sun confine Earth's field to a "magnetosphere", and at about 10 Earth radii on the sunward side create a boundary to the Earth's environment. Inside the magnetosphere the magnetic field is that of the Earth; outside it is the interplanetary field.

MAGNETOSPHERE AND BOUNDARIES



Although some kind of interactions had been anticipated for many years, it remained for satellites to establish their existence, their nature and to identify the boundaries, the transition region, and the structure of the magnetosphere. These interactions are very complicated and our understanding is still rudimentary.

We want to know more about:

- The nature of the boundary and the shock front
- The way the particles penetrate the boundary
- The formation and maintenance of the tail and its extent

GEOPHYSICAL MISSIONS FOR STUDY OF THE NEAR-EARTH ENVIRONMENT

Mission	Primary Types of Measurement: Composition	Temperature	Density	Solar Radiation Absorption	Thermal Particles	Low Energy Particles	Electric Fields	Auroral Emission	Airglow	Plasma Properties	VLF	Magnetic Fields
Photochemistry	√	√	√	√	√				√			
F-Region Physics	√	√	√	√	√	√	√		√		√	
Plasmapause	√	√				√	√		√	√	√	√
Auroral Physics	√					√	√	√	√	√	√	√

MAGNETOSPHERIC MEASUREMENTS

Mission	Primary Types of Measurement							
	Energetic Particles			Fields				Neutral Particles
	Cosmic Rays	Trapped	Plasma	Terrestrial	Mag. Fluctu-ations	Electric	Inter-planetary	
Outer Radiation Belts		√	√	√	√	√		
Magnetospheric Tail			√		√	√		
Magnetospheric Neutral Points		√	√	√	√	√	√	
Magnetospheric Boundary (Transition Region & Shock)			√	√	√	√	√	
Lunar and Cislunar Environment	√		√				√	√
Galactic and Solar Energetic Particles & Interplanetary Medium	√		√				√	

- The formation and maintenance of the Van Allen radiation belts
- The energy transfer mechanisms in the magnetosphere
- The origin of magnetic storms

The mechanism of the shock front is poorly understood, as is the transfer of energy from the solar wind to the magnetosphere. This transfer is a major problem in physics and undoubtedly plays a major role in the dynamics of the radiation belts, aurora and ionosphere.

The geomagnetic tail is important in the study of the dynamics of the magnetosphere. According to some theories, charged particles from the sun enter through this region and become an important source of particles in the radiation belt.

The outer radiation belt, extending between two and eight Earth radii, contains intense particle fluxes whose origins are only beginning to be understood.

The primary types of measurements needed for magnetospheric research are shown above.

These phenomena must be correlated with events occuring in the interplanetary region if we are to interpret the function of the solar wind and to understand the energy transfer mechanisms.

INTERPLANETARY SPACE

To understand the Earth environment, all forces acting on it must be known. The interplanetary program (together with the astronomy program) is concerned with the solar wind, magnetic field, galactic and solar cosmic rays and interplanetary dust.

The region between the Earth and the sun, once thought to be a nearly perfect vacuum, is now known to contain a solar wind composed mainly of low energy hydrogen ions, electrons, and some heavier components streaming continuously away from the sun. From time to time,

SOME NOMINAL CHARACTERISTICS OF THE SOLAR WIND		
	NOMINAL	RANGE
VELOCITY	500	300-700 km/sec
DENSITY AT 1 AU	10	3-70 protons/cm^3
FLUX AT 1 AU	5×10^8	10^7-10^9protons/cm^2-sec
ENERGY	1	0.4-4 kev/proton
COMPOSITION	H, few % He	<10% He
MAGNETIC FIELD	6	3-15 gamma

more highly energetic solar protons, emitted as a part of violent solar flares, constitute a potential hazard to astronauts. The solar wind carries a weak magnetic field which, although 10,000 times weaker than that of the Earth, is an important factor affecting interplanetary space.

More remains to be learned about the solar wind:

- Its origin and composition and how these are related to other characteristics of the sun
- Its path in space, whether it rotates with the sun and if it does how far out
- The extent of the *"heliosphere"* in the ecliptic plane, and toward the ecliptic poles
- The variation of the solar wind in time

Dust forms a significant part of the space environment. An investigation of the distribution of dust near Earth, the interaction characteristics of the dust, and the composition of the dust have definite implications for astronomy. In addition, these characteristics are important in assessing space hazards and the deterioration of equipment due to dust abrasion.

So far, penetration probabilities and flux measurements have been made over limited size ranges and in limited regions of space. The populations and characteristics in the entire range 10^{-6}–10^{-12} gm are still to be determined. It is desired to measure the influx spectrum in this range.

Measurements desired in the 1 AU region should include:

- The mass distribution of cosmic dust in the mass range—10^{-9} to 10^{-12} grams
- The variations of the cosmic dust populations.
- The general velocity distribution of small cosmic dust particles and its relationship to particle origin and lifetime in the solar system
- The extent of spatial perturbations in the flux density of cosmic dust particles to determine the relative dust stream concentrations to sporadic cosmic dust concentrations.

It is desired to measure the composition, structure, and surface interactions of interplanetary dust from 1 AU out to the vicinity of Jupiter. These measurements should emphasize the Asteriod belt because of the higher probable population of dust in that region.

COSMIC RAYS

Cosmic rays are of two types: solar and galactic. We now have a fair understanding of the composition, flux energy spectra, and time behavior of both types, but some answers are needed regarding:

Solar Cosmic Rays

- How they are produced
- How they get their energy
- How they propagate through interplanetary space
- Whether their occurrence can be reliably predicted

Galactic Cosmic Rays

- How they originate
- What the flux is outside the solar system
- What portion of the energy in the universe they carry
- How they are affected by interstellar and interplanetary magnetic fields

Galactic cosmic rays are believed to fill the galactic disk and the halo around it. There are indications that these cosmic rays are much more intense in the galaxy at large than they are near the Earth, where the solar wind with its magnetic field tends to exclude them. If they are indeed more intense throughout the galaxy, then cosmic rays may have played a controlling role in the dynamics and evolution of our galaxy.

EXPLOITATION OF SPACE AS A LABORATORY

Space affords a unique environment for the performance of experiments not feasible on Earth and for the investigation of plasma phenomena on a large scale. The injection of chemicals and particles into a space environment enables their dispersion to be studied, enables questions in cometary physics to be investigated, and incidentally provides an important tool for the determination of electric fields. A space platform permits the conduct of experiments in an environment effectively free of gravitational forces enabling basic problems in crystal growth, liquid transport and biological behavior to be investigated. Delicate tests of the general theory of relativity may also be performed in this environment by making accurate measurements of clock rates and by observing the precession of a gyroscope. The technology developed for these purposes provides direct benefits to the production of improved time standards and guidance equipment.

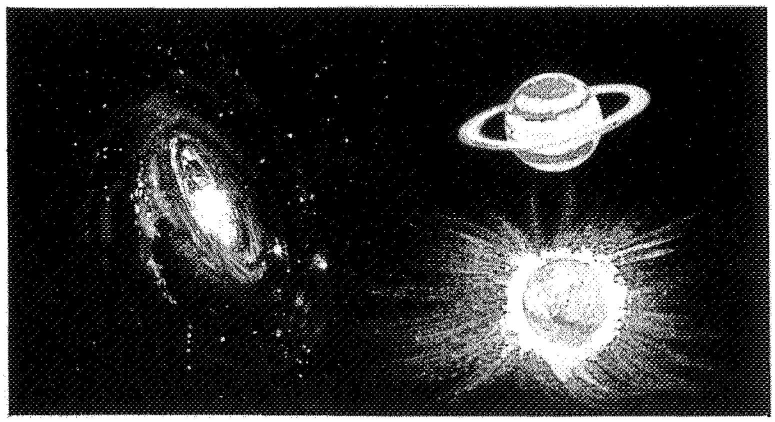
Above the absorbing layer of the Earth's atmosphere two types of high energy physics investigations may be pursued. The relatively small number of incoming extra-high energy particles may be observed and measured before they react with the Earth's atmosphere. It is believed that these come in from outside the solar system, and their study provides a logical complement to gamma ray astronomy. In addition, high energy interactions may be studied by allowing these particles to collide with target material under controlled conditions and observing the results. Available energies are much higher than can be obtained from accelerators, and even a few well-recorded interactions could profoundly affect our understanding of the basic nature of matter.

Plasmas are partially or wholly ionized gases and constitute what has sometimes been called a "fourth state of matter." A better understanding of the physics of plasmas is likely to yield benefits in the form of improved devices for power conversion, and provides a base for interpreting some of the phenomena observed by the Planetary and Astronomy programs. Dense plasmas play an important role in stars; tenuous plasmas fill the universe, and plasma interactions are thought to account for the energy radiated by pulsars, by quasars, and by the radio sources on Jupiter. Some plasmas can be studied in the laboratory; but in other cases, they must be studied on a larger scale. In the Earth's environment, the particles which constitute the solar wind interact with the Earth's atmosphere and magnetic field, producing a shock front. On Venus and Mars, the interactions are demonstrably different, due to the effective absence of a planetary magnetic field. A comparative study of these two plasma regimes not only increases our knowledge of plasmas, as such, but also sheds light on the environments of the planets themselves.

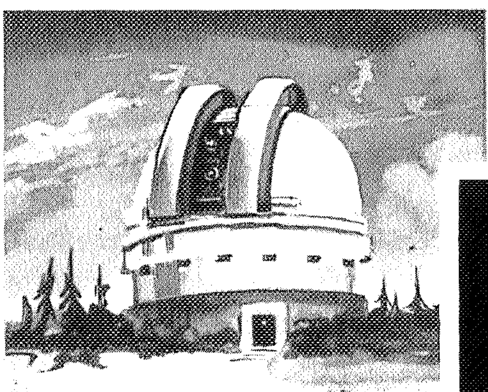
WHAT IS ASTRONOMY?

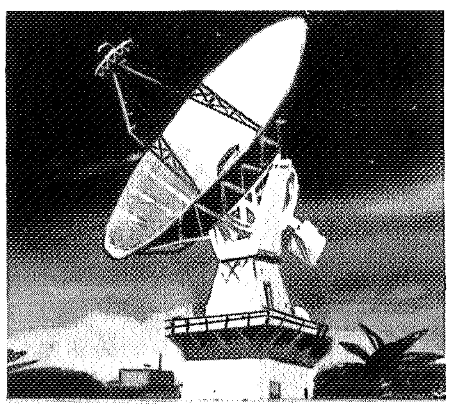
It is the Study of
Extraterrestrial Bodies
& Remote Regions
of Space

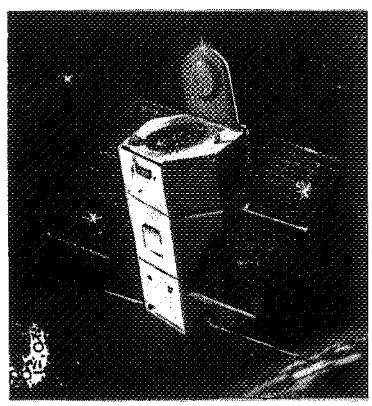
By Their Radiations:
Heat, Light, Radio,
Ultraviolet, X-Ray
& Gamma Ray



THROUGH THE USE OF TELESCOPES







objectives in astronomy

ADVANTAGE OF SPACE ASTRONOMY

To the earth-based astronomer, the Earth's atmosphere is a blanket obscuring our view of radio frequency and infrared spectra, and completely blocking the ultraviolet, x-ray, and gamma-ray radiation coming from space. Even the visual images we see from Earth are distorted and clouded by turbulence and scattering of light in the atmosphere. Space astronomy will open up for the first time a total view of the celestial bodies. In general, for the sun, the best ground-based telescope offers no better resolution than an ideal 12" instrument in space. Larger telescopes in space will thus reveal new spectra and orders of magnitude increase in the detail of distant objects.

THE SUN

There are three major reasons why the Sun is important: first, because of its intrinsic interest as the only nearby star; second, because of its effects on the planets and, in particular, the Earth; and third, because it is a valuable astrophysical laboratory.

As the only star on which detailed observations can be made, the Sun holds a unique position in stellar astronomy because the disk of the Sun can be resolved, and single features (sunspots and flares) can be observed. Spectral scans across the disk can give directly the temperature and density in the photosphere as a function of depth. The solar atmosphere is used as a standard against which theories of stellar atmospheres and spectral-line formations are tested. Furthermore, the Sun is a stable main sequence star that serves as a photometric and spectroscopic standard for stellar work.

The understanding of solar physics is indispensable to the understanding of the physics of the Earth and other planets. The Sun is a source of virtually all the heat and light a planet receives. Solar radiation interacts intermittently with the atoms and molecules in planetary atmospheres, produces ionospheres, maintains planetary heat budgets, is responsible for weather, and controls any life that exists on the planets. Particle flux from the Sun affects the ionospheres and planetary magnetic fields, produces aurora, and changes chemical abundances in planetary atmospheres through nuclear reactions. The whole solar system can be viewed as being imbedded in the outer solar corona.

There are available in the Sun combinations of temperature, density, and physical scale quite beyond terrestrial capabilities. Thus, the Sun has been exploited as a laboratory by researchers in several branches of physics; for example, scientists have used the Sun as a source for spectra of wavelengths that are not otherwise producible in the laboratory. The Sun has also been important to the study of nuclear reactions and to test theories on the origin of the elements. The solar atmosphere provides a large-scale laboratory in which phenomena of aerodynamics and hydrodynamics can be observed. The solar atmosphere can be regarded as a giant plasma which provides unique opportunities for the study of plasma physics and magnetohydyrodynamics.

STELLAR EVOLUTION AND GALAXIES

The evolution of the stars is of interest not only in stellar astronomy, but also with respect to the sun which, itself, is a star. By studying many stars of different size, age, and mass, we can theorize on the evolution of a typical star. The history of a star is associated with changes of the central core, the radius and other properties of the star.

The ultimate demise of a star, something never witnessed by man, is thought to occur in cataclysmic steps, such as the explosive expulsion of its envelope (the nova process). Stars probably pass from birth to death, exchanging material with the interstellar medium and converting lighter elements into heavy elements in the process. The cataclysm of the nova may scatter remnants far into space and continue to produce the strong radio signals and strong x-ray emission observed by satellites and rockets.

To build a picture of stellar evolution, we need to study individual stars, examining their atmospheric temperatures and densities, their compositions, and magnetic fields. Stars produce radio bursts and have flares similar in character to solar flares.

In addition to studies of individual stars, much is to be learned about associations of stars and star systems. These families, in mutual gravitational association, number hundreds, thousands, even tens of thousands. Our galaxy itself is a spiral and is to be contrasted with the numerous elliptical and irregular galaxies which large telescopes have revealed to us.

The physics of the universe, that is, the general discipline of relativistic cosmology, has been developed largely by studies of the recession of remote galaxies; however, we appear to have succeeded in making direct observations of the residual microwave radiation associated with the initial explosion of the universe. Such information relates to the ultimate questions: When did the universe begin; what is its history; and what prospects does it have?

INTERSTELLAR SPACE AND COSMOLOGY

Much remains to be learned about the matter and radiation in interstellar space and the relation of this region, with its cold gas and dust, to the stars and star systems themselves. Important to the physics of the universe is knowledge of how energy is distributed between the stars on the one hand and the cold plasma and dust of interstellar space on the other.

Other properties of interest in the interstellar medium are the magnetic fields, the cosmic rays which are in some ways associated with them, and the radio frequency emission from the matter between the stars.

The importance of stellar/interstellar phenomena in cosmology is illustrated by the stellar conversion of matter to heavier elements, referred to above, and the subsequent return of that matter to interstellar space. A theory of the mixing of stellar *populations,* that is, old and new type stars, the former containing principally hydrogen and helium, and the latter, significant amounts of heavier elements, is a contribution of modern astronomy. The great Orion nebula illustrates some of these points, showing the dust illuminated by the stars and the emergence of young stars from the plasma.

QUASARS

The *quasi-stellar radio sources* (quasars) and their discovery illustrate the ever-quickening and exciting pace of modern observational astronomy. In their quest to identify radio stars with familiar visible objects, astronomers were baffled by strong radio sources which appeared unrelated either to galaxies or to super-nova remnants. About three years ago a number of these radio sources were identified with peculiar blue star-like objects. Their spectra showed exceedingly large red shifts indicating

ATMOSPHERIC SCATTERING PROHIBITS OBSERVING THE FAINTEST ASTRONOMICAL OBJECTS
4. ONLY THE BRIGHT INNER CORONA VISIBLE FROM THE GROUND
5. FROM A ROCKET THE FAINT EXTENDED CORONA CAN BE STUDIED

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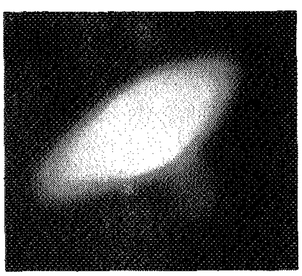

TELESCOPE RESOLUTION
EVERY INCREASE YIELDS EXCITING NEW INFORMATION
ANDROMEDA NEBULA

1. ½ DEGREE
2. 1 ARC MINUTE
3. 1 ARC SECOND

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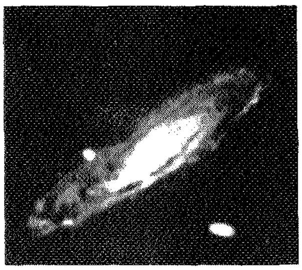

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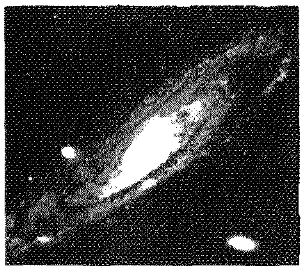

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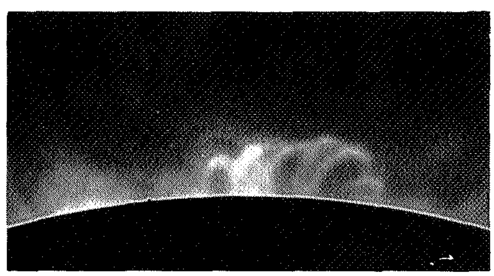

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motions away from us at speeds up to one-third the velocity of light. Since the initial discovery, astronomers have compiled a list of more than 65 objects for which velocity measurements have been made. It was immediately recognized that other faint blue "stars" may be similar high velocity objects, but not radio sources. Relatively, the non-radio blue objects appear to be extremely abundant.

The large red shifts appear to mean that the objects are receding from us very fast. If we apply Hubble's law of the expanding universe, we must conclude that these objects are very remote and therefore exceedingly bright: In fact, they would be some 40 times brighter than the largest galaxy known, and the energy necessary to keep such an object shining continuously would be stupendous. An alternative theory would place the quasars closer to us and about one thousand times smaller, but still so bright as to stagger the imagination.

A further problem with quasars is that several of them vary in brightness, over times of the order of a few weeks. To vary so rapidly, the Quasars must be small enough that light rays take no more than a month to traverse them. This size would be many orders of magnitude smaller than a galaxy, whose brightness they exceed by many times!

Thus, we discovered these puzzling objects in the universe only three years ago. They present ponderous difficulty in interpretation and we have not begun to understand what they are or how they operate.

PULSARS

One of the most exciting discoveries in recent years has been the detection of pulsars, non-random radio signals from outer space. Pulsars are a radio phenomenon. Their outstanding characteristic is that they emit short bursts of very high energy at extremely regular intervals. As an example the first pulsar discovered (late 1967) has a period of 1.33730109 seconds. The short duration of each pulse indicates that pulsars are small objects. Their distances as yet are very tentative but they appear to be located within our galaxy, perhaps as far away as the spherical halo around the galactic disk. Eleven pulsars have been found as of September 1968.

Since pulsars are the first non-random signal received from outside the Earth, scientists at first seriously posed the question whether these could be intelligent signals from a distant civilization. They disproved this to their own satisfaction and are seeking other explanations. One of the more likely possibilities is that the signals are emitted from a rapidly rotating neutron star which pulsates and is embedded in a gas cloud. A neutron star is a small dense body where there is no longer any recognizable atomic structure and the fundamental particles are packed together. This is the postulated final state in the evolution of a star. If this is indeed what pulsars are it is the first time these hypothetical bodies have been detected.

Theoretical work is being done on the x-ray production of neutron stars. The next challenge will be to try to observe pulsars in the x-ray region of the spectrum using space vehicles.

PLANETOLOGY

Planetology, discussed elsewhere as a separate section of this document, will be greatly dependent on astronomical observation for a long time to come, especially for the outer planets. We seek to learn all we can about the planets' surfaces, atmospheres, meteorological processes, and their natural satellites. Knowledge of the planets is significant not only to the evolution of the solar system but also to the early history of the Earth, the surface details of which have been obliterated by ages of erosion, sedimentation and geological upheaval.

WHY SPACE ASTRONOMY?

The history of progress in astronomy has always been marked by mileposts of improved techniques of observation. Each major advancement in the power of the astronomer's tools has resulted in new discoveries which then have revolutionized our picture of nature. The advent of astronomy from space, free from terrestrial contamination, represents a current major advancement in techniques.

1. GALILEO'S DRAWING OF THE MOON (1610)
2. SURVEYOR I PHOTOGRAPH DETAILS OF LUNAR ROCK
3. LUNAR ORBITER II VIEW OF THE CRATER COPERNICUS

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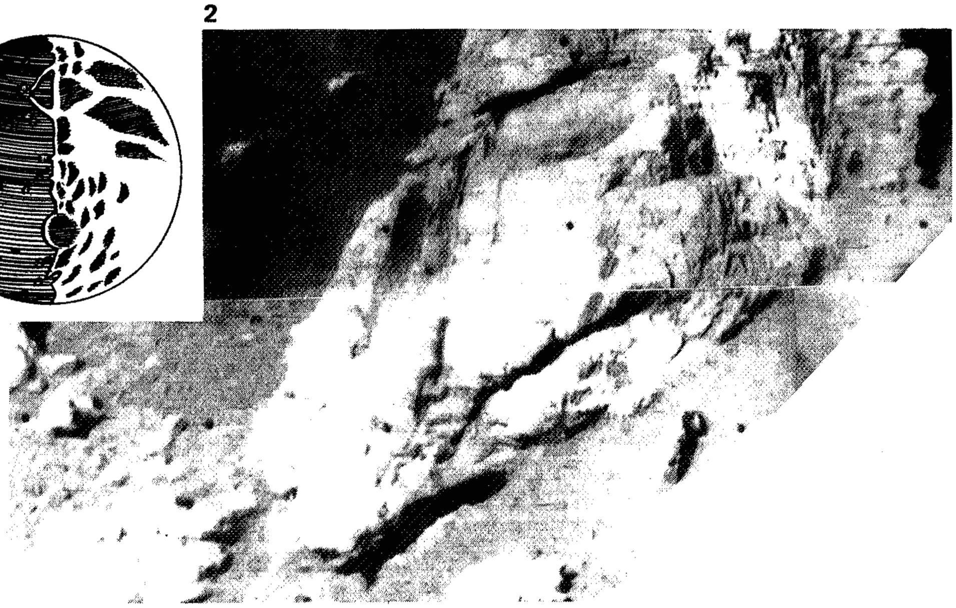

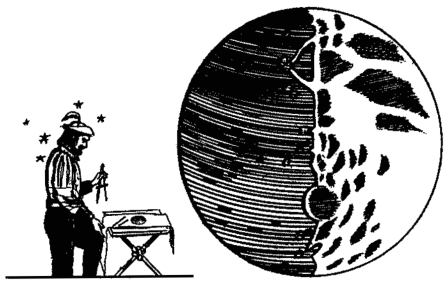

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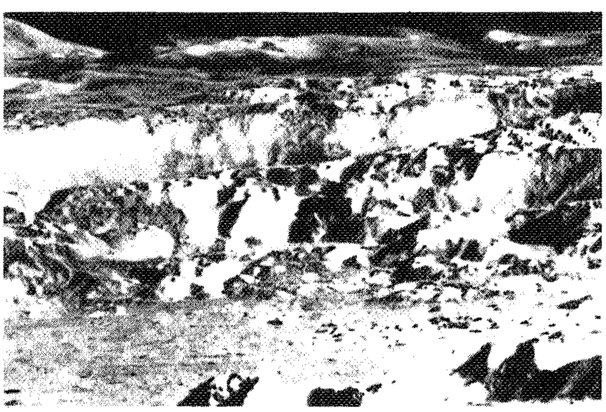


objectives in lunar exploration

ABOUT THE MOON

The Moon, with its 12,000,000 square miles of surface and diameter of 2,160 miles, is our nearest neighbor in space. Nowhere else in the solar system is a natural satellite so large in relation to the body around which it revolves. In a way, Earth-Moon is a double planet. The two adjacent objects may have been formed at the same time and in the same manner. If this is true, the Moon, which lost its atmosphere because it lacked enough gravity to hold it, may be like a book containing the secrets of Earth's first billion years of life. The record on Earth is lost or masked by the contortive and destructive processes of mountain-building and subsequent erosion which have removed all traces of the earliest days. The surface of the Moon is the handiest and most promising place to look for the missing evidence.

Throughout all previous time the Moon has been inaccessible to us. Men for uncounted centuries have stared at it wonderingly, but only when the telescope was invented did they begin to comprehend its features. Even now, after a long history of improvement, the best telescopes give photographic resolutions of the Moon no finer than half a mile or so, though visual telescopic resolutions are somewhat better.

UNANSWERED QUESTIONS ABOUT THE MOON

Still, the greatly improved knowledge of the Moon that we have gained from telescopic data has raised far more questions than it has solved. The telescopic data left us with questions such as: What caused the craters, and when? What are the maria, those largely smooth, sea-like patches? What are the rays, which look like the frozen remains of a tremendous prehistoric splash? What gives rise to the three great fracture systems on the Moon's surface? Why are there no folded mountains, as on Earth? What material is the Moon made of? What is its surface covered with? Does lunar material reach the Earth in the form of debris from meteor impacts? Is the Moon active or inactive internally? What is its internal structure? What role did the Moon play in the history of the Earth-Moon system—of the solar system?

The advent of the space program has given us the proper tools for obtaining answers to these questions and others, by permitting us to develop, through scientific investigations, a comprehensive understanding of the Moon's surface and its interior, in terms of its structure, composition, processes, environment and history. This understanding is needed not only to develop a perspective in viewing our own planet and the solar system in which it resides, but also to determine the extent to which the Moon can be exploited for astronomical and other scientific research.

WHY EXPLORE THE MOON?

The yardstick against which a lunar exploration program must be measured is the degree to which it succeeds in achieving the following objectives.

First, to observe and define the morphology, sequence and relationships of major rock units exposed on the surface of the Moon; the structure of the lunar interior and its relation to features on the lunar surface; and, the nature of processes which modify the lunar surface.

Second, to understand the relation of the Moon to the Earth and to other planets of the Solar System by comparative study of the form, composition and history of the Earth-Moon system; the ages of lunar rocks and features in terms of major events on Earth; and the processes that shape man's terrestrial environment.

Third, to use the Moon as a platform for the study of solar and cosmic phenomena and possibly as a source of valuable resources.

THE MOON AND THE HISTORY OF THE SOLAR SYSTEM

The historical record preserved in the Lunar surface bears upon several processes of the solar system. In contrasting the older with the younger deposits, we can ask what has been the distribution in time and in mass of solid bodies impacting the Moon. The history of cosmic radiation and changes in its intensity or character should be recorded in the upper most surface units. Some of these units probably have been exposed for a brief fraction of Lunar history. The problem of origin of planetary bodies would be greatly aided by examination of a primordial or very ancient surface of one of the bodies of the solar system, by studying its chemical and isotopic composition, or even by measuring the strength of early magnetic fields in the solar system through paleomagnetic measurements on ancient volcanic rocks.

Many basic problems of the Earth can be approached by comparison of the Earth with the Moon. We still do not understand the evolution of the Earth's crust as it has been thoroughly reworked by surface waters. The Moon has apparently been uncomplicated in this way, and possibly may show evidence of protocontinents. It may be the best place to see what an early crust looks like. The processes of mountain building on Earth are only partially understood, in part because tectonically active areas are covered by thick sedimentary deposits. On the Moon tectonic deformation of the surface of a planet can be examined without the camouflaging effect of water erosion, sedimentation, or oceans. Similarly, volcanic products that on the Earth are contaminated by passing through chemically reworked surface sediments, should, on the Moon, be free from such effects.

LIFE, PAST OR PRESENT, ON THE MOON

Another important facet of exploring the Moon is to determine if life is present, the nature of living organisms and the state of biological evolution, or, if there is no life, the presence and nature of organic compounds related to past or future life. If the past environment of the Moon was favorable, primitive life forms may have arisen, and such forms may have been preserved in their original state. Surveyor spacecraft have already found the predominant elements of the universe on the Moon. The precise form in which these elements exist and how this form relates to the forms found in living organisms are still unsolved.

WHAT WE NEED TO LEARN ABOUT THE MOON

Starting with the broad objectives for exploring the Moon, it is possible to list the information required as:

Geology

Stratigraphic sequence, record of early history, correlation with events on Earth

Detailed structural relations between geologic units

Genesis of the fine and gross structural features

Processes of erosion, surface transportation, impact, evaporation and recondensation

Geophysics

Nature of internal structure and composition

Dynamical interaction of the Earth-Moon system

Heat flow from the interior

Geochemistry

Over-all degree of chemical differentiation, predominant processes in determining chemistry and morphology of the surface

Bulk composition and relation to Earth, Sun and other planets

Chemistry and mineralogy of magmatic materials (if any)

Composition of absorbed gases and transient atmosphere (if present)

Cosmic ray and solar wind history, rates of surface turnover

Particles and Fields

Interaction of Moon and solar wind: shock front, ionized atmosphere, associated magnetic fields, bulk conductivity

Interaction of Moon and cosmic radiation: luminescence and induced radioactivity

Internal magnetic fields (if any); constraints on composition and temperature

Bioscience

Evidence for organic or proto-organic materials on or near the surface

Presence of living organisms or fossilized remains of biota or pre-biota beneath the surface

Astronomy

Assessment as to the suitability of the lunar environment for conducting investigations from the surface of the Moon

LUNAR EXPLORATION HAS ALREADY BEGUN

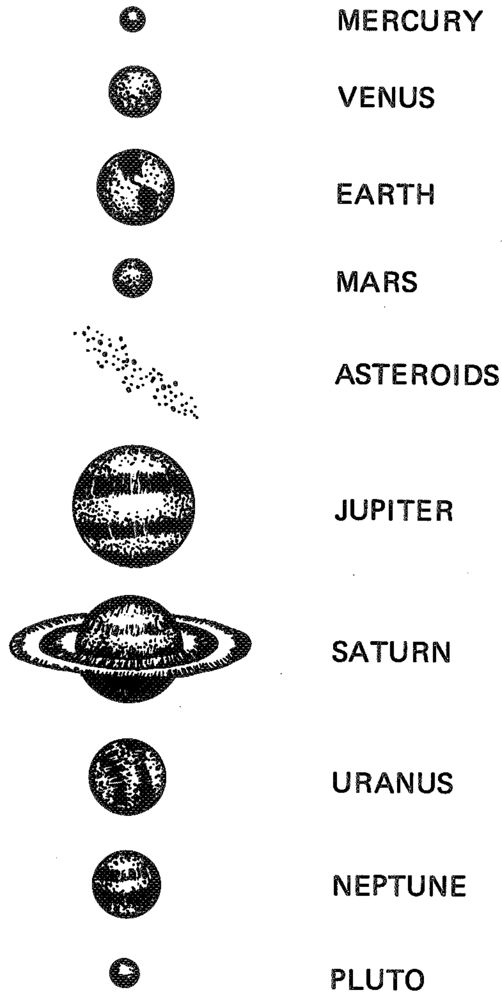
A wealth of information has already been obtained from telescopic observations and from such spacecraft as Ranger, Surveyor, Lunar Orbiter, Luna and Anchored IMP.

Earth based telescopic observations have yielded comprehensive imagery of nearside surface features at approximately 3000-foot resolution. Lunar Orbiter has increased this resolution to 150-500 feet on the nearside and 150-1500 feet on the farside. Detailed views have been obtained of selected maria and highland sites at 3-foot resolution by Ranger and Lunar Orbiter. Cartographic charts and geologic maps have been and continue to be prepared on the basis of this imagery. This work confirms previous hypotheses concerning the presence of both impact and volcanic processes on the lunar surface, and it provides information on the nature of some erosion and transportation processes.

The USSR spacecraft, Luna IX and XIII, and the Surveyor missions showed the details of the surface material and local topography to less than a tenth of an inch in addition to measuring the behavior and strength of the soil at their landing points. Surveyor chemical analyses of the basalt-like composition of mare sites are in agreement with measurements from the Soviet orbiter Luna X which are the same as should be expected if the maria are formed of basalt.

The position of the center of mass of the Moon with respect to the Earth has been refined from previous telescopic observations, by tracking of Soviet and U.S. lunar orbiters. The lunar orientation and rates of change, the physical librations, are now known to about 650 feet on the surface. The gravitational field has been described through the fifth degree and fifth order of a spherical harmonic expansion. Telescopic measurements of the nearside surface yield an accuracy of approximately 3000 feet horizontally and 5000 feet vertically on the overall size, shape and topography.

In the particles and fields area, Luna II indicated that any lunar magnetic field was less than 1/10,000th that of the Earth. Anchored IMP (Explorer 35) measurements suggest a very weak surface magnetic field of even less strength. Luna X and Anchored IMP measured the interaction of the Moon with the Earth's magnetospheric tail, the solar wind, and cosmic radiation.



1. MARS
2. VENUS
3. COMETS
4. METEORS

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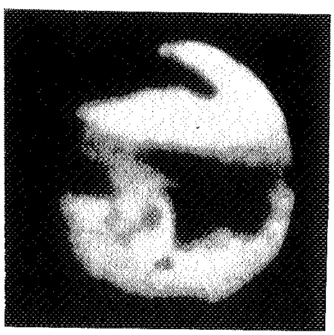

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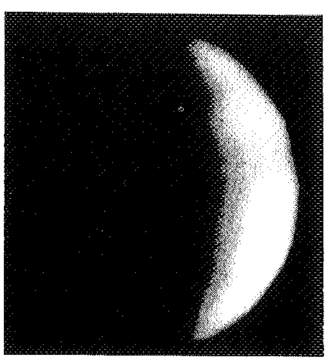

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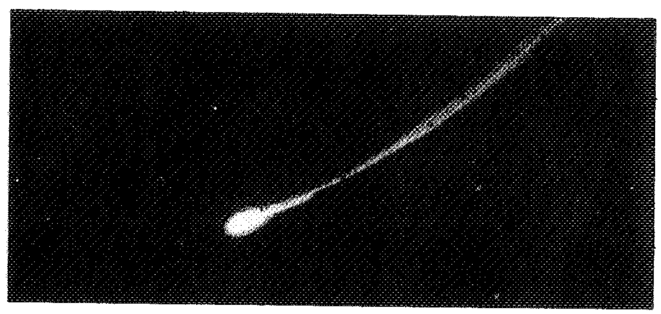

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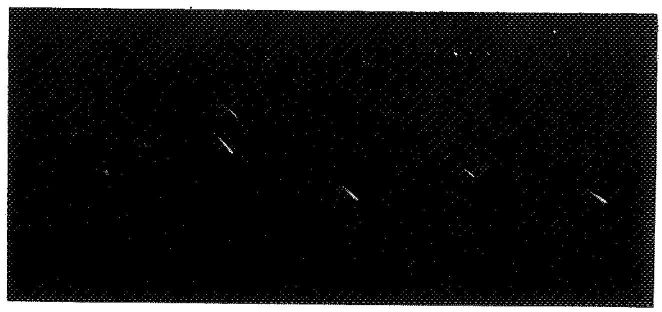


objectives in planetary exploration

ABOUT THE PLANETS

Nine planets circle the sun. We inhabit one of them. Two others, Venus and Mars, approach us on occasion as closely as 30 to 40 million miles which is only a stone's throw on the scale of astronomical distances. In many respects, we know less about these bodies, the Earth included, than we know about distant stars tens of trillions of miles away. We do not know how the planets came into existence nor how the continents and oceans on Earth, for example, were formed, nor of what materials the interiors of the Earth and other planets are composed. (The materials in the Earth's crust are known but there is strong evidence that the interior of the Earth is very different.)

LIMITATIONS OF CURRENT PLANETARY KNOWLEDGE

More is known about stars than planets for two reasons. First, a star is a self-luminous body which radiates a copius amount of light. The analysis of the wavelength contained in this light tells us the composition of the stars' surface layer.

In some stars there is enough turbulence, enough mixing and turning inside the star so that we can assume that the light coming from the surface of the star represents in its spectrum the composition of a fraction of the star's interior.

Second, and even more important, stars have widely different ages. We see stars in the process of formation, stars that are young, middle-aged, old, and nearly extinct. In the last few decades, in the study of these stars we have learned much about the complete life cycle of a stellar body.

But the skies do not reveal the past history of the planets. It is believed that every planet in the solar system is roughly the same age as the Earth, 4.5 billion years. At the present time, planetary science is in a more primitive state than astrophysics. It is even difficult to find out what conditions were on the Earth when it was a young planet because the contortive and destructive processes of mountain-building and subsequent erosion have removed all traces of the earliest days of this planet. And those conditions are of keen interest because they influence modern ideas on the origin of life on the Earth. There is evidence that life began on the Earth in the first billion years of its existence. But under what environmental condition it did arise, we do not know.

WHAT PLANETARY EXPLORATION WILL REVEAL

We have made the best measurements possible of the Earth's history, environment, and physical laws from Earth, but these are limited by our inability to stand off and look at the total picture. An exploration of the solar system will help us to predict the future of the Earth; to tell what part of our environment is the universe's environment and to broaden our skill in physical science to make life easier here on Earth.

Exploration of the Moon, Venus, and Mars bring us to the threshold of the new era in science. A knowledge of their present state will not immediately reveal the past of the Earth, but carefully designed planetary experiments analyzed by scientists with a broad understanding of the Earth as a planet will tell us much. The initial flights to the Moon, Venus, and Mars have already revealed vital and significant information about these bodies. Since the Moon has been discussed in a previous section, the following paragraphs review where we are in our understanding of the planets and what new questions about them need to be answered.

ABOUT MARS

The ruddy glow of Mars has attracted man's curious attention for many centuries. When big telescopes first brought some of its surface features into focus, they served mostly to stir up controversy. Some astronomers saw canals there, others did not. The controversy aroused widespread interest in Mars and made it the favorite planet of fiction writers. The haunting possibility that some form of extraterrestial life exists or has existed there has heightened fascination of Mars for both scientist and the general public.

Earth-based investigations of Mars have mapped the surface features with a ground resolution of some hundred kilometers and explored its overall physical parameters. There is a thin but unmistakable atmosphere containing small amounts of water vapor, a trace at most of oxygen, and more carbon dioxide than in our own atmosphere. The warmest surface temperatures are comfortable by human standards, but the daily temperature range is severe—approximately +80°F to -90°F at the equator. Significant amounts of water could be present in the form of ice, but the long familiar icecaps on Mars do not necessarily consist of frozen water. They may be formed of frozen carbon dioxide.

The red planet's transparent atmosphere allows Earth-based observations of its surface; but high resolution images were impossible to obtain because of the great distance, until Mariner 4 made its spectacularly successful flight past Mars in 1965. The Mariner photographs show an important point about Mars; namely, that it has preserved the record of its past better than the Earth. Erosion on the Earth, mainly by running water and also by winds, combined with extensive geological activity has moved surface materials from one place to another and churned them over in a time scale of 10 to 50 million years. The events that have occurred earlier than that are not directly detectable.

WHAT SHOULD WE LEARN ABOUT MARS? WHY?

Preliminary data indicates conditions on Mars may be inhospitable to man, but as laboratory experiments have demonstrated, some lower forms of life can exist under these conditions and conceivably isolated areas may provide an environment suitable for higher forms of life. Even if there is no indigenous life there now, man has a strong interest in whether it may have never developed and why, or whether it existed once and is now extinct. The findings could be of significant value in improving our understanding of how life evolved on Earth.Scientists also believe that the study of Mars will lead to a better understanding of our earthquakes and weather. The determination of the importance of radiative heat transfer in the Mars atmosphere has already improved our ability to predict weather on Earth.

The major scientific unknowns about Mars can be summarized as:

- The existence now or in the past of life of any kind
- Possible differentiation of the interior of the planet into a core, mantle, and crust, and the presence of geographical as well as vertical differences within the planet
- The internal activity of the planet from a seismic, volcanic, and tectonic point of view
- The physical, chemical, and minerological composition of Mars
- The character properties and behavior of the Martian atmosphere
- The interaction between the solar wind and the ionosphere

ABOUT VENUS

Venus is a planet of mystery, a cloud cover hides direct visual observations of the solid surface. The recent success of Mariner 5 and the USSR's Venus 4 spacecraft and the success of Mariner 2 in 1962 have enabled man for the first time to delve further into the nature of this planet.

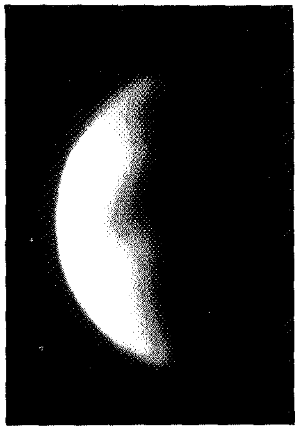
These spacecraft confirm the belief of many scientists that its surface temperature is very hot, possibly as high as 880°F. The pressure at the surface is 20 to 100 times that on Earth. Its atmosphere has also been found to be very much unlike the Earth in terms of its very high carbon dioxide content and very low amounts of oxygen and nitrogen. These spacecraft have also indicated that Venus has little or no magnetic field and no trapped radiation belt like that on the Earth. Ground-based observations continue to press for more information on the planet's atmosphere and topography of its surface. Recent radar investigation, for instance, has disclosed four areas that are of different roughness than their surroundings.

WHY VENUS SHOULD BE STUDIED

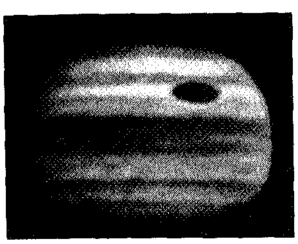
Even with these initial findings, Venus still holds its mystique. What is the nature of its clouds? Is it eternally shrouded in clouds, or could we see through to the surface with higher resolution pictures? Why is the surface of the planet so hot at its equator? Has it always been that hot? Are the polar regions quite cool; i.e., like ice, or also hot? Do any forms of life exist in the cooler regions of the atmosphere? Did life ever exist on the planet? What is the composition of its surface? Is the interior of Venus differentiated into a core, mantle and crust? What is the interior activity of the planet? What is the interaction between the solar wind and the ionosphere?

Not only will the answers to these questions permit a better understanding of the origin and evolution of the solar system and of life, but because of the complex nature of the Venusian atmosphere, they may permit a better insight into the future evolution of our own atmosphere. Venus has apparently evolved an atmosphere of predominantly carbon dioxide, which traps solar heat to produce a very hot surface. The carbon dioxide in the Earth's atmosphere has risen appreciably in the past 20 years. Will the amount of carbon dioxide in our atmosphere continue to increase and the amount of oxygen decrease? Will the Earth's atmosphere tend to become hotter? In other words, will our planet tend to become like Venus? The exploration of Venus will hopefully give us these answers.

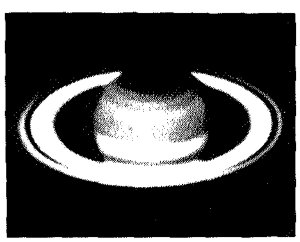
VENUS



EARTH



JUPITER



SATURN

ABOUT JUPITER AND THE MAJOR PLANETS

Giant Jupiter, nearly 11 times bigger than the Earth, is an exceedingly interesting object of study. It is the largest planet in the solar system. It is also the nearest of the four major planets (Jupiter, Saturn, Uranus, and Neptune) which are thought to resemble it in composition. Jupiter is quite different from Earth and the Earth-like planets—Mercury, Venus, Mars, and Pluto.

Huge as Jupiter is, it consists largely of light material. Its core may be composed of solid hydrogen. Its mantle is thought to have normal molecular properties. Its atmosphere is very thick with methane and ammonia in the upper layers. However, the major atmospheric gases are hydrogen and helium.

Jupiter is also a most active planet. Its atmosphere is in continual motion and exhibits a stormy equatorial current. It has a magnetic field an order of magnitude stronger than Earth, and the planet's magnetosphere is tremendous, extending many millions of miles into space.

Jupiter emits bursts of powerful radio signals in various wavelengths and is believed to have a strong ionosphere. The long wave radio emission originates from only a few localized areas. This emission is modulated by Io, innermost of the large satellites.

What the Major Planets Will Tell Us

The most important aspect of Jupiter is the fact that its great mass and high gravity is thought to prevent it from losing the material from which it was originally formed—part of the primordial solar nebulae. The planet's composition may thus constitute a record of the early stages of formation of the sun and planets. Expanded study of Jupiter should broaden our perspective in probing the origin of the solar system.

Jupiter is also notable for the large red spot in its atmosphere. One theory is that this is a chemical mix of biological building blocks created from simple gases by lightning discharges. Study of this mysterious red spot may provide insight into the origin of life on Earth.

Looking to the other major planets, there is a good possibility that the chemical composition of Saturn, Uranus, and Neptune also represents a sample of the original nebula. The ring structure of Saturn requires an explanation of its origin, composition, structure, variation, and ultimate stability. Uranus is apparently composed of significantly heavier materials than either Jupiter or Saturn. This fact is relevant to theories of solar system origin as is the curious orientation of the Uranus axis of rotation, which nearly coincides with its orbital plane.

The characteristics of the major planets of initial interest are:

- Their composition, structure, and thermal history
- The type and dynamics of their atmosphere
- The nature and characteristics of their magnetic fields and radiation belts
- The causes and origin of Jupiter redspot, radio emissions and the rings of Saturn
- The characteristics of their satellites
- Their geodetic parameters

OTHER BODIES OF THE SOLAR SYSTEM

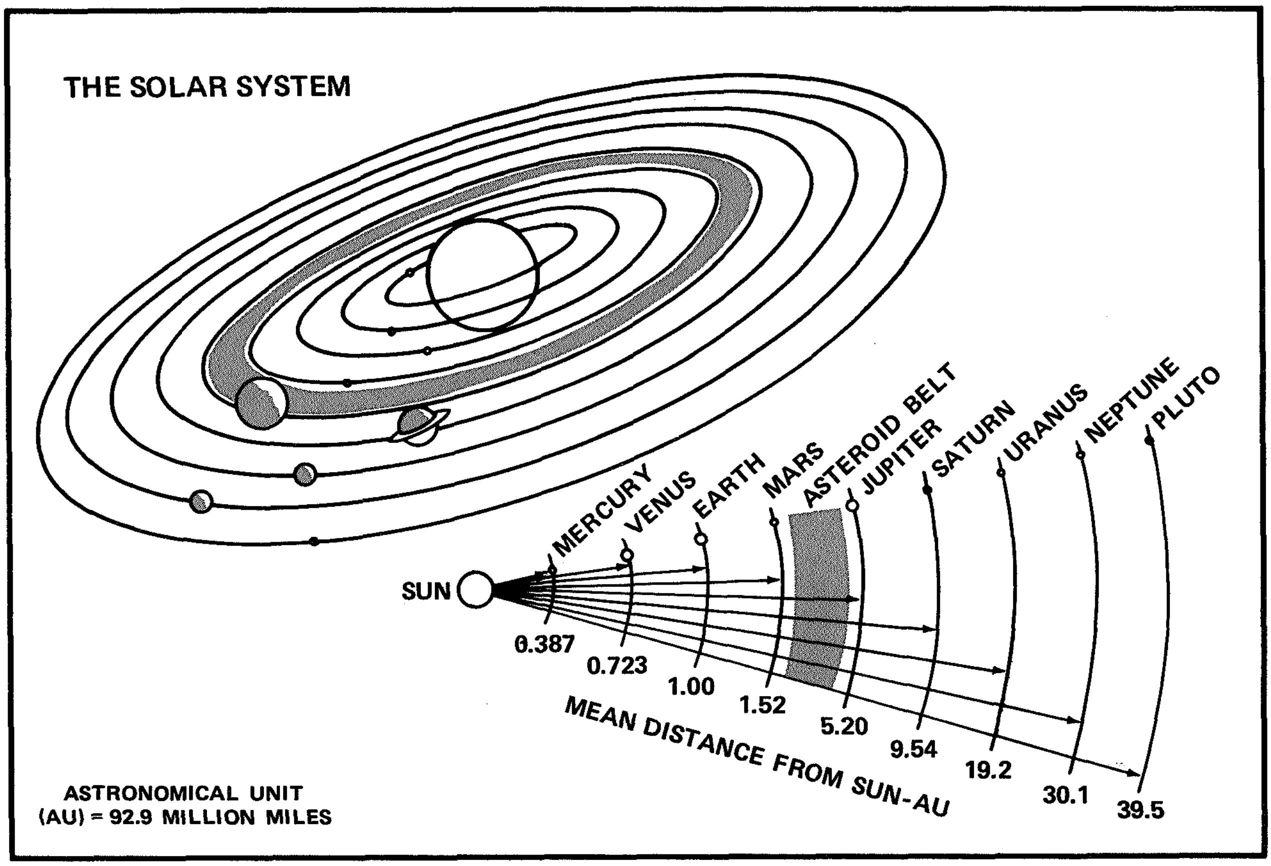
The general objective of systematically investigating phenomena in the solar system is to provide data and conclusions for a comparison of the planets, and for understanding the evolution and future developments of the Earth. This objective will be more fully realized if our future exploration also encompasses the planets Mercury and Pluto, the comets, and the asteroids.

The planet Mercury is the nearest planet to the sun in our solar system. While it is about a third of the diameter of the Earth, it has an average density about the same as that of the Earth. The length of its year is 88 days and it was thought to rotate on its axis with the same period. Recent radar observations have shown that it rotates on its axis in 59 days which is two-thirds of its orbital period. It was always thought to be a body without an atmosphere because of the great heat absorbed by the side that faces the sun. The cooling provided by the newly discovered rotational period may permit a tenuous atmosphere, but it will be less than that on Mars, i.e., a few tenths of a percent of the atmosphere on Earth.

Due to its extreme distance and small size very little is known about Pluto. It is an unusual planet, with an apparent high density and an elliptical orbit tilted 17 degrees to the ecliptic plane. A better knowledge of Pluto will be needed to complete our understanding of the origin and evolution of our solar system.

The asteroids offer an insight into planetary structure and evolution. They may be large fragments of the interiors of originally large bodies or they may represent primordial condensation of the solar nebula that never grew into planets.

A comet is surely one of the more complex solar system bodies, with its many interactions with basic solar fields: viz, gravitational, electromagnetic, electrostatic, magnetic and hydrodynamic. Measurements of these fields, throughout the coma and tail, could lead to a theoretical interpretation of their effect on both charged and uncharged matter. In addition, scientific facts which lead to an interpretation of the origin of comets may well be extrapolated to help explain the origin of the solar system as a whole.



objectives in bioscience

THE SIGNIFICANCE OF SPACE BIOLOGY

NASA's Bioscience program is a search for knowledge which will substantially enlarge man's understanding of life and the mechanisms of living organisms. Its research into the origin of life, the existence and nature of extraterrestrial life, and the influence of environment on living organisms will aid in the elevation of biology from a descriptive to an analytical and quantitative science. It may lead to the discovery of a universal theory of biology comparable to the universal theories of the physical sciences, which have led the way to Twentieth Century technologies. This far-reaching objective, with the benefits that flow from it to enrich the life of man, is an aim of the Bioscience program.

Fundamental bioscience is making extraordinary strides. Within the past few years, man has come to understand the essential biochemical constituents of life and the mechanism of coding and replicating hereditary information. The principal aspects of this exciting and highly significant development, DNA, RNA, the genetic code, and biological storage and retrieval of information are areas of both exceptional challenge and rapid progress. The structure and secrets of biological macromolecules are yielding to steady attack.

Space bioscience must therefore meet vigorous competition for attention. It has compelling claims to that attention, however, for it provides a new perspective on the central scientific questions in the field. The new perspective derives from experimentation in conditions and situations that cannot be duplicated on Earth.

SPECIFIC OBJECTIVES

The objectives of the Bioscience program are:

To study the effects of space and planetary environments on living Earth organisms, and the adaptation of organisms to these environments, exploiting for biological research, the unique conditions accessible through space flight – weightlessness and effective removal from periodicities related to Earth rotation and revolution.

To detect the existence of extraterrestrial life within the solar system; to study its origin and nature, and to assess its level of development.

To develop fundamental theories and theoretical models relative to the origin and development of life.

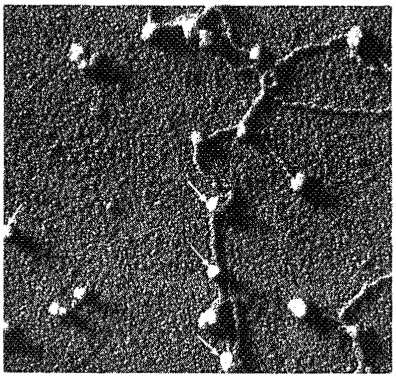
To conduct a preventive program to protect the Moon and planets from contamination by Earth life forms, and to protect the Earth from back contamination by returning spacecraft which might possibly carry extraterrestrial organisms.

BIOLOGICAL RESEARCH IN SPACE

The most significant characteristic of life is the capacity of living organisms to maintain a uniform internal environment in the face of altered external conditions, or to modify the environment to the advantage of the organism, and to adapt genetically to improve the probability of survival. In other words, there is a pervasive and complicated interrelationship between the basic biological functions and the environment. There are both obvious and subtle differences between the environment of a spacecraft in orbit or interplanetary flight and that found on Earth. There is no doubt whatsoever that the space environment will have an effect on Earth life forms. An obvious and most important objective of the Bioscience program is to determine what this effect will be so that we can assess the risks of long duration manned space flight and devise preventive measures to insure success of missions and the physical well-being of astronauts.

There is, however, another extremely important objective in the study of space environment on living organisms.

1. NEW ELECTRON MICROSCOPE MAGNIFIES 400,000 TIMES, REVEALING THREADS OF DNA AND BALLS OF RNA THAT PROVIDE PATTERN FOR CELL REPRODUCTION.
2. AUTOMATED URINALYSIS DEVICE FOR PRIMATE EXPERIMENT IN BIOSATELLITE. ADAPTABLE FOR USE IN HOSPITALS.
3. SEARCH FOR EXTRATERRESTIAL LIFE BEGINS WITH STUDY OF PRIMITIVE LIFE FORMS.
   a. 2.7-BILLION-YEAR-OLD FOSSIL
   b. CULTURED LIVING COUNTERPART.



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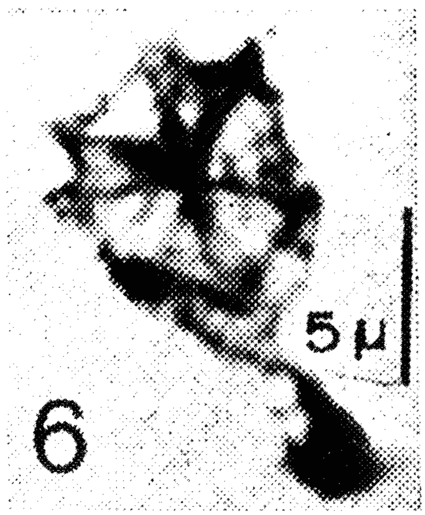

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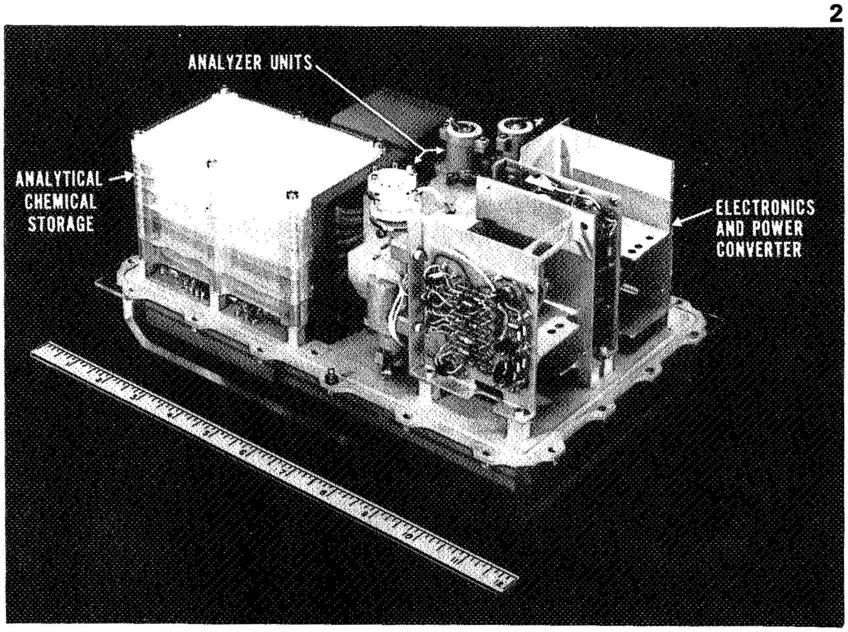

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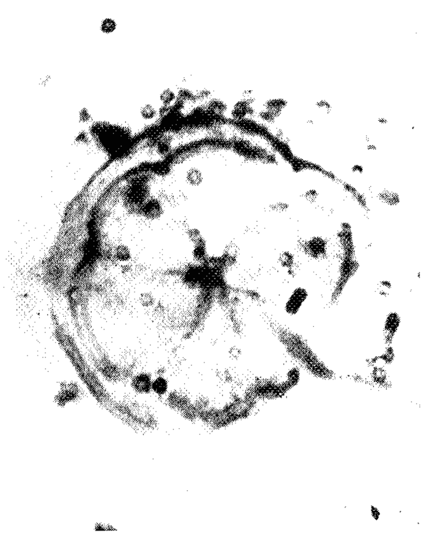


Historically, the key to understanding biological functions has been research which inquires into the reactions of organisms to variations of environmental forces. If we know how an organism senses and reacts to environmental stimuli, we know a great deal about the mechanism and function of the organism. There are environmental forces to which all known forms of life have been continuously subjected on Earth. The Space Program now offers the exciting opportunity to vary some of these geophysical forces to permit environmental research never before possible. Accordingly, the Bioscience research on the effects of the space environment on living organisms proceeds as an important effort in support of manned flight and as scientific research of great importance for its own sake, as well as for future possible application to medical, physiological and social problems.

The space environment for these studies is one which is removed from the Earth's gravitational forces – removed from the Earth's magnetic fields – removed from the Earth's periodicities and perhaps removed from other phenomena unrecognized at present. It provides the possibilities of radiation in different portions of the frequency spectrum and high energy primary cosmic rays which cannot be duplicated at present on Earth. The environment will be one of isolation, absence of conventional orientation cues, new social interaction in small groups, possible one gas low pressure atmosphere, and a closed ecology.

The Bioscience program of research encompasses investigations into the reproduction, growth and function of a wide range of biological specimens in the space environment to determine the effects of these individual features as well as combinations of these components. There are fundamental questions common to both animals and plants, such as, "How do organisms perceive gravitational strength and direction?" and "How do organisms use gravitational information to control growth and development?" The very low gravity or weightlessness uniquely achieved in space flight is the essential ingredient for these investigations.

There is a need to study the long-term effects of primary cosmic rays, which produce long ionization tracks through living tissue. As stated earlier, this is difficult to study on Earth. The effect is cumulative and the long-term effects of this radiation need careful study before man undertakes flights of long duration.

Study of activity cycles, biorhythms and biological clocks will be important objectives of Bioscience space research. The absence of day-night cycles and removal from Earth's rotation and lunar and other cyclic geophysical phenomena, possible only in space flight, will permit new insight into the origin and effects of biological rhythms. There is the expectation that these studies will discover the degree to which biological rhythms, including those of the human being, are dependent upon geophysical forces and periodicities. Will the rhythms continue unaltered in space, will they change, or will they disappear? This particular research is of significance to the projected long-term manned flights. It is also of interest from a purely scientific viewpoint, and it has interesting potential for medical purposes.

Any prospect of subjecting men to the unique stresses imposed by the space environment, especially those involving extended missions, raises new and unsolved questions about behavior. We are almost totally ignorant about the way the human brain controls behavior. The mechanisms of consciousness, motivation, memory and calculated response to stimuli are unknown. Behavioral effects caused by weightlessness, lack of familiar sensory stimulations, alteration of day-night cycles and social isolation have already been shown to affect perception, sensory and muscular control, coordination, spatial orientation, learning motivation, social behavior and sustained vigilance. It is for these reasons that the Bioscience programs will dedicate a portion of their space research to the effects of space environment on behavior.

Animal experimentation will be a necessary and important part of the research. The use of animal subjects permits far more rigorous control and more sharply defined experiment than is possible with human subjects. It also permits the employment of measuring devices and procedures, such as deep brain electrodes, long-term cardiovascular and urinary tract catheters, deep body biotelemetry implants, the use of radioisotopes and biochemical or histological examination of parts or the entire body. These techniques cannot be used on man.

THE ORIGIN OF LIFE

Is there life elsewhere in the universe? What is the nature and origin of life? How does the Bioscience program relate to the study of the origin of life? According to the best and most firmly established scientific evidence, the chemical composition of the entire visible universe (many billions of stars) is remarkably constant throughout, and consists of the same elements that are found on Earth. Primitive Earth is believed to have had all of the elements present in approximate proportion to their cosmic abundance. If this is true, it would have had a chemically reducing atmosphere composed largely of methane, ammonia, water vapor and hydrogen.

There is evidence to indicate the Earth retained its primitive hydrogen atmosphere for some fraction of its first billion years of existence. This gives rise to the speculation that the constituent chemicals for living organisms were created in this primitive atmosphere. In 1953, Miller and Urey reported on experiments in which they created some of the basic building blocks of living things simply by subjecting a primitive atmosphere to electrical sparks. Since that time, using other sources of energy as well, practically all major building blocks of living things have been created in the laboratory, including pieces of the genetic substance DNA. Since all living things, from bacteria to man, have the same general chemistry, these discoveries suggest that life would arise as an inevitable consequence of the laws of physics and chemistry, wherever conditions were favorable for chemical evolution.

Because the prebiological chemistry on earth is masked by contemporary biological activity, the real test of this hypothesis as to the origin of life will have to come from study of prebiological as well as biological evidence that may still exist on the Moon or other planets of our solar system, which may still be in earlier stages of the atmospheric evolutionary cycle through which the Earth is going. Such study is one of the more important objectives in exploring the Moon and the planets. If prebiological or biological evidence is found elsewhere in the solar system, it will indicate the probability that life is widespread in the universe, that it may be similar to our terrestrial life, and that certain biological concepts have universal validity. On the other hand, a totally unexpected type of biology may be discovered from which it may be possible to draw even more far-reaching conclusions regarding the universal nature of life. Finally, if no pre-life, life, or fossil record is found, it would be of equal, if not greater, significance to understand why life did *not* originate in the other places.

LIFE SUPPORT FOR ASTRONAUTS

The confinement of human beings in the restricted environment of a spacecraft for periods of time as long as a year or more raises formidable problems of life support system design. It is appropriate to bring to bear biological research in the search for a solution through the use of biological regenerative systems. In the presence of sunlight, a green algae called *Chlorella* can convert waste carbon dioxide to oxygen and foodstuffs. A bacterium called *Hydrogenomonas* can take in hydrogen (obtained by electrical breakdown of water to hydrogen and oxygen), carbon dioxide and urine to produce foodstuffs. These systems show promise and warrant additional research. Another long-range biological investigation underway involves the study of depression of metabolism in order to conserve food and oxygen and for possible protection against high radiation hazards.

CONTAMINATION AND STERILIZATION

When spacecraft go to other planets or the Moon and return to Earth, it is necessary to take stringent measures against contamination. This means that we must very carefully sterilize spacecraft to avoid carrying Earth organisms to the other planets, since this could forever confuse the information as to what sort of life exists on that other planet. It also means that we must take all necessary precautions against the possibility of introducing dangerous extraterrestrial contamination into the Earth's Biosphere.

Contamination control on a spacecraft that will land on another planet is currently planned to assure, within a probability of .999, that the planet will not be contaminated during the period of biological exploration. The achievement of spacecraft sterility is a complex problem requiring new technology and materials leading to improved reliability of spacecraft hardware. Because the interiors as well as the surfaces of the various components must be sterilized, the restrictions placed on planetary spacecraft exceed those presently imposed in surgical procedures.

The potential hazard presented by possible introduction of extraterrestrial contamination by spacecraft returning to Earth from manned Lunar missions has been considered by NASA and other federal agencies. In order to coordinate this activity an interagency committee consisting of representatives from NASA, Departments of Agriculture, Interior, and Health, Education and Welfare was established to recommend the criteria and procedures for control of back contamination. To carry out the requirements for quarantine control on manned Lunar missions, NASA will make use of the Lunar Receiving Laboratory (LRL) at the Manned Spacecraft Center. In addition to many other functions, the LRL will insure the confinement of the astronauts and Lunar Samples behind biological barriers until they can be examined and then released with complete safety to the world.

c) The extension of communications of all types to world-wide coverage, particularly to the areas unaccessible by past techniques, to greatly improve the efficiency, economy and reliability of communications, world-wide and national.

d) The development and adoption of systems of navigation and traffic control to achieve safe, economical and swift air and sea transportation at much higher traffic densities.

e) The accurate location of geographic features.

objectives in space applications

BROAD OBJECTIVES IN THE APPLICATIONS PROGRAM

The steadily increasing density, mobility and complexity of modern society has generated major problems, whose solution may be found or substantially assisted by the application of capabilities developed for the space program. Initial applications to the fields of meteorology and communications are well known. Typical objectives of the space program for application to man's benefit are directed towards:

a) A more precise knowledge, inventory and use of the earth's resources, particularly those of the United States.

b) A more precise knowledge and understanding of man's environment on earth and of the forces controlling it, to allow accurate short and long term forecasting and to allow man's eventual control of his environment.

SPECIFIC INVESTIGATIONS REQUIRED

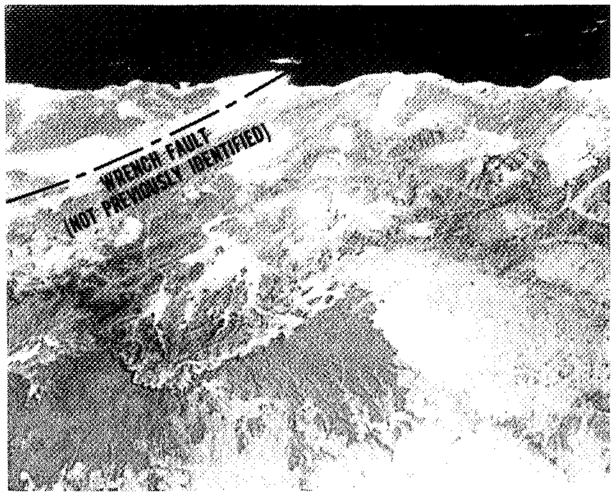
These broad national needs and objectives give rise to NASA objectives for improvement in the existing operational systems in communications, meteorology, and geodesy and toward development of the technology and space procedures for Earth resources survey and navigation/traffic control.

Specific NASA objectives in space applications encompass investigations in the following areas:

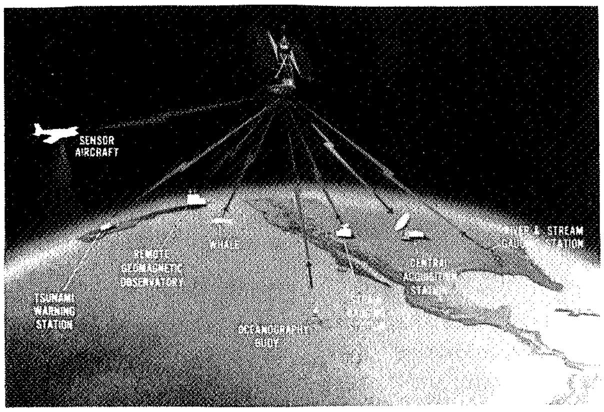
- The techniques of observing the Earth and its atmosphere from space for detailed analysis of the resources of the Earth and its oceans and for accurate long range weather forecasting.
- The use of satellites in communications, including broadcasting, data collection and transfer, traffic control and navigation.
- The unique capabilities of satellites for geometric and gravimetric geodesy.
- The investigation of the potential role of man in the operation of space systems, and in the development and space qualification of sensors, antennas, stabilization systems, receivers, transmitters, and power supplies.

EARTH RESOURCES

Man's activities on Earth are largely efforts to utilize and develop natural resources for his needs. These resources, an invaluable, limited commodity, must be used wisely as the Earth's population expands. Yet proper use depends on proper perspective. That perspective can be gained only by a total overview, obtainable by cataloging and monitoring agricultural, forest, mineral, marine and cultural resources, and water supplies. In addition, meteorology is a closely related element in the total picture; its assessment and prediction are already well-established and entering the operational phase on a synoptic scale.



GEMINI V PHOTO OF RED SEA COAST OF SAUDI ARABIA



EARTH RESOURCE SURVEY DATA WHICH CAN BE COLLECTED BY SATELLITE

During the past three decades, civil and commercial interests have used airborne photographic and infrared devices extensively, and gravitational, magnetic and radioactive measurements have been applied to the search for mineral and petroleum resources. These activities have pointed up the potential for remote-sensing of natural resources on a wide scale. Photographs and personal observations from Gemini spacecraft have shown dramatically the possibilities that satellites afford for viewing large areas of the Earth's surface simultaneously.

With suitable instruments, it is clear that satellites could conduct global surveys that would assess timber stands, grass cover, crop health; the extent of snow and ice; oceanographic features and the migrations of fish; areas of human activity; and geological formations. For geological data, a one-time operation would suffice. In most cases, however, where seasonal or even shorter-term changes are important, continuous observations or frequent periodic surveys will be needed as, for instance, to check on the state of health of crops, the extent of glaciers and ice packs. For continuous or periodic surveys, automated, long-term operational satellites eventually will be needed.

Many of the phenomena that each natural-resource discipline wishes to observe and record from space have been identified. The instruments needed to gather these data, and procedures for their use, have been selected for feasibility studies. One of the main objectives of the early program is to determine the best combination of instruments and the most effective resolutions for observing the widely varying natural resources.

The five major areas of interest are: Agricultural and Forestry Resources; Geography; Hydrology and Water Resources; Oceanography; and Marine Resources. The U.S. Departments of Agriculture, Interior, and Navy have interagency agreements with NASA to aid in the development of this program and are coordinating the various user requirements for each discipline.

COMMUNICATIONS

Reliable communications weld together the world's daily activities in government, finance, commerce, education, transportation, industry, and military affairs, as well as in private matters. Communications traffic is rising at a pace far faster than that of population growth.

Satellite communications relays were developed as the most promising means of satisfying the urgent international need. In numerous areas, they are more than competitive with other means of communication. Overseas shortwave radio, for instance, is not fully predictable, owing to atmospheric and ionospheric disturbances, while satellite communications, invulnerable to weather and independent of ionospheric conditions, are dependable. Underseas cables, although dependable, do not have the capacity for television transmission; satellite relays do.

Communication as used here means the conveying, by satellite relay, of intelligence (aural, visual, data, signal or record traffic) exclusive of tracking, telemetry, and command. It includes (1) the kinds of service normally provided by common carriers and by broadcasters; (2) specialized services historically provided by other private agencies and by the government such as air-sea rescue and air traffic control; and (3) space service such as spacecraft-to-spacecraft-to-ground station communications.

On the domestic scene, NASA will continue to study future applications of satellites for communication as they can be applied to multiple access small terminal (including aircraft) point-to-point services; spacecraft-to-spacecraft-to-ground communications; and broadcasting of monochrome and color television program material either directly to conventional or modified home receivers or to relatively inexpensive community and institutional receivers for distribution to homes and classrooms.

For all of these applications, NASA must continue to explore the use of new areas of the radio frequency spectrum as well as to study ways in which to use more efficiently those frequencies in current use: The radio frequency spectrum is a limited national resource that must be effectively managed if many of the future applications of space technology are to be realized.

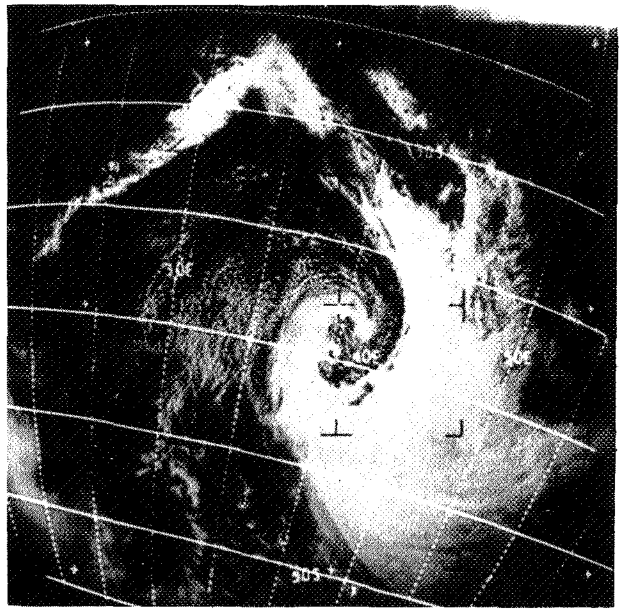
METEOROLOGY

Rocket photography of the Earth began in 1946. The results immediately indicated that it would be useful to take pictures of weather conditions as they evolved, and that the means to do so would soon be at hand. The potential of weather photography was dramatically highlighted in October, 1954, by Aerobee color pictures of a complete tropical storm over Texas and New Mexico. Conventional weather observation had failed to identify the storm's cloud cover as due to a disturbance of nearly hurricane proportions. It was then clear that weather photographs taken from above would give forecasters broader information and a valuable opportunity to improve predictions.

The chance which came with the creation of artifical satellites, was promptly seized upon for weather photography. Their unqualified success has led to the evolution of an operational weather-satellite system, which space science is still in the process of improving and extending in forecast range capability. The potential financial return from better and longer-range forecasting alone would equal a large part of the national space program budget. A report by the National Academy of Sciences-National Research Council has estimated that around $2.5 billion a year could be saved by farmers, fuel producers, public utilities, builders, and water managers if they were provided with more accurate and extended weather forecasts.

The NASA Meteorological Programs will provide the space technology to permit the operational acquisition of data which, together with the current conventional observational data, will increase the knowledge and understanding of the Earth's atmosphere; will improve the ability to forecast the weather over extended time periods; will provide, through the observations and knowledge of the state-of-the-atmosphere, a basis for appropriate weather modification and control experiments, and will provide the technology for detection of air pollution. In addition, as part of the national space effort, these objectives may be extended to apply to the exploration of the atmospheres of other planets.

The overall objective in meteorology is subdivided into two principal subobjectives: (1) development of technology required for operational meteorological systems and (2) determination of the composition and structure of the atmosphere.



EXTRATROPICAL STORM VIEWED BY ESSA–III

NAVIGATION/TRAFFIC CONTROL

Increases in air traffic over the oceans and other unpopulated areas, plus advances in aircraft speed, have created problems of navigation, traffic control, and communications that threaten to become acute, especially in the crowded routes above the North Atlantic.

These problems will become far more ominous when supersonic transport planes begin scheduled flights. They lend urgency to the long technical effort which will be required to provide all-weather, continuously available, accurate navigation systems. Present electronic navigational aids – omni-range, Loran, Shoran, and Omega – are not adequate to cope with expanding traffic and rising speeds. Two years ago, a Federal Aviation Agency study pointed out that present separation standards for aircraft crossing the North Atlantic – 120 nautical miles laterally, 20 minutes flying time longitudinally, and 2,000 feet vertically – are dictated by inadequacies in the present system and are "extremely wasteful of air space." If air space is to be better utilized, without jeopardizing safety, there is a growing need for navigational systems that will locate and track aircraft with finer resolution in both space and time.

For surface craft, there is at present no single navigation system that can provide a commercial or civilian ship's captain with an accurate position fix whenever he needs it, anywhere in the world, in any kind of weather.

Research by the U.S. Navy has provided the basic technology and procedures for first-generation navigation systems utilizing satellites. The Navy's Transit satellites have demonstrated the use of space technology to provide both surface vessels and submarines with precise position fixes in all kinds of weather. The first civilian vessel to make use of the same system—Columbia University's three-masted schooner, Vema, engaged in oceanographic research—has reported it to be highly successful. Vema, in the North Atlantic in the fall of 1966, a season when celestial observations were possible only once or twice a week, got 20 navigational fixes a day from passing Transit satellites. Furthermore, the fixes were accurate within yards, whereas celestial navigation involves possible errors of miles.

Even this promising advance in the state of satellite navigation is flawed, however. The shipboard equipment is costly and complex. Computation time runs six to eight minutes. Navigation fixes can be made only when a satellite swings by on its 90-minute orbit of the Earth. And the system does not communicate the user's position to shore stations for use in traffic control or possible rescue missions.

Satellite navigation still needs much work to adapt it to civilian and commercial use. Costs must be brought down. Weights and volumes must be reduced. Navigation by satellite must be fitted to the small user—private boats and planes. It must be fitted to the rapid user—the forthcoming supersonic transports. Finally it must be fitted to average skill and training. Space techniques are going to have to be adapted to navigation systems that will be both inexpensive and simple to operate and maintain, and will utilize on-board equipment. The systems must be able to display position fixes at frequent intervals, within seconds of making the measurements. They must also report positions instantly to traffic control centers on shore and to rescue services, if needed.

NASA's objective is to support research and technology programs directed toward developing the methods, techniques, and spaceborne equipment that will make navigation/traffic-control satellites a reality in the 1970's.

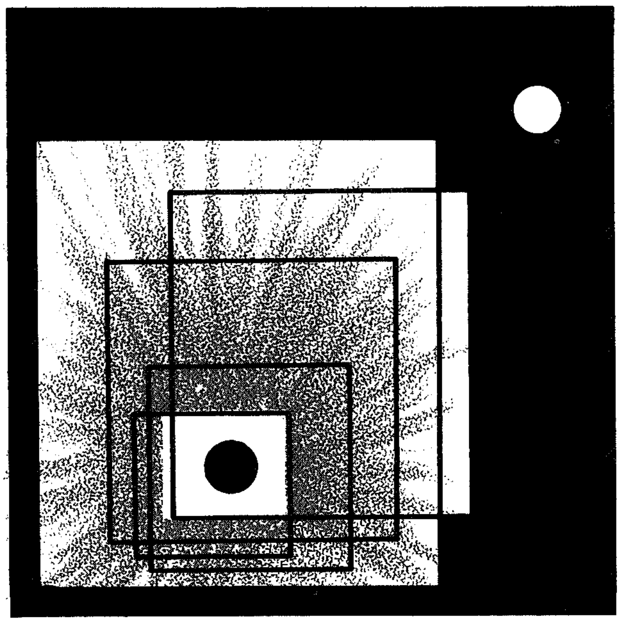
GEODESY

The scientific objective of geodesy is to determine the shape and size of the Earth and its gravitational field, and to support Earth-oriented sciences. The practical objective of geodesy is to perform those measurements and computations required to establish the control points needed for mapping the Earth's surface accurately. The use of satellites has brought great advances. More was learned in the first few months of satellite geodesy than in the previous two centuries. The practical geodetic aspect of mapping and charting has received marked impetus from the National Geodetic Satellite Program. This program, in which NASA, the Department of Defense, and the Department of Commerce participate, began in 1962, after the launching of Anna 1B, the first U.S. satellite with geodesy as a major objective. The program is international in character, because of the need for global observations. Two of its chief purposes are to: (1) Establish a worldwide geodetic reference system and determine the positions of control stations in the system to within 10 meters; and (2) refine the definition of the structure of the Earth's gravitational field by establishing the coefficients required for such a description in a spherical harmonic development through the 15th degree and order and refine the location and magnitude of significant gravitational anomalies.

Satellite geodesy is not intended to improve internal accuracy of local geodetic networks, though it may be used for that purpose. Rather, its goal is to provide vital information enabling systematic connection of the various local networks with one another and with the physical Earth on a far more precise basis than was previously possible. Use of satellite techniques allows geodetic ties over areas of difficult access, like oceans, thereby permitting the resolution of uncertainties about the relative location of continents.

Practical applications dominate satellite geodesy, but science is also served. Geodetic satellites can ultimately provide data for investigations of (1) continental drift and vertical uplift of land masses, (2) wandering of terrestrial poles, (3) measurements of land motions along fault zones, in relation to distant reference points, and (4) long-term changes in the Earth's gravitational field and motions of its anomalous regions. Astronomy, geology, seismology, geomagnetism, and galaciology will benefit directly from the accurate positioning capability of the program. And oceanography will make immediate use of the accurate positioning capability, and in the future, the ability to monitor rapidly the changing shape of the ocean surface from satellites.

3 views on relative emphasis



Recognizing that resources, human or economic, will never be available in amounts adequate for the prosecution of all proposed good programs and missions, decisions must be made as to which should be selected and implemented. One of the main purposes of documents such as this is to provide early familiarization with the more promising of the future programs to encourage and facilitate early and objective consideration of them so that every opportunity will be exploited to make the proper selection.

These program options have been identified as means of fulfilling the objectives of the National Aeronautics and Space Administration. These objectives can be summarized as follows:

Source: National Aeronautics and Space Act of 1958

"(c) 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 of 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 non-military 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."

Many individuals and groups have expressed their views as to the content of the space program and the relative emphasis which should be applied in selection of the future space programs. The recommendations are not unanimous and frequently reflect the different backgrounds of their authors. A number of these views are quoted below:

Source: President's letter of January 27, 1965 transmitting Report to the Congress on U.S. Aeronautic and Space Activities of 1964

"...We expect to explore the moon, not just visit it or photograph it. We plan to explore and chart planets as well. We shall expand our earth laboratories into space laboratories and extend our national strength into the space dimension."

Source: Summary of conclusions of Space Science Board summer study at Woods Hole: During June and July, 1965 *(see Space Research: Directions for the Future report)*

"We recommend planetary exploration as the most rewarding scientific objective for the 1970-1985 period. In pursuing this goal we recommend a reasonable balance between lunar and planetary programs.

"All of our astronomy working groups project a need for large orbiting telescopes and anticipate the availability of man to adjust, maintain, and repair these national facilities.

"All of the working group reports make clear that the exploration of space requires the utilization of both ground-based observations and studies with balloons, sounding rockets, and satellites.

"The distinction between manned and unmanned programs is an artificial one; scientific objectives should be the determining factors.

"The report of the Working Group on Medicine and Physiology concludes that before man can be safely included in missions of planetary duration, an orbiting research facility for the study of long-term effects of space flight is essential."...

". . . rough figures suggestive of the Board's sense of appropriate priorities and balance appear in the following table,"

1969-1972 per year (billions of dollars		
	FY 67	Projected
Planetary exploration (unmanned) Voyager and small probes	0.1 (2%)	1.0 (20%) (increasing)
Lunar exploration (manned)	3.6 (72%)	1.75 (35%) (decreasing)
Earth-orbital missions (manned and unmanned)	0.3 (6%)	1.25 (25%)
(astronomy at all wavelengths)		(0.6)
(biology and medicine, geophysics, etc.; applications)		(0.65)
Other endeavors	1.0 (20%)	1.0 (20%)
Total	5.0 (100%)	5.0 (100%)

Source: Planetary Exploration 1968-1975
A Report of a Study by the Space Science Board—June 1968, National Academy of Sciences, National Research Council

The following excerpts from the Summary of Principal Recommendations concerning program emphasis are:

- We recommend that a substantially increased fraction of the total NASA budget be devoted to unmanned planetary exploration
- We recommend that duplicate missions for a particular opportunity be undertaken only when a clear gain in scientific information will result from such double launches
- We recommend that NASA initiate now a program of Pioneer/IMP-class spinning spacecraft to orbit Venus and Mars at every opportunity and for exploratory missions to other targets
- We recommend the following larger missions to Mars: A Mariner orbiter mission in 1971, and a Mariner-type orbiter and lander mission, based on a Titan-Centaur, in 1973
- We accord next priorities (in descending order) to a Mariner-class Venus-Mercury fly-by in 1973 or 1975, a multiple dropsonde mission to Venus in 1975, and a major lander on Mars, perhaps in 1975

Source: President's Science Advisory Committee report to the President prepared by combined Space Science and Space Technology Panels, February 1967 Abstracted from White House Press Release February 1967.

"... The Panels rejected the adoption of a single new dominating goal for the space program but recommended eventual manned planetary exploration, integrating manned and unmanned efforts directed toward the following major objectives:

- A limited but important extension of Apollo in order to exploit our anticipated ability to explore the Moon:
  1. Continue manned expeditions at an initial rate of one or two per year, with each manned expedition provided sufficient logistics support to permit a stay time of several days and astronaut mobility of several miles to provide for study and exploration of interesting features of the Moon.
  2. Provide unmanned Lunar landers during the early 1970's capable of landing significant scientific payloads anywhere on the Moon.

A strongly upgraded program of early unmanned exploration of the nearby planets, on a scale of time and effort that will enable the results of this program to contribute significantly toward the planning of future manned expeditions.

- A program of technology development and of qualification of man for long duration space flight in anticipation of manned planetary exploration. Recommendations are:
  1. That programs in Earth orbit be established to determine the effect of prolonged exposure of man (about 100 days or more) to the space environment, to learn how to predict these effects for individuals not yet exposed, and to devise ways to ensure and improve man's effectiveness.
  2. That the proposed orbital workshop experiment of the Apollo Applications Program proceed . .
  3. That arrangements be developed between NASA and the USAF to use the MOL program as an important source of data on the capabilities of man for extended space missions to supplement information from early AAP missions.
  4. That a program of study and advanced development be initiated promptly with the objective of a launch in the mid-1970's of the first module of a space station for very prolonged biological studies of man, animals and other organisms in Earth orbit.

- The extension and vigorous exploitation of space applications for the social and economic well-being of the nation and for national security. Recommendations are:
  1. That a far more intensive effort be carried out to examine the applicability of satellite technology to the missions of all the Federal agencies.
  2. That, whether the proposed space application systems are manned or unmanned, a reasonably clear case of potential benefit should be shown to exist before significant developmental costs are assumed and, further, relative cost effectiveness criteria should be used in decisions between manned and unmanned operational systems.

- The exploitation of our capability to carry out complex technical operations in near Earth orbit for the advance of science, particularly astronomy. Recommendations are:
  1. That the government adopt as a primary goal in the application of space technology for scientific purposes a program of research leading to the establishment in Earth orbit of a number of astronomical facilities, which by the end of the 1970's will constitute an orbiting astronomical observatory capable of: (a) taking advantage of the regions of the spectrum not accessible from the ground as well as other advantages of instruments in orbit such as much higher resolution; (b) scientific control directly by astronomers on the Earth; (c) extended useful life through intermittent maintenance and modernization by servicing in orbit. This program should be evolutionary with each step big enough to be significant but not so grandiose that it cannot be modified as new discoveries and technological advances become available.
  2. That NASA should develop arrangements for working with the scientific community to permit the most effective use of the investments in this astronomy program.

- The Panels recommend increased emphasis on international cooperation as the space program develops. They urge that all agencies having related interests actively support international programs in space involving the fostering of cooperative efforts through organizations such as the International Council of Scientific Unions.

Source: L. B. Johnson: State of the Union Address, January 17, 1968.

"We must also improve the lives of children already born in the villages, towns, and cities on this Earth. And they can be taught by great teachers through the miracle of satellite television–and we are going to bring to bear every resource of mind and technology to make this dream come true."

Source: Congressman Joseph Karth. Quoted in General Electric Company magazine Challenge—Winter, 1967

"Tracing national growth directly back to research and development is a tough job, but one thing is clear—that every nation in the world that is unable or fails to carry out an aggressive research and development program also fails to develop an economy that educates, feeds, houses and clothes its people. It's also one of the reasons underdeveloped countries are underdeveloped. The long-range prospects for progress through the space program are enormous, but these prospects must be sold to the public and top policy-makers in terms of what makes sense for the overall benefit of society."

Source: Williard F. Libby: Director of the Institute of Geophysics and Planetary Physics, UCLA. Talk presented at AIAA Fourth Annual Meeting, October 23-27, 1967, Anaheim, Calif.

"Meteorology and the atmospheric sciences continue to benefit very substantially from the space program. We can see immediately the great potential usefulness of a system of orbiting satellites for gathering of weather data and depositing them quickly in a worldwide center where a giant computer would process them for early use by forecasters. This would seem to be a most important international project for the improvement of weather forecasting. Also, such data would have important scientific value. They probably would give us a better understanding of the circulation patterns and the energy flow over the Earth's surface after it is deposited from the Sun. All these observations on a worldwide scale would be taken more or less at the same instant and seemingly would give us the information we need for more accurate forecasting and a substantial scientific advance in meteorology."

"So the single most consuming scientific question of the space program undoubtedly is: "Does extraterrestrial life exist in our solar system?" The biologists are preparing and bracing for the answering of this question experimentally. But this lies entirely in the future, although, hopefully, not too far in the future. I think by the time we get to the Moon we will be well down the road toward answering it, but this may not be so. It may be some time before we can get to Mars, on the Voyager program or with the manned program, so we can get our answer there. And Venus lies even farther away."

"It is clear that, of all the sciences, the future benefits from the space program will lie most in astronomy. It is as though we have been looking at the stars from the bottom of a 30-ft-deep swimming pool, and now we come to the surface and we look out and we can see, for the first time, clearly. Some achievements have been made to date with rockets, principally the discovery of the X-ray stars, but we all await an orbiting observatory or a Lunar base as the birth of a truly new day in the history of this great subject.

I have heard astronomers question the space program for reasons of underfunding of ground-based telescopes, but I have never heard one deprecate the promise of a telescope outside the atmosphere. They may argue as to whether the orbiting observatory should be manned or not, but none will argue that a telescope on the Moon, if it could be put there and manned, would be invaluable."

Source: Simon Ramo; Chairman, TRW Inc. Talk presented at AIAA Fourth Annual Meeting, October 23-27, 1967, Anaheim, Calif.

"In particular, I believe it is possible now to be quite certain about one thing: We have it within our power of choice to so exploit what we have learned about space technology as to produce values for our society in the '70s substantially greater than the entire space program will have cost in the '60s."

"I would first base the space program on greatest priority attention to the near-in space programs which directly affect the economy, the security, the control of and enhancement of the operations of our two-dimensional society here on Earth."

"At the same time, from the technological standpoint as well as from the standpoint of economics and society in general, I would recognize that such programs must compete for the same kind of technological resources as programs that relate to our urban problems, city development and redevelopment, medical care, technological aids to education, and surface and air transportation, to name a few.

"When the properly balanced program including all these requirements is created, I believe that it will enhance the near-in, largely unmanned, instrumented space technology. The program will be a growing one more or less in proportion to our gross national product, or even perhaps accelerating beyond the GNP rate of growth, because of the leverage which unmanned space technology provides for further economic growth and world stability."

SOURCE: From statement by ESSA, Dept. of Commerce dtd. 15 February 1968, prepared in response to request of Committee on Astronautics and Space Sciences, U. S. Senate.

. . . other Planetary Atmospheres. NASA studies of the atmospheres of other planets will contribute to the ESSA mission in several important respects. Such contributions will lead to an increased understanding of our atmospheric and ionospheric regions by providing comparative data for testing theories pertaining to these regions.

Recent studies of Earth's atmosphere have shown, in contrast to the usual suppositions, that some of the atmospheric constituents tend to vary over long time periods. The carbon dioxide cycle is of 2 years' duration, while that for oxygen is about 3000 years. These changes may be related to long-term climatic variations such as those associated with the glacial periods but may also be affected in a new and unpredictable way by human activities such as large scale burning of hydrocarbon fuels. Thus, encroaching developments of mankind can cause a long term increase in carbon dioxide accompanied by a decrease in the amount of oxygen present in the atmosphere.

The testing of physical hypotheses requires experimental studies which in turn require the ability to vary the physical parameters involved. Since it is not possible to control the geophysical process of the Earth and its atmosphere, only long period variations can be observed and analyzed. The atmospheres of other planets, each of which has a different set of atmospheric parameters, thus can be considered natural laboratories for studying the Earth's atmosphere. The variations in planetary mass, temperatures, and chemical composition of these atmospheres can be related to variations in the terrestrial atmosphere. Thus it is of crucial importance to study these atmospheres thoroughly to obtain a greater understanding of the Earth's atmosphere.

The structure, density, and height variations of the ionosphere, the region utilized in long-distance radio communications, also depend on variations of atmospheric parameters, which, for example, can affect the height and electron density of these layers. Thus, a complete understanding of the ionosphere depends very much on an understanding of the atmosphere itself. Studies of the atmospheres of these planets having ionized regions will provide comparative data which will significantly increase understanding of the Earth's ionosphere."

Source: Findings, Conclusions and Recommendations of the Central Review Committee of the 1967-1968 Summer Study on Space Applications—Useful Applications on Earth Oriented Satellites—National Academy of Sciences, National Research Council for NASA—Excerpts from preliminary draft relative to program emphasis.

"The benefits expectable from space applications appear to be large—larger than most of the Study participants had originally believed, and certainly larger than the costs of achieving them. We are convinced, however, that an extensive, coherent and selective program will be required to achieve these benefits. We therefore recommend that NASA, in its future programs and activities, give greater emphasis to Earth-satellite programs having beneficial applications."

"We are convinced that the present space applications program is too small by a factor of two or three, if we measure it in the light of the substantial opportunities that can be pursued effectively only if the financial support is increased. The additional funding would permit expansion of the applications program, and would enable the nation to proceed toward excellent investments in operational applications systems. NASA would be able to carry certain work through the space-flight operational experimental phase, so that both the potential and the problems of future systems could be thoroughly understood. We recommend the commitment of additional Federal funds to support, in certain applications, both prototype operations and an expanded research and development program that will test out the technical capabilities and benefit potentials of other practical applications. We believe that funds of the order of $200-300 million a year will be required to support the space applications program at a level that is in the best interests of the United States."

. . . . the manned "program will provide significant opportunities to test sensors and to prove out techniques useful to applications considered by this Study. However, the use of manned vehicles *per se* does not at present appear necessary or economically desirable for the operation of the various space-applications systems considered by this Study. We believe that the systems proposed for providing near-term practical and economical benefits to the United States public and to mankind generally will be achieved more effectively and economically with automated devices and vehicles" . . . .

"We recommend that NASA, in cooperation with the Department of State, continue to develop its international programs concerned with space applications, even in the face of budgetary problems, to ensure the development of a favorable climate and basis for international acceptance and use of practical space applications." . . .

"We conclude that, in the near future, satellites can be flown with imaging sensors that can provide useful output data. . . . A commonality approach among forestry, agriculture, geography, hydrology, and possibly oceanography is feasible. Moreover, if a properly phased R&D effort could be started immediately, an operational system for over-all Earth-resources information seems realizable within a decade. We recommend that NASA promptly initiate a pilot program to provide pictorial information in familiar and immediately usable form. This early system, of the Global Land Use (GLU) type would furnish much of the understanding required for future, more advanced systems."

"We recommend an increase in the support of sensor-signature R&D, convinced that a modest investment here will engender great advances in understanding how satellites may be used for beneficial purposes."

"We recommend NASA continue to support and expand its programs aimed at securing the quantitative, world-wide atmospheric information required by the meteorological community for mathematical models of the world weather system . . . ."

"The geosynchronous meteorological satellite is a more effective platform than it was first considered to be especially for real-time surveillance of special weather phenomena. We recommend NASA continue to exploit this usefulness, leading toward fully available capability by 1971 . . ."

"We recommend the development and operational deployment of a data-collection satellite system to provide for the interrogation and collection of data from large numbers and types widely distributed data platforms such as hydrologic gages, meteorological balloons, oceanographic buoys and other sensors and the relaying of that data to specific data-processing centers."

"Broadcast by satellites is technically feasible at any level of sophistication . . . we recommend steps be taken to implement . . . a multi-channel distribution system for the use of network television transmission for both the private and public sectors of the industry, and . . . a nine-channel system of the "teleclub" type for educational, instructional and informational television for developing countries, as well as for those audiences spread throughout the United States who are indeed sparse, but who require and need programming suited to their special interests, e.g., physicians, lawyers, engineers, educators."

"A satellite system for navigation and traffic control over the North Atlantic appears to be cost-beneficial for shipping alone provided all carriers are included (and would also provide for aircraft). We recommend that immediate system definition and synthesis be undertaken, that the necessary organizational entities be identified, and the necessary R&D be started for establishing a North Atlantic satellite navigation and traffic control system to provide en-route traffic control of transoceanic aircraft, traffic control of surface vessels in confluence areas, and improved search and rescue operations at sea."

Source: Physics of the Earth in Space, A Program of Research 1968-1975, The Report of a Study by the Space Science Board, National Academy of Sciences, at Woods Hole in August 1968—The following excerpts from the Principal Recommendations on program emphasis are:

"The Study defines a program of satellite space probe and sounding rocket missions for a concerted attack on questions of fundamental physical mechanisms of the Sun-Earth system, in contrast with the exploratory surveys that characterized the past decade. We place particular emphasis on coordinated investigations and on the development and utilization of new experimental techniques. We also stress the importance of organizing a major observational effort during the 1974-1975 period of low solar acitivity."

". . . . The recommended program requires a level of support close to that of the last six years."

The report recommends high priority and growth of the sounding rocket program support, achieving roughly a 36% increase by 1971 and about a 12% annual increase thereafter through 1975.

Additional recommendations include:

". . . . We recommend that balloon, aircraft and ground-based observations continue to receive support in space science programs. We also recommend that NASA participate in the development of unmanned, ground-based geophysical observations with telemetry capabilities for remote read-out . . ."

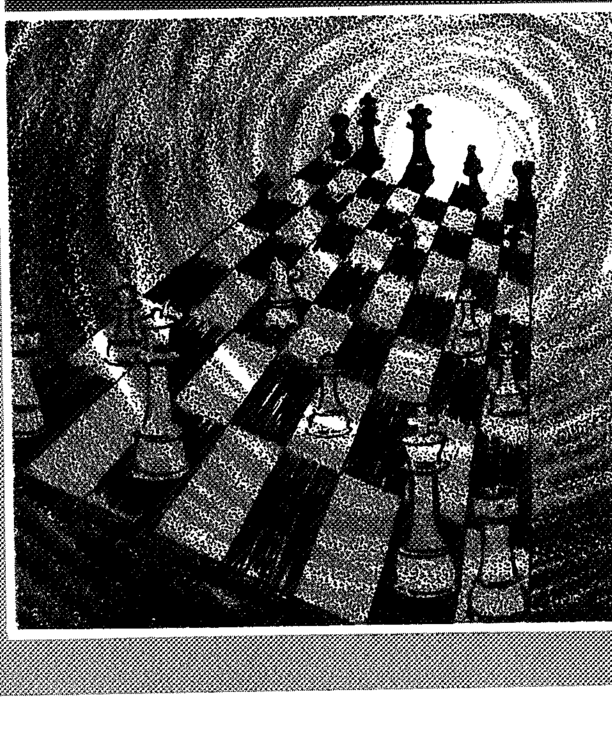
". . . . The NASA grants for pre-doctoral traineeships have encouraged graduate education in a wide range of disciplines associated with space science and technology. The importance to society and the Nation of advanced education in these fields is so great that we urge that this program be restored to the 1966 status."

Source: Remarks by President L. B. Johnson at Houston, Texas 2, 1968

"Our space programs for the decade of the Sixties are drawing to a close. Yet a mighty intellectual and technological effort, such as you are now engaged in here, cannot just be turned on and off. We must stay the course. We must continue to build new strength by using the strength we have. We must continue to cross over new frontiers. This will certainly be our certain course in the next decade."

4

strategy for space exploration



strategy for space physics

In order to achieve the objectives of Space Physics, observations are required at different locations within the Earth's atmosphere and throughout the solar system, with a variation in the timing of the measurements. These spatial and temporal requirements are:

- Global
  - Surface
  - Upper atmosphere and ionosphere
  - Magnetosphere
- Interplanetary space near the Earth
- Various positions around the sun at the radial distance of the Earth
- Various positions toward and away from the sun
- Variations over an entire solar cycle
- Diurnal effects throughout the seasons
- Simultaneous experiments in different locations

The order in which the observations are made is also of importance since they must contribute to an ever-broadening understanding of the Earth's environment and the external forces acting upon it, in accordance with the progression outlined on the next page.

THE ROLE OF PRESENT PROGRAMS IN SPACE PHYSICS (Through FY 68)

More than ten years of effort have gone into investigating the environment of the Earth to altitudes of the order 60,000 km. Although the effort may seem small, when it is recognized that this region of space encompasses one thousand times the volume of the Earth, a remarkable amount of information already has been made available, and a whole range of phenomena have been observed. It is clear that the Sun causes and controls most of these phenomena but the detailed mechanisms whereby they are produced and controlled are not yet understood. Obtaining such an understanding is the basic goals of the next phase of research into the Earth's space environment. For such understanding is the necessary pre-requisite for optimum use by mankind–forecasting seems to be nearly within our grasp, and modification still remains a dream for the future.

Many of the current programs in space physics are being continued but with increasing sophistication because of advances in instrumentation. Their missions will take advantage of the opportunity to observe the phenomena in space related to maximum solar activity. Combined with knowledge already obtained of the phenomena at minimum solar activity, the new results should answer many questions, particularly those related to understanding the upper atmosphere processes and solar cosmic rays and the hazards they pose. The spacecraft currently in use in these programs are discused briefly below.

Orbiting Geophysical Observations (OGO)

The OGO spacecraft allow simultaneous performance of many interrelated experiments on a stabilized, high data rate satellite. The investigations are concerned with the geophysical environment as affected by solar activity, the energy forms of interplanetary and galactic medium, and the physics of the terrestrial magnetic field and atmosphere.

The correlated multiple experiments of an individual OGO spacecraft offer advantages that are enhanced by nearly simultaneous measurements from several observatories, using orbits that are highly elliptical, low altitude orbits, and orbits at different inclinations. Spacecraft in elliptical orbits are used to study the natural radiation belt of the Earth, the geomagnetic field far from Earth, the region where interaction occurs between the geomagnetid field and solar wind, and the interplanetary medium. Spacecraft in low altitude polar orbits investigate particle precipitation, auroras and the ionosphere and upper atmosphere, as affected by solar and other influences.

MAGNETOSPHERE

- GROSS FEATURES
- NATURE OF BOUNDARIES
- MECHANISM OF ENERGY TRANSFER ACROSS BOUNDARIES
- MECHANISM OF ENERGY TRANSFER WITHIN THE MAGNETOSPHERE
- FORMATION & MAINTENANCE OF RADIATION BELTS
- CAUSES OF MAGNETIC STORMS

GALACTIC COSMIC RAYS

- GROSS FEATURES
- NATURE OF SOURCE
- VARIATION THROUGHOUT INTERSTELLAR SPACE
- INTERACTIONS WITH MAGNETIC FIELD, INTERSTELLAR SPACE & INTERPLANETS
- ENERGY CONTENT

EARTH'S ENVIRONMENT

- GROSS FEATURES
- GEOGRAPHIC VARIATIONS
- TIME & SEASONAL VARIATION
- VARIATION WITH SOLAR CYCLE & GEOMAGNETIC ACTIVITY
- CONTROL MECHANISMS
- CHEMICAL, PLASMA & ENERGY PROCESS

INTERPLANETARY SPACE SOLAR WIND

- GROSS FEATURES
- COMPOSITION & VARIATION WITH DISTANCE FROM SUN
- NATURE OF SOURCE
- PREDICTIONS

SOLAR COSMIC RAYS

- GROSS FEATURES
- HOW ENERGIZED AT THE SUN
- VARIATION THROUGH SPACE
- PREDICTIONS

To date, 5 OGO spacecraft (1964, 1965, 1966, 1967 and 1968) have provided major scientific information. The fourth and fifth are both still fully operational and the first three are currently yielding data from 38 experiments. A remaining launch is scheduled for 1969.

Interplanetary Monitoring Platform (IMP)

The IMP spacecraft studies the radiation environment of cislunar space and monitors this region over one eleven-year cycle. High apogee orbits enable the monitoring of the conditions outside the Earth's magnetic field.

The first IMP spacecraft, Explorer XVIII, launched in 1963, was followed by five additional spacecraft, the most recent having been flown in July, 1967. Forthcoming are launches in 1969, 1970, 1971, and 1972.

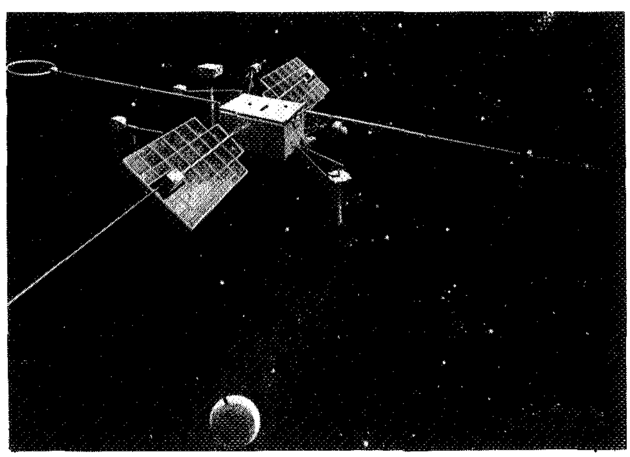
All IMP's to date have operated successfully to add to our understanding of Sun-Moon-Earth relationships particularly as they relate to the interplanetary radiation and solar particle environment.

International Satellite for Ionospheric Studies (ISIS)

The ISIS program, developed in cooperation with Canada, will continue to investigate the physics of the ionosphere by making a variety of closely coordinated measurements using both radio and orbit measurement techniques. The basic objective is to increase our understanding of the way in which the ionization is produced, moved and removed as well as affected by a variety of disturbances. The spacecraft are provided by Canada, the launch vehicles by NASA, and the experiments are chosen internationally in open competition. This work is of direct significance to radio communication, as it is the ionosphere that makes long-range transmission of radio waves possible.

Scout Explorers

The Scout Explorer program features relatively small spacecraft and has evolved into three types of projects:



(1) University projects; (2) the Small Scientific Satellite (SSS series); and (3) the Cooperative projects.

An example of the University projects is the Injun V, developed by the University of Iowa under the leadership of Dr. James Van Allen, to study relationships between particles in the Earth's magnetic field and very low frequency radio noise; another example is the OWL Project, developed at Rice University under Dr. Brian O'Brien, to perform auroral and ionospheric studies.

The Small Scientific Satellites Program will enable individual experimenters to fly entire payload of integrated sets of experiments without having to take on the responsibility for the spacecraft itself: A basic spacecraft structure will be used for all missions, drawing upon a stock of off-the-shelf modular subsystems. This approach will increase the overall reliability and will reduce preflight costs by eliminating the need for new design and testing of subsystems for each succeeding mission. A primary objective of the 1970 mission is to investigate the proton ring current about the Earth, a phenomenon of great interest associated with geomagnetic storms.

In the Cooperative Explorer Program, a foreign country or organization provides the spacecraft while NASA provides the launch vehicle, conducts the launch, and provides tracking and data acquisition support. Included are cooperative satellite projects with the United Kingdom, Canada, France, Italy, Germany, and the European Space Research Organization (ESRO). ESRO I and IIb were launched successfully in 1968. German and Italian missions are scheduled for 1969 and 1970. The fields of study range from the Earth's atmosphere and ionosphere to solar physics.

TABLE I
THE PRESENT GEOPHYSICAL PROGRAM
(Through FY 68)

	Cy	68	69	70	71	72	73
OGO (A-F)		E	F				
IMP (A-J)			G	I	H	J	
ISIS (A-C)			A	B	C		
Scout Explorers		4	1	5	1		

Pioneer

The objective of the Pioneer Program is to observe the interplanetary medium on a continuing basis as the sun passes through its 11-year cycle, gathering data simultaneously from widely separated points, including the opposite side of the sun from Earth at roughly the distance of the orbit of the Earth.

The Pioneer spacecraft was specifically designed to leave the Earth and orbit the sun. Pioneers VI, VII, and VIII, launched in 1965, 1966. and 1967, are still contributing to our knowledge of the interplanetary medium. Now that the initial objective has been met of obtaining data on the gross features of interplanetary space, our interest has shifted to detailed temporal and spatial fluctuations. These investigations will involve simultaneous measurements made from spacecraft at different locations in the solar systems. In other words, the current objective is synoptic rather than single point measurements.

During the period of solar maximum, emphasis will be placed on solar cosmic rays, especially those associated with large flares, in part because of the importance of understanding the phenomena itself and in part to predict the radiation hazards to astronauts.

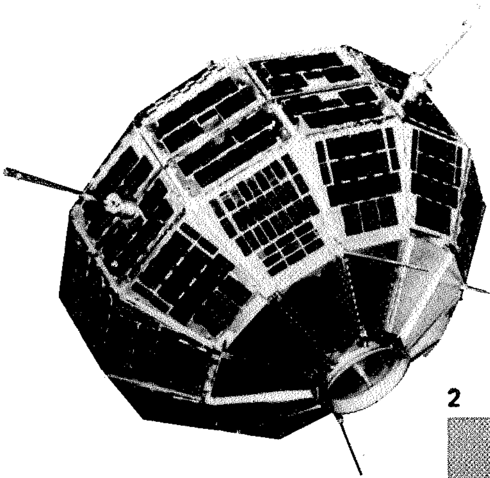
Pioneer launches are scheduled for 1968 and 1969 to optimize deep space coverage near solar maximum and to capitalize on improved lifetimes for these missions.

FUTURE REQUIREMENTS

For research in space physics, as in other fields, we first require essential measurements to answer specific questions; thus we must improve and refine the tools we have and also get new tools as needed. This means that spacecraft must carry instrumentation directed to and duly matched to specific mission investigations. To establish the proper background of requirements against which to plan the spacecraft and their instrumentation, the fields of study are divided into a number of mission areas.

Investigations of the Near-Earth Environment

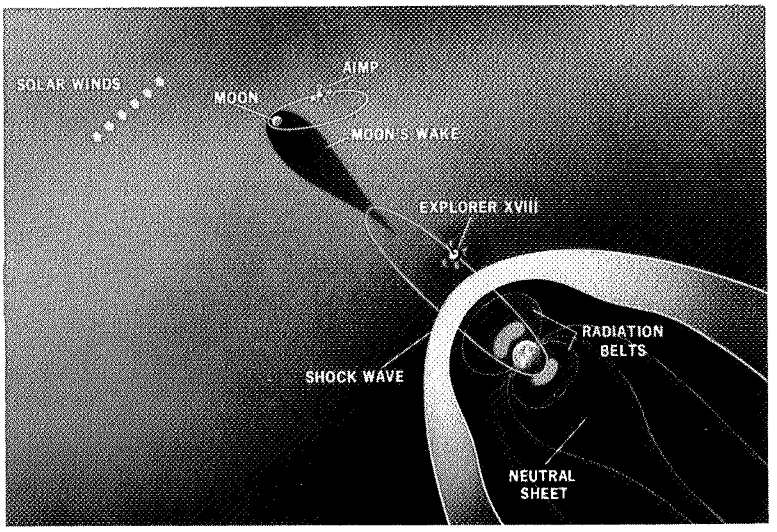
The *Photochemistry Mission* is intended to explore the region of the atmosphere between 120-300 Km. This region heretofore has been inaccessible to satellites because of excessive air drag. Initial rocket probings have indicated that this region is that most directly affected by solar radiation and that it contributes greatly to what happens in the upper atmosphere. Most of the absorption of solar ultraviolet takes place here causing temperature and chemical changes important to the state of the atmosphere above it. The region would be accessible to satellites featuring on-board propulsion to counter the air drag. Simultaneous measurements must be made of atmospheric density, temperature and composition, of influx of energy from the sun and from particle precipitation, of emission of energy through airglow, and of the controlling influence of the geomagnetic field.



1

1. ALOUETTE - B
2. IMP EXPLORER REGIONS OF INVESTIGATION
3. PIONEER COVERAGE OF SOLAR ACTIVITY

2



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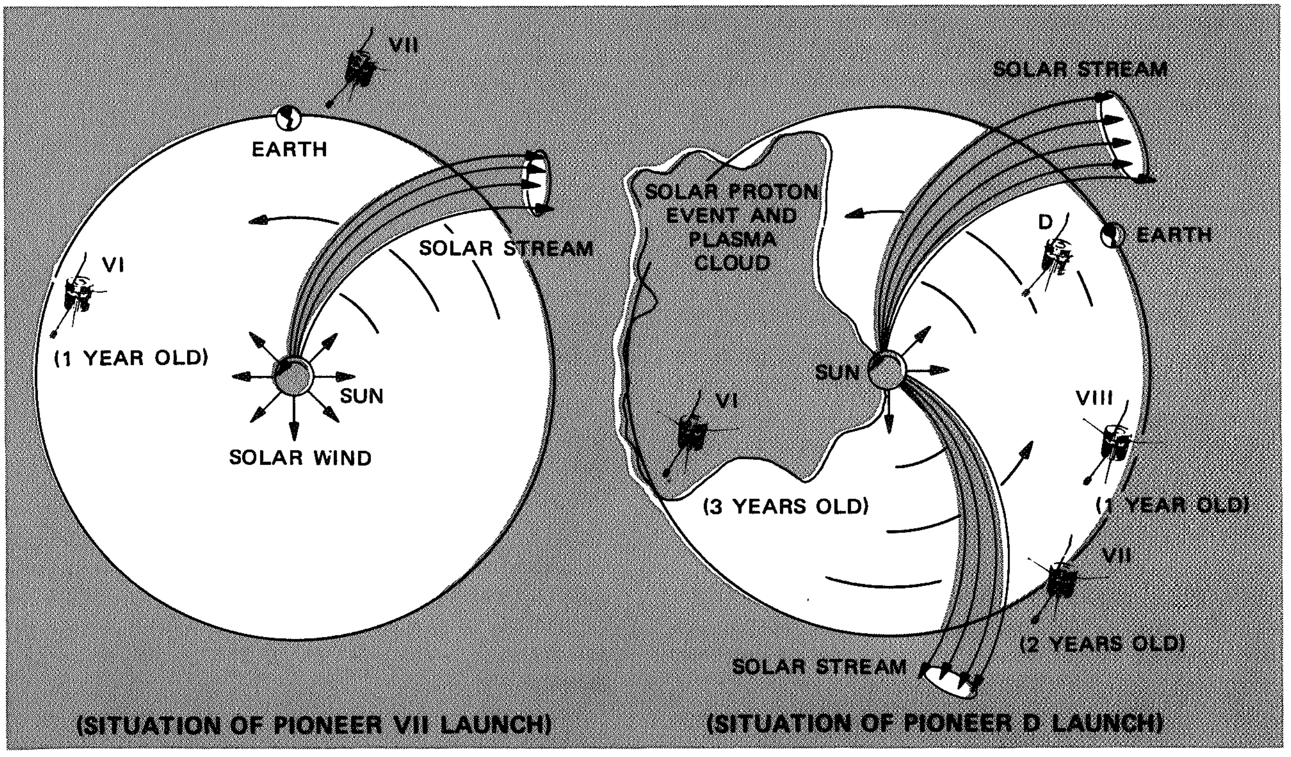


The *Plasmapause Mission* will explore the region from about 3.5 to 6 Earth radii where an abrupt decrease in charged particle concentration has been observed. It is surmised, that the plasmapause represents the area where the energy contained in the high-density low-energy plasma balances the energy contained in the low-density high-energy particles of the outer radiation zones.

The *F-Region Mission* will study the important physics of the upper portion of the ionosphere extending from 200-2000 Km where the paths of ionized atoms are convected by the magnetic field, giving rise to electrical fields and currents in lower altitude regions. The relative roles of ion production, loss, diffusion, and convection are important not only to the lower ionosphere, but perhaps in the formation of the Plasmapause.

The *Aurorai Mission* will continue the study of the processes and mechanisms leading to the formation of auroras and other polar cap phenomena.

Study of the Magnetosphere

Four magnetospheric missions are indicated below. In order to meet previously stated objectives we must observe the magnetosphere simultaneously at many locations, especially on points close to the boundary features.

The *Magnetospheric Boundary Mission* will study the region of the magnetosphere, giving particular attention to the mechanisms of energy and particle transfer, which are largely unknown. Measurements will be made of particle migration across the magnetospheric boundary and of plasma instabilities which are associated with the interaction and interconnection between the solar and terrestrial magnetic fields.

The *Magnetospheric Neutral Points Mission* will investigate instability and particle injection occurring in the magnetosphere above the poles. The polar region will be studied to determine its role as the accelerator of auroral particles.

The *Outer Radiation Belts Mission* will concentrate on the belts to identify the plasma processes occurring in these regions: Correlations, with precise time resolution, between particles and fields will be desired, therefore, various orbits must be used. Several simultaneously operating satellites will map out the behavior of this region as affected by the solar wind plasma.

The *Magnetospheric Tail Mission* will study the structure and dynamics of the geomagnetic tail, the mechanisms that maintain the tail structure with its plasma sheet and neutral sheet, and the particle acceleration processes.

Study of Interplanetary Space

It is generally accepted that the gradient and structure of cosmic rays and the solar wind are not constant throughout space nor over a solar cycle. Consequently, in order to understand these processes, one must have several similarly instrumented observation points scattered through the solar system. Missions in an Earth orbit, together with spacecraft in heliocentric orbits will provide information on space "weather" over observational distances extending inward to the sun and outward to 4 AU from the sun.

The program for the exploration of interplanetary space will be directed to the solar wind and magnetic field, galactic and solar cosmic rays, and interplanetary dust. Small, relatively inexpensive spacecraft will be put into heliocentric orbits both close to the sun and farther out than the Earth; the spacecraft will be sufficiently inexpensive to permit several launches per year, in that way permitting synoptic observations of the solar system.

A small interplanetary probe for missions in toward the sun, *Sunblazer,* will observe space weather near the sun, and also study the sun as a star.

A closer approach to the sun will be provided by a solar probe especially designed to withstand the close-in environment. Such a probe will permit direct measurements in the solar corona in regions where existing methods fail. As with the Pioneer spacecraft, the studies will not be limited to "space weather" alone, but will examine the sun in terms of the astrophysical problem of determining the structure and evolution of stars. One such solar probe is called Helios. This is a cooperative venture with Germany in which the U.S. will participate in the experiment package and launch the spacecraft. The mission is to explore the interplanetary environment from 1 AU to .3 AU. Helios is intended to follow up the propagation measurements made through this region on Sunblazer by more detailed *in situ* measurements.

The very flexible Pioneer spacecraft, with modifications, could investigate the interplanetary region through the asteroid belt at four AU. One question of great interest is the change in cosmic ray intensity as one moves outward in the solar system away from the Sun. Currently a "shielding" effect by the sun is assumed, but its magnitude is unknown. Pioneer based observations could for the first time permit an estimate of galactic cosmic ray intensities in interstellar space, well removed from the sun.

In addition to their scientific interest, the interplanetary missions will be of practical value. Measurements of the micrometeoroid hazard in the asteroid belt are needed for design of spacecraft for Jupiter and other deep space missions.

For the outermost interplanetary measurements, there is the possibility that spacecraft, by passing close to Jupiter could use that planet's gravity to stretch the missions beyond Jupiter (at five AU) with reaonsable trip times. For instance, distances of 10 AU could be reached in approximately 3 years. In addition, deflection by Jupiter's gravity could be used to direct a space probe out of the plane of the solar system to make measurements impossible for us now. Such a trajectory cannot be accomplished directly without the use of large launch vehicles for minuscule payloads.

Use of Space as a Laboratory

A number of missions have been identified to use space as a superior or unique physics laboratory. These include:

A *relativity mission* to test the predictions of Einstein's general theory of relativity which concerns gravitation. This general Theory of Relativity predicts a difference in rate between a clock on Earth and a similar clock in orbit at a lower gravitational potential. To test this, a hydrogen maser clock is being developed, which it is proposed to fly in a synchronous orbit. A time shift of 46 microseconds a day is predicted. No definitive tests of the General (as opposed to Special) Relativity Theory have yet been made. The validity of this theory is of great cosmological significance. A side benefit arises from the development of better standards of time.

- The study of *spacecraft environment* which has not been adequately investigated. The interactions with the medium produce a wake–it is hoped to map this with a maneuverable subsatellite. The dynamics of the debris which accompany a spacecraft need to be investigated, since they contaminate the environment of the spacecraft and its instruments. The behavior of these contaminants is similar to the coma and tail of a comet. In addition, the wall-free environment can be used to perform radio experiments by exciting the plasma with a radio transmitter.

- Investigation of the *behavior* of *liquids, solids* and *gases* under effectively gravity free conditions. Surface forces may be studied in an effectively gravity-free environment in an orbiting spacecraft, and a number of questions resolved on flame propagation, drop and bubble dynamics, etc.

- Orbiting of a *high energy physics laboratory,* where the flux, energy spectrum and charge composition of primary cosmic rays with energies in the range 100-10,000 BeV can be measured. In addition to the cosmological importance of these observations, they will define the nature of the particles that are available for ultra-high energy elementary particle studies. The design of later particle interaction experiments to be performed on space stations after the middle of the decade will be based on the results from these experiments.

- Investigation of different *large-scale plasma regions.* Preliminary analysis of data from Mariners IV and V indicate that the plasma environments of Mars and Venus are quite different from those of Earth. Comparative studies of the solar wind/atmosphere interactions are likely to shed light not only on the general class of plasma physics questions which will improve our understanding of the fourth state of matter, but also on the questions which concern the nature and evolution of the planetary environments themselves. It is a near-term objective to continue these comparative studies, and to determine the relationships between the interactions to the difference in atmosphere and the difference in magnetic field conditions.

Spacecraft Concepts for Space Physics Research

The evolution of the geophysical satellite has progressed through several generations; from small satellites for exploratory missions to large observatory class satellites for interdisciplinary investigations which carried many experiments for detailed simultaneous measurements of previously known phenomena. Because we are dealing with very complex environments where the dynamic factors are of extreme importance, we must go even further in the correlation of phenomena throughout space and time. It is proposed to extend the period of use of the Atmosphere Explorer to initiate the geophysical missions being planned for implementation during the next decade. The smaller Scout Explorer Spacecraft will continue to be used where a small number of experiments suffice. ISIS, for example, will continue to study the ionosphere over an entire solar cycle.

The clustered Satellite Series will provide for placing several satellites, carefully spaced, in the same Earth orbit, using typically two to four spacecraft per mission. These spacecraft will remain close together to study the fine structure of the magnetosphere boundary and shock front. In this way, a three-dimensional time-varying picture of the environment will be obtained.

In interplanetary space, a family of modest spacecraft–the Sunblazers and the Pioneers–will investigate the solar "weather" between the sun and Earth and beyond, out through the asteroid belt.

In summary, the Space Physics research spacecraft can be categorized as follows.

The *Interplanetary Monitoring Platform* will study cislunar space over the solar cycle, from a variety of high apogee orbits, reaching beyond the Earth's magnetic field.

The *ISIS Program* will pursue the physics of the ionosphere through observations of free electrons and ions as a function of time and position. Measurements of sufficient rapidity and over a sufficiently long time interval will permit determination of various cyclic and short-term variations.

The *Atmosphere Explorer (Low Perigee)* will study the atmosphere where the density of the atmosphere is still appreciable and where long orbital lifetimes will be possible only by use of on-board propulsion systems to compensate for aerodynamic drag losses.

The *Small Scientific Satellite (SSS)* is a relatively inexpensive, Scout-launched Explorer suitable for a variety of Space Physics Earth orbital missions. The limited payload capability (4-6 experiments) is enhanced by a ground reprogrammable telemetry system which permits several options for scientific data acquisition.

The *Clustered Satellite Series* will provide for simultaneous measurements of physical parameters in great detail within and at the boundaries of the magnetosphere.

The *Sunblazer, the Pioneers, and other Interplanetary Probes* out of the ecliptic plane and beyond the orbit of Jupiter will initiate the systematic study of space weather and other phenomena in interplanetary space.

Piggyback and Cooperative Opportunities

These opportunities involve the use of space on missions primarily devoted to other purposes. Inevitably compromises in mission parameters must be accepted, so that these are only suitable for a limited class of objectives. The critical altitude range of 150-600 km is excluded. As examples:

- The Apollo and its follow-on manned Earth orbital missions appear suitable for certain observations of air-glow, gegenschein, chemical releases, cosmic dust and cosmic rays. A maneuverable subsatellite would enable wake interaction studies to be made. Early manned Earth orbital missions could support a number of "space laboratory" objectives including observations of spacecraft environment and the behavior of liquids, solids and gases near gravity free conditions. Manned Earth orbital missions in the mid-1970's would have a high energy physics laboratory as a major element.
- Nimbus, with 3-axis stabilization, could support auroral and air glow work.
- OSO appears inherently capable of measuring the input of solar energy needed for studies of the aeronomy of the thermosphere and the photochemistry and dynamics of the ionosphere.
- Pioneer, Mariner and Small Planetary Orbiter missions are expected to contribute heavily towards interplanetary investigations. to plasma studies and to the study of the boundary between the solar wind and the Earth's environment.

strategy for astronomy

In order to obtain answers to the scientific questions of the astronomy program, a wide variety of specialized spacecraft and instruments are required to cover the complete electromagnetic spectrum for the sun, planets, stars, galaxies, nebulae, and interstellar and intergalactic space. These range from small to large spacecraft with increasing sophistication for handling data, and from systems that are stabilized by spinning or gravity gradients to those with active 3-axis stabilization with pointing capabilities measured in fractions of an arc second. The presently approved missions and the missions planned for the future will provide the means to continue the survey and moderate resolution studies of bright celestial objects and to advance to the high resolution observations of faint and very distant celestial objects using a wide variety of detectors.

In general, all astronomy experiments flown on Earth satellites have been initiated after closely associated instruments have been thoroughly tested in the rocket, balloon, or aircraft programs. A particular investigation may proceed to greater resolution and finer pointing with larger instrumentation via a sequence including Explorers, Observatories, Apollo Telescope Mount (ATM), Astra, and finally, the National Astronomical Space Observatory. This series, tending toward ever greater distances and astronomical resolution in the investigations, reflects the strategy in the Astronomy program. Accordingly, the elements in this series and their research functions are described below.

SOUNDING ROCKETS

Sounding rockets, utilizing one to four stages, lift scientific instruments through the earth's atmosphere into space above. Their value results from their relative simplicity and low cost. They can perform scientific observations of several minutes duration. For example, studies of the stars in the ultraviolet have been made by telescopes with primary optics up to 13-inches in diameter. Initially, data from only very bright stars were obtained because the instrumentation was spinning. More recently, it has been possible to obtain data from fainter stars due to the development of a rocket guidance system that permits pointing at a number of individual stars during the rocket flight.

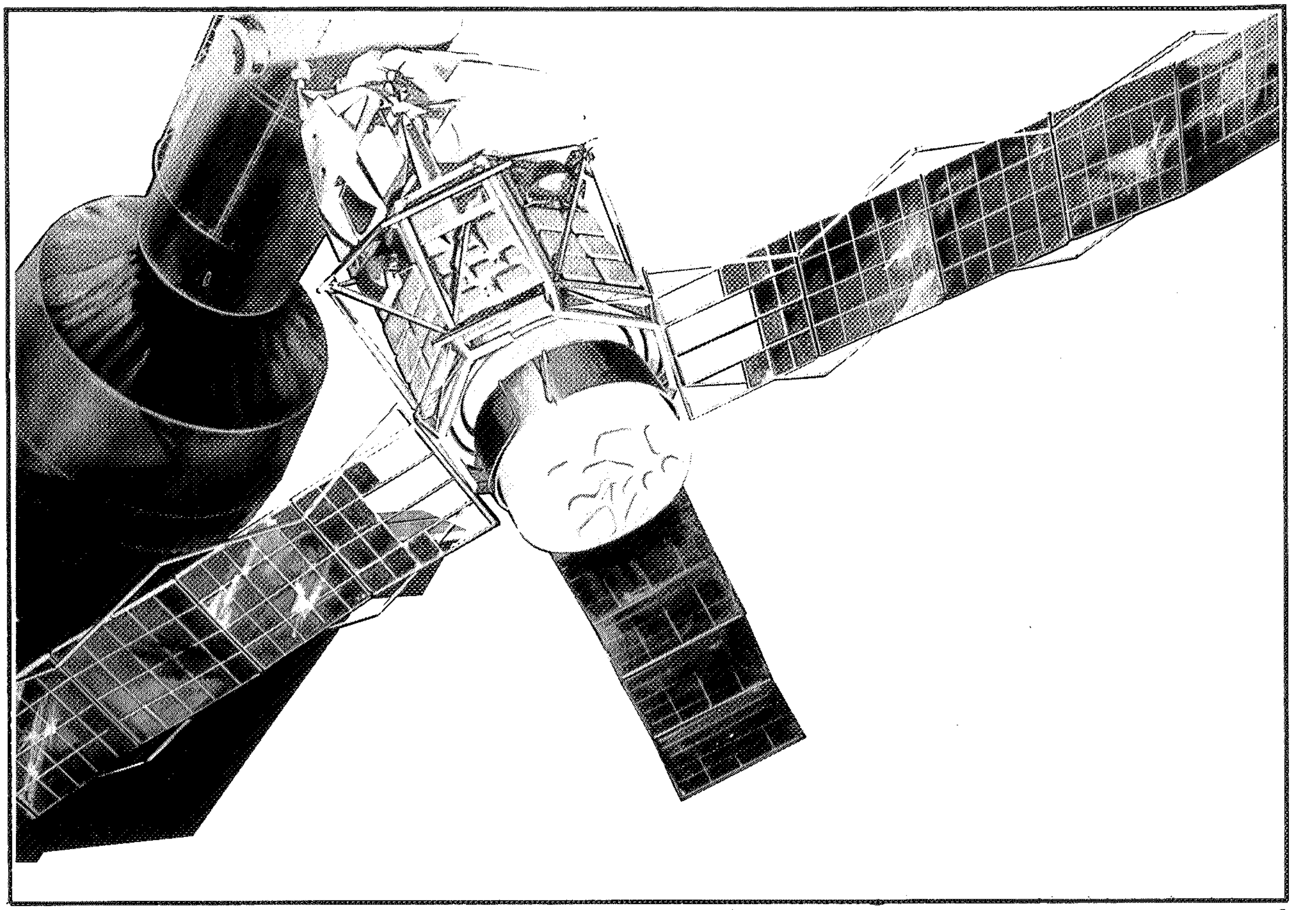
In the exciting new field of X-ray astronomy, celestial sources of X-rays were first discovered via sounding rockets and over 40 X-ray sources have been observed. The accurate positions of some of these have been determined and the spectra of several obtained. It is important to exploit the full capability of sounding rockets by firing larger and more sensitive experiments and pointing systems of improved capability.

In addition to the specific scientific results obtained, the sounding rockets provide a very valuable base for testing prototype instrumentation for ultimate application in long duration experiments on the larger orbiting spacecraft.

ASTRONOMY EXPLORERS

Explorer satellite projects in the astronomy program are directed toward observations in either the gamma-ray, X-ray or long-wave radio regions of the spectrum. These Earth orbiting spacecraft are small observation platforms which perform the initial study of celestial sources and phenomena. Generally, the Explorers are used to gather the first systematic scientific data in a particular spectral region, or to perform initial observations in new spectral regions which are virtually unexplored.

The current Astronomy Explorer Program includes two Radio Astronomy Explorers (RAE-A launched in July of



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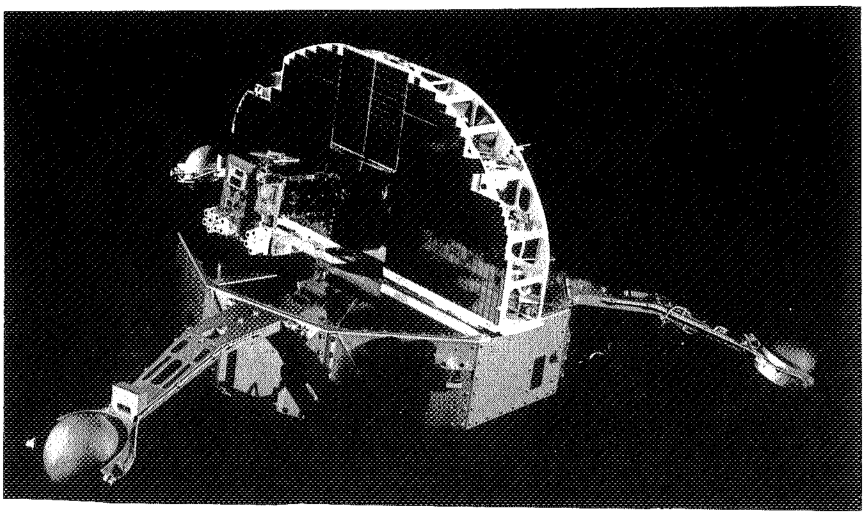

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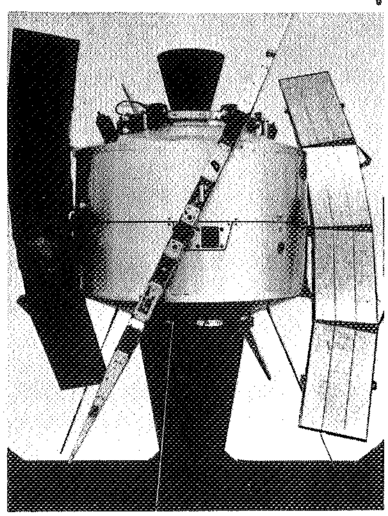
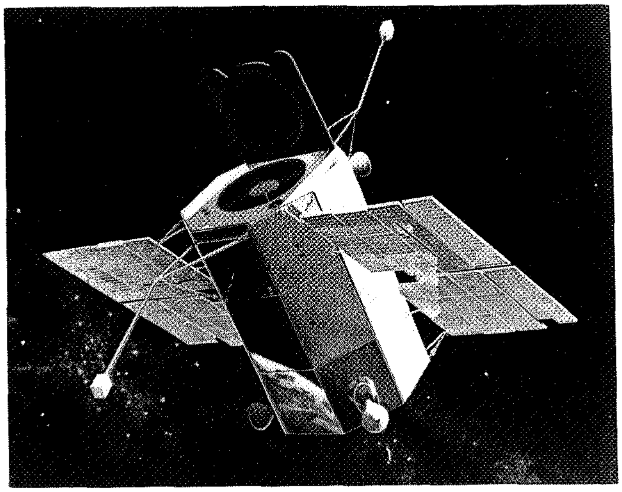


3

1. APOLLO TELESCOPE MOUNT
2. ORBITING SOLAR OBSERVATORY
3. RADIO ASTRONOMY EXPLORER



ORBITAL ASTRONOMICAL OBSERVATORY

1968 and RAE-B, scheduled for 1969) and one stellar X-ray Explorer (SAS-A in 1970). In order to achieve the objectives of the Astronomy Program, additional Explorers will be required for broad surveys and special studies of stellar X-ray, gamma-ray and ultraviolet sources, and solar phenomena. One example is SAS-B which would survey gamma-ray sources.

ASTRONOMY OBSERVATORIES

Orbiting observatories, such as the Orbiting Solar Observatory (OSO) and the Orbiting Astronomical Observatory (OAO) permit major steps forward in the astronomy program. The OSO Program obtained a large quantity of very valuable and unique solar data from the spacecraft launched to date, particularly OSO III and OSO IV. The OSO Program is planned to continue solar observations over at least one solar cycle (11 years), in order to measure the full extent of the solar activity. The increases in spacecraft capability such as guidance accuracy, telemetry, and command capability and experiment power, weight and volume will allow the flight of considerably improved and important experiments. The OAO can carry a telescope system over 36-inches in diameter and up to 10-feet long, and can provide precise pointing and transmission of video data. The OAO approved experiments cover the range from broad based survey photometers to narrow-band high-resolution spectrometers. Also included in the planning as a future possibility is a *Guest Observer* mission which will provide an opportunity to determine the problems and solutions of time sharing a space telescope. These are automated astronomy missions and, of necessity, they require photoelectric recording of data onboard the spacecraft and telemetering the data to ground stations.

ATM and Astra missions will provide the capability to fly OAO size instruments designed to make use of man in orbit. First and foremost perhaps, man and his recovery will make possible the use of film for data (image) storage and transmission. Further, man can select desirable targets for study, monitor equipment, align instruments, change sensors, and replace failed parts, enhancing reliability and mission life. ATM, as now conceived, is a short duration mission which can test the feasibility of manned astronomical observations. Astra will be designed to operate as an automated spacecraft; however, it can be man-assisted to increase the range of astronomical measurements that can be made with the single set of primary optics by changing the auxiliary instrumentation. The use of film will permit high-resolution photographs in all optical wavelengths ranging from ultraviolet to infrared. Both ATM and Astra will provide the experience required for the design, development, and use of the National Astronomical Space Observatories.

NATIONAL ASTRONOMICAL SPACE OBSERVATORY (NASO)

An orbiting astronomical facility in space will consist of large aperture, precision instrumentation to conduct a wide variety of astronomical observations in wavelengths ranging from hard gamma-rays to long wave radio waves. Because the instrumentation will be designed with nearly optimum theoretical performance, it will be possible to obtain heretofore unachievable resolution in images of celestial objects, ranging from the sun and planets to very distant radio galaxies. These observations are of importance to our studies of the evolution and present conditions of the universe and the solar system. They will contribute significantly to our understanding of such unusual and complex objects as the solar corona, radio galaxies, quasars, and X-ray sources. As celestial objects and detail far beyond current ground based capabilities will be observed, these observations will become a means of answering man's fundamental questions about the structure, origin, and evolution of the universe. The use of man in the adjustment and maintenance of the instruments and changing of auxiliary instrumentation should permit these very large "telescopes" to be used for several decades on a very wide variety of problems by many astronomers both in this country and abroad.

TECHNOLOGY DEVELOPMENT

Technological developments needed to support the planned astronomy programs cover a wide range of problems, some of which will require new approaches. These include guidance and control, structural stability, instrumentation design, and detector technology. A Manned Orbiting Telescope, which would weigh many tons, would have to be pointed anywhere in the sky with an accuracy of one arc second or less, and hold the pointing within a total angle of less than 0.01 arc seconds. Moreover, it must be possible to change the pointing from one source to another with reasonable speed and frequency. To meet thermal conditions, the supporting structure must hold components many tens of feet apart in position relative to one another within one thousandth of an inch or better. For the large radio arrays, the components must be aligned relative to each other to a few feet over distance of several miles.

The requirements of the National Astronomical Space Observatory will place more severe demands on optical materials and surface accuracies than ground-based applications, and the problems of the space environment will dictate new design to facilitate space use of the instruments on such a wide range of scientific problems in various wavelengths. Finally, detectors must be improved to give long service in the space environment with good angular and energy resolution. For example, films now useful for astronomy deteriorate when exposed to the cosmic rays in high Earth orbit or on the moon, and ultraviolet-sensitive films are difficult to handle because they are pressure sensitive and they scratch and distort easily. Yet, film is an unrivaled data storage medium at the present time, and no purely electronic imaging detector currently available compares in sensitivity and resolution. Infrared detectors must be cooled for maximum sensitivity, requiring the development of long-life cryogenic systems. Finally, plans for using man will require a careful consideration of the man-instrument interface with new design and operational approaches.

strategy for lunar exploration

EXPLORATION PHASES

The lunar exploration program is based on the thesis that the Moon is a planetary body, in many ways similar to the Earth. This thesis, which is supported by the studies and spacecraft data results obtained thus far, allows us to proceed along a path of experience established in exploring the Earth. The major advantage in this approach is that most terrestial techniques and experimental equipment, as well as the scientific rationale for developing hypotheses or avenues of investigation, can be utilized in directing our efforts. Thus, rather than being an exotic object, the Moon becomes a familiar subject to deal with, and one that can be explored with confidence. Surprises, however, cannot be ruled out and of major interest will be the degree to which the Moon differs from the Earth.

Terrestrial experience suggests a three-phase approach to lunar exploration: first, preliminary observation and discovery; next, exploration; and finally, comprehensive investigation.

The first phase of preliminary observation and discovery is nearly completed. The automated spacecraft programs, particularly Surveyor and Orbiter, have greatly increased our fundamental knowledge of the Moon so that we are now ready to proceed with confidence into the next phase—one in which man will play the leading role. At present, tools and experiments which have been designated for the first manned exploration missions are being prepared, as are maps of the landing sites. All available information has been utilized to propose theories to be tested on the lunar surface by experiment and observation. The first phase forms the framework in which the analysis of the results from succeeding phases will be integrated.

The second phase of the lunar program, exploration, should include both orbital and surface missions to significantly broaden our understanding of the Moon. The emphasis during this phase will be on the conduct of geoscientific experimentation supported by contributions from other scientific disciplines. Major experiments will hinge upon skilled conduct of field investigations, the return of lunar material from known geological settings, and the emplacement of long-lived networks of geophysical instruments to monitor lunar processes.

Observations by astronauts qualified as field geologists will be most important in defining the nature of lunar surface features and processes. From analysis of the returned samples, unique geochemical, cosmological and biological data are expected as well as preliminary age datings of significant lunar events. The geophysical networks, coupled with orbital surveys, should permit us to interpret the internal structure of the Moon, just as we have developed an understanding of the Earth's interior. Early exploration phase missions will emphasize sites which encompass key lunar features, and the return of information with lunar-wide importance.

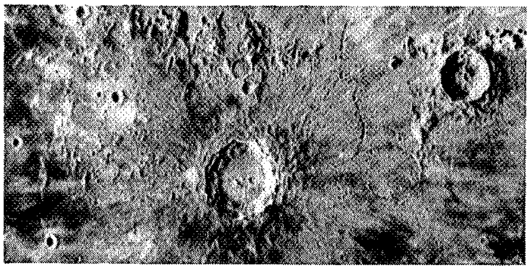
The final phase of lunar exploration, comprehensive investigation, would depend upon the results of the early exploration phase. Detailed structural and stratigraphic studies may include drilling, specialized field observations and geophysical surveys. Searches for resources and environmental studies may also be conducted to determine experiments which the Moon can best support, if utilized as a large space station.

To achieve the objectives of the lunar program, the strategy during the exploration phase would include the steps below:

- By orbital survey, locate the key positions on the lunar surface where contacts and structural relations between different surface features are best exposed and where other objects of special interest occur

1. COPERNICUS
2. LUNAR FLYING UNIT
3. LUNAR ROVING VEHICLE
4. EARLY EXPLORATION PHASE MISSIONS

1



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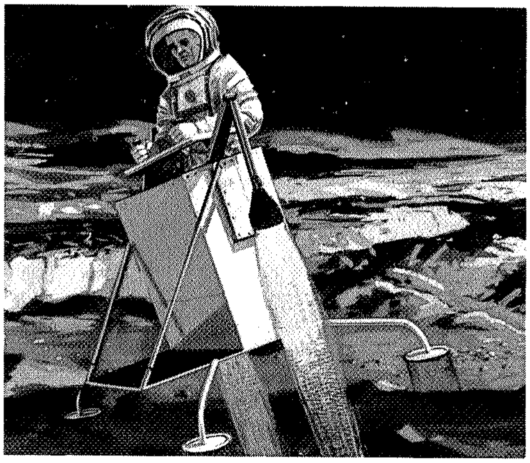

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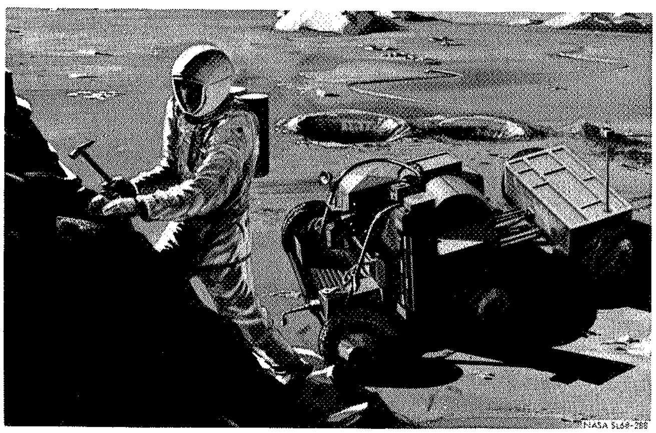


4

1964-1968

RANGER–LUNAR ORBITER–SURVEYOR

- SMALL SCALE FEATURES
- APOLLO SITE MAPPING
- SCIENCE SITE COVERAGE
- SOFT LANDING FEASIBILITY
- DETAILED SURFACE TEXTURE
- SOIL STRENGTH
- CHEMICAL COMPOSITION

1969-1970

APOLLO

- INITIAL MANNED LANDINGS
- FIELD GEOLOGY AND PHOTOGRAPHY
- SAMPLE RETURN FOR EARTH ANALYSIS
- GEOPHYSICAL MEASUREMENTS
  –INTERIOR STRUCTURE
  –NEAR SURFACE LAYERING
  –RADIATION ENVIRONMENT
  –HEAT FLOW

1971 AND BEYOND

POST APOLLO

- EXTENDED DURATION MOBILE EXPLORATION
- TOPOGRAPHIC, GEOLOGIC, GEOPHYSICAL SURVEYS
- DETAILED SUBSURFACE INVESTIGATIONS
  –SEISMIC
  –THERMAL
  –ELECTRICAL
- SOIL MECHANICS
- SAMPLE COLLECTION AND IN-SITU ANALYSIS
- SAMPLE RETURN FOR DETAILED ANALYSIS
- REMOTE SENSING OF SURFACE FROM ORBIT
- ASTRONOMY OBSERVATION
- EROSIONAL PROCESSES
- ATMOSPHERIC ANALYSIS.

- Conduct local studies of the major features on the lunar surface at the sites identified from orbit
- Collect representative samples of lunar material as part of the geologic mapping program for detailed analysis after return to Earth
- Emplace widely spread instrument nets for long-term monitoring of the lunar interior and environment
- Undertake long range traverses across the surface of the Moon to tie together local studies and regional investigations
- Conduct compositional and structural mapping from lunar orbit to support the surface investigations
- Continually analyze and integrate results of these studies in order to optimize the preparation and execution of future exploration.

Further guidelines for shaping the lunar exploration strategy include these broad precepts: 1. Scientific questions of major importance for which clear and broadly-revealing answers can be obtained should have priority in assignment of missions and allocation of experimental payload; 2. Initial missions would stress the use of existing manned and automated lunar flight capability introducing only limited hardware modifications and new developments; 3. An evolutionary approach to exploration should be followed, undertaking progressively more difficult mission objectives; 4. An optimum balance of orbital and surface measurements must be the goal of the overall program.

It may be seen that the strategy involves several closely knit modes of exploration–Orbital Reconnaissance, Surface Reconnaissance, Surface Science Stations, and Sample Return.

ROLE OF PRESENT PROGRAM

Results of the past programs such as Lunar Orbiter and Surveyor have shaped the investigations planned for the first manned landings on the Moon. The early Apollo landings will 1) collect lunar material for return to Earth, 2) emplace geophysical instrumentation for long-term observations and 3) conduct field geology investigations. One or more landings sites in the maria are expected to be visited.

Results of the *field geology* experiment will include the determination of lithologic composition, structure and thickness of surficial layer, and the composition and origin of material underlying the lunar plains.

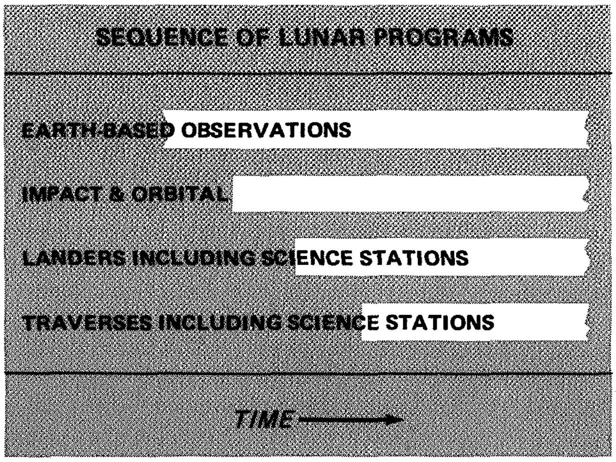
The returned *lunar samples* will yield petrographic, mineralogic, chemical, elemental and isotopic data, indicating textural and lithologic information on rock forming, rock erosion and transportation processes, absolute age dating, and the extent of widescale chemical differentiation. The presence of organic or proto-organic material in the samples will also be determined, and initial studies may be made on the extent of spacecraft contamination of landing sites.

Automated instrumentation called the Apollo Lunar Surface Experiments Package (ALSEP) will be left behind on the Lunar surface after the astronauts have returned to Earth. It will perform a variety of geophysical, geodetic, and particles and fields measurements. Quakes, tides, free oscillations and steady state net heat flux of the Moon's interior will be recorded, together with the seismic properties of the near surface to a depth of about 500 feet. The range from Earth and corresponding position coordinates of the ALSEP location will be determined to ± 30 feet, resulting in greatly improved knowledge of the Lunar orbit and librations. The magnitude and temporal variations of any equatorial surface field will be observed, together with the interaction of the solar wind with the Moon. In addition, the electromagnetic diffusivity, constituents of the Lunar atmosphere and charged particles in the magnetosphere will be measured.

Early Apollo *investigations* will be limited to very short staytimes and to the immediate landing area. These restrictions neither detract from their scientific importance nor disrupt the overall exploration strategy: the return of samples from any locale will provide a great advance in our knowledge. Several landings on maria are required in order to understand one of the largest topographic units on the Moon. Our strategy will be to land these missions on different maria for initial sampling, as well as to provide a significant spread in the location of our geophysical instruments. As our capability with the Apollo equipment increases, it may be possible on the second or third mission to land at a selected point in the mare which will afford the astronauts the best chance of studying mare composition. Two mare landings appear sufficient early in the program. If other considerations require us to return to the mare on the third mission, important new objectives can be defined, especially if landing to a precise point is possible. The strategy after these missions emphasizes landing on non-mare material, and candidate highlands areas have been selected which, in conjunction with the mare studies, will provide for detailed comparision of the two primary morphological and probably chemically different provinces of the Moon.

FUTURE REQUIREMENTS

The accumulation of information from the automated spacecraft as well as knowledge gained from ground-based observations has been an important part of planning for the early Apollo landings and the scientific exploration during the missions. The Apollo Lunar Exploration Program would extend and expand upon those science experiments.



The primary areas for scientific investigation during the phase of lunar exploration immediately after early Apollo include both reconnaissance surveys, addressed to the major geological and physiographical provinces on the Moon, and local studies, concentrating on a wide variety of specific sites and features. The purpose of the reconnaissance surveys is to obtain information which can be extrapolated to as wide an area of the Moon as possible. The local studies center on features and areas critical to an understanding of lunar processes and to determining the relative ages and structural relations (stratigraphy) of lunar surface units.

The prime requirements recognized by the planning groups are mobility and staytime for extended Lunar exploration. In addition, the report of the President's Science Advisory Committee emphasizes the requirement to explore remote areas of the Moon. The report stresses a continuing program of manned landings at the rate of one or two per year, plus development of complementary automated lunar explorations systems:

"One must proceed soon to develop both the means for extended visits to the Moon and the mobility to reach terrain unsuitable as a landing site with sufficient supporting equipment to carry out the various explorations and scientific tasks which may then seem appropriate."

"Since we expect that it may prove valuable to send manned expeditions to parts of the moon not accessible to the present Apollo system (e.g., the polar regions). planning should be initiated to enable the achievement of this capability in the 1975–1980 period."

A conference of leading scientists was held at Santa Cruz, California in 1967 to study strategy and missions for the post-Apollo period. Their recommendation was that a Lunar Flying Unit be developed immediately for later Apollo flights. The astronaut's increased mobility range would allow exploration of Lunar surface features such as large craters and their environs as far as 7 miles away from the landing site. A further recommendation stressed early development of a surface rendezvous capability, and the development of a dual-mode Lunar roving vehicle. This vehicle would provide increased surface mobility and would be capable of operation in either a manned or automated mode.

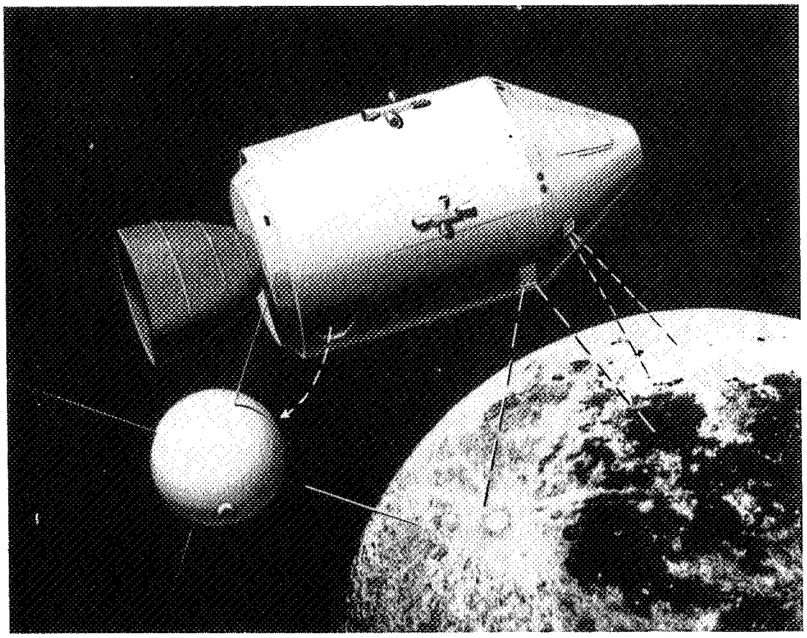
Manned missions for lunar exploration after the first Apollo landing can be placed in three categories: (1) single-launch Saturn V lunar landings, (2) dual-launch Saturn V lunar landings, and (3) manned lunar orbital flights.

The single-launch landings would provide limited duration missions, possibly using the Lunar Flying Unit, to visit a number of sites such as in the Crater Copernicus. One of the most intensively studied features on the Moon, Copernicus shows mare and highlands stratigraphic units which crop out in the 15,000 feet high crater walls. Ledges exposed in the central peak may include rock layers brought up from a depth of about six miles below the lunar surface. The fields of small cones and flow lines on the crater floor have been interpreted as volcanic in origin.

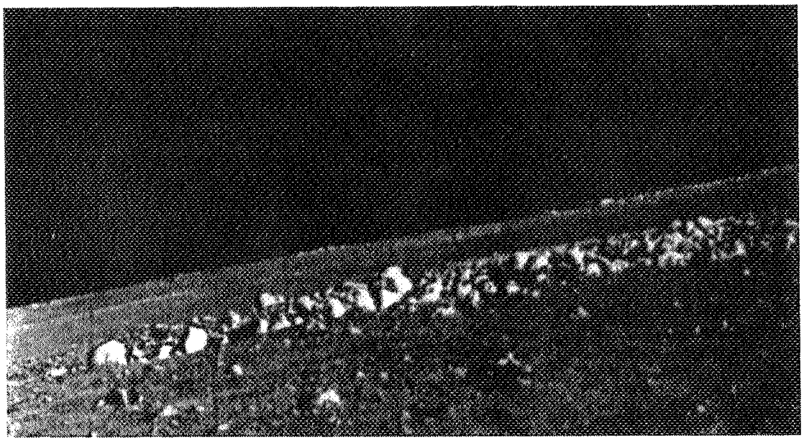
The dual-launch Saturn V landings will provide extended exploration time and long-range mobility. The dual-mode roving vehicle, scientific instruments, and fuel for the Lunar Flying Units would be carried to the Lunar surface in an automated Lunar Payload Module. Later, the Manned Saturn V would land nearby.

From Lunar orbit, important engineering and scientific objectives would be attained, such as additional photography to support later landings in rough sites of high scientific interest and ultimately to support extended traverses, when sufficient mobility has been acquired. Remote sensing instruments in Lunar orbit are needed for broad regional coverage and environmental measurements. Manned missions solely for these purposes may be necessary but it is hoped, instead, that the needs can be fulfilled from the Command and Service Module, which remains in orbit during a landing mission and can carry instrumentation or deploy subsatellites.

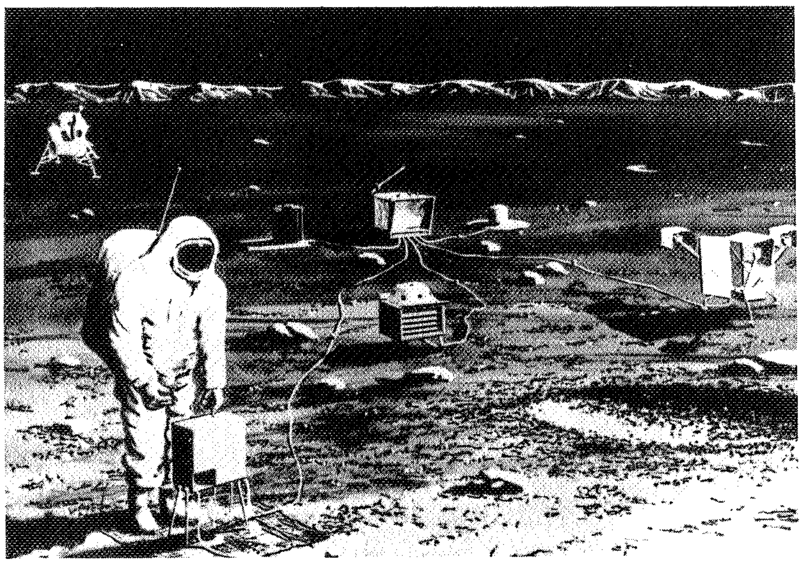
Except for the ALSEP currently under development for the initial manned landings, the science packages being considered for Apollo Lunar exploration are being defined at this time. Experiments can be conducted on the Lunar surface, during traverses by the astronaut, by deployment of science stations and with the aid of a



1. **EXPERIMENTS IN LUNAR ORBIT**
   - COMMAND MODULE
     - VERTICAL AND OBLIQUE PHOTOS
     - FEASIBILITY OF REMOTE SENSORS
   - SERVICE MODULE–INSTRUMENT SECTOR
     - METRIC MAPPING
     - PRECISION ALTIMETRY
     - MICROWAVE RADIOMETRY
     - X-RAY, INFRARED AND ULTRAVIOLET SPECTROSCOPY
   - SUBSATELLITE
     - MAGNETOMETRY
     - RADIATION ENVIRONMENT
     - GAMMA-RAY SPECTROSCOPY
     - GEODETIC TRACKING
     - (RELAY COMMUNICATIONS)



2. **SURVEYOR I PHOTOGRAPH ROCK FIELDS ON THE MOON**



3. **ALSEP DEPLOYED**

laboratory in the Lunar Payload Module. Some of the packages under consideration are listed below:

The *Advanced Apollo Lunar Surface Experiments Package* is a growth version of ALSEP designed to carry additional experiments involving, for example, biology and astronomy, and having greater interchangeability of instruments. The objectives of the Advanced ALSEP's would be to measure and monitor the internal energy regime of the Moon, the interaction of solar and cosmic environment with the Lunar surface, and the response of the Lunar mass to gravitational forces exerted by the Earth and other solar system bodies, and to search for evidence of organic or proto-organic materials.

The objectives of the *Lunar Surface Traverse* are the direct observation, interpretation, and mapping, by an observational scientist, of field relations, direct measurement of near-surface structural relations and properties, the extensive selection and collection of representative samples for return and analysis on Earth, in-situ diagnostic testing as necessary for selection of significant samples and conducting magnetic, gravity, and active seismic surveys. After the astronauts have returned, further traverses could be made by the automated rover and additional information collected.

With extended mobility, the astronaut could make a comprehensive sample collection along the traverse by sampling major rock units for age dating, petrographic classification, chemical composition, evidence of organic materials, and variations in regional geologic units. Instrument examples include a 10- to 30-foot drill, sample collection tools, sample containers, and simple diagnostic instruments such as an x-ray spectrometer. The astronaut would emplace geophones and explosive charges for the measurements to determine shallow structure and thickness in the near-surface layers.

Continuous measurement could be made, along the traverse, of gravity and magnetic fields for correlation with geologic and seismic data and for interpretation of deep structural expression of surface features.

Using the instruments of the *Lunar Payload Module Laboratory* carried in the first (automated) LM of a dual-launch mission, the astronauts could perform preliminary diagnostic tests on Lunar samples to guide subsequent traverses during the same mission, and to select the more significant samples for return and detailed analysis on Earth.

The objective of the *Remote Geophysical Monitor* is to establish a widely-spaced net of seismometers and other network instruments over the face of the Moon in conjunction with Advanced ALSEP deployment by manned landings. It has been recognized that the acquisition of more complete Lunar geophysical data would require simultaneous measurements at a number of sites using long-lived automated instrument stations. The Remote Geophysical Monitors would provide a network of many widely-spaced units with a minimum lifetime of two years operating simultaneously to allow detailed study of geologic, geophysical, and geodetic information. Data from seismometers deployed over the Lunar surface would be fundamental means of understanding the interior structure and the evolution of the Moon.

Each Remote Geophysical Monitor would be a fully-automated, compact, and rugged package including scientific instruments, power supply, transmitter and receiver, command decoder, and data subsystem. Monitors would be deployed from the roving vehicle, from the Lunar Flying Unit, and directly from Earth by means of a Surveyor-like spacecraft.

The President's Science Advisory Committee has endorsed the concept behind the Remote Geophysical Monitors in the following words:

> "One important component of this program during the early 1970's will be unmanned spacecraft capable of landing significant scientific payloads anywhere on the Moon, particularly the Lunar poles."

The *Command and Service Module Science* and *Substallite* are related. The objectives are to survey the surface of the Moon from Lunar orbit by vertical and oblique photograpy; to obtain radiometric and infrared measurements of the Lunar surface; and to measure the near-lunar environment, e.g., magnetic fields, nuclear particles, and density.

Data obtained by photography of the Moon would be the basis for the development of Lunar metric and compositional maps. Radiometric and spectroscopic measurements of the Moon from orbit will provide scientific data bearing on the near-surface gross structural and geochemical characteristics. Data on the near-lunar magnetic fields and radiation environment would be useful in conjunction with that obtained on the Lunar surface in determining the overall effects on Lunar surface materials and processes.

The equipment to make these measurements would be carried in the Command and Service Module and the Subsatellite. Experiments would be conducted by the astronaut left in Lunar orbit while his companions are on the surface, and by the subsatellite after it had been ejected into Lunar orbit.

strategy for planetary exploration

GENERAL STRATEGY

The early Mariners and successful Lunar missions proved our ability to explore nearby planets. But how should we go about this in the most effective manner? Let us look first at the process of exploring the planet Earth, for it is often by simile that science enables the logic of a new fabric to be woven.

Man began the exploration of Earth by taking a close look at his local environment, gradually widening his circles to encompass larger areas. He developed tools to provide greater mobility and to increase the effectiveness of his observations. Equipment that allowed him to take a magnified look at the finer detail of his environment and to obtain a better view of the entire solar system increased his perspective in the scheme of things. Only in recent years was it possible to look down upon his planet and tie all of his superficial observations together. With this capability in hand, he now has the exciting decision as to how to explore a new planet in the most logical way.

When we look at the sequence and methods used in exploring Earth we quickly reach the conclusion that a new planet should be explored in almost exactly the opposite manner. We should begin with a view of the entire planet from the vantage of orbit. We should conduct reconnaissance of its gross features, clouds, mountains, and polar caps. We should begin our exploration of its surface only after gaining knowledge of its characteristics on a large scale.

To reach the surface we must pass through whatever atmosphere the planet may hold. To prepare for this soundings should be made to complement the observations from orbit. A detailed knowledge of a planet's atmosphere not only offers many answers to the nature of the planet itself but will prepare us for engineering a successful landing.

The third phase will involve the landing in sites preselected for their significance as indicated by reconnaissance from orbit. Areas appearing most suitable for life might be preselected; other likely choices will initially include "interface regions," such as land-ocean boundaries, the edge of a polar cap, the bottom of a rill or valley, or a high plateau suitable for distant observations.

Successful landings might soon be followed by automated expeditions on the surface with vehicles having a mobile capability. Such vehicles might be guided remotely from Earth, even though not in real time, affording the transposition of man's eyes and decision-making ability without risk to life. In due course man would follow his equipment to the planet based on his knowledge and confidence that his own presence in the continued exploration and exploitation of the new world would be significant.

Before proceeding with a review of the strategy for each planet, the question as to priority for the different planets must be answered. The priority list of the planets, established by national groups of scientists such as the Space Science Board of the National Academy of Sciences, places Mars on the top of the list because of the chance that Mars may harbor some form of life. Venus is a close second because of its complex atmosphere followed by Jupiter and Mercury. However this priority list is subject to reevaluation as new information is obtained.

MARS

The plan for Mars missions includes for reference the Mariner IV flyby in 1965 and the two flyby missions approved for 1969. Orbiting missions could begin in 1971 by placing an adaptation of the Mariner 69 Mars spacecraft into orbit with retropropulsion directly

STEPS TO THE SCIENTIFIC EXPLORATION OF A PLANET MARS MISSIONS

KNOWLEDGE GAINED

DATA RELATED TO:

POST '73 ORBITER/ LANDER SURFACE SCIENCE
- Surface Composition
- Seismic Activity
- Meteorology

Knowledge gained:
- Origin of Solar System
- Influence of Solar System on Man

TITAN MARS '73 ORBITER/ LANDER ENTRY SURFACE SCIENCE
- Atmosphere Composition Temperature and Pressure
- Surface Characteristics
- Surface Moisture
- Active Biochemistry

Knowledge gained:
- Interrelation of Atmosphere to Surface
- Physical Properties
- Potential Life Environment
- Origin of Life

MARINER '71 ORBITAL SCIENCE
- Topographic & Thermal Mapping
- Seasonal Variations of Atmosphere & Surface
- Atmosphere Dynamics

Knowledge gained:
- Potential of Life
- Planet History
- Solar Wind Interaction

MARINER '69 NEAR FLYBY SCIENCE
- Improved Photometric Characteristics
- Closer Examination of Ionosphere & Atmosphere
- Planet Radius

Knowledge gained:
- Surface Maps
- Atmosphere Composition
- Global Structure

MARINER IV '64 FLYBY SCIENCE
- Interplanetary Information
- Imagery to Define Type of Surface and
- Exact Position of Planet

Knowledge gained:
- Particle & Fields
- Surface Types
- Size, Mass and Position

PRE-'64 ASTRONOMY
- Orbit and Position
- Gross Character

Continuing Observations to Expand and Confirm Information

Knowledge gained:
- Planetary Models

ADVANCES IN SCIENCE DATA RETURN FROM MARS MISSIONS

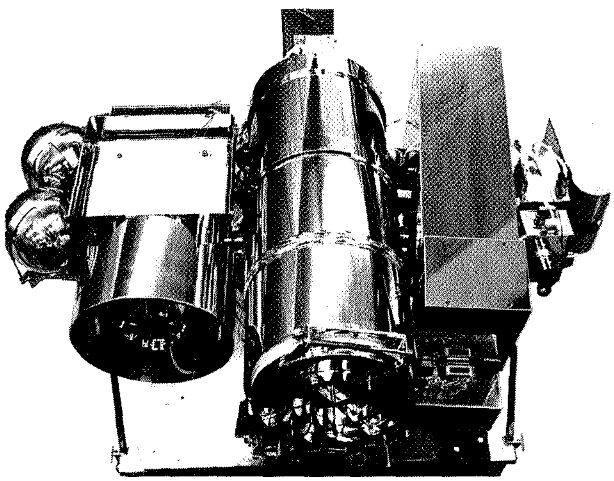
MARINER IV '64
- First Look at Surface (1%)
- Absence of Radiation Belts
- Lack of Trapped Electrons No Magnetic Fields
- Electron Density Profile of Ionosphere
- Atmosphere Characteristics
  - Density
  - Refractivity
  - Scale Height
- Zodiacal Dust Mass and Distribution

MARINER MARS '69
- Increased Imagery of Surface (10%)
- Thermal Mapping
- Atmosphere Composition
  - Minor Constituents
  - Organic Molecules
  - Pressure Variation
  - Density Variation
- Ionosphere Electron Profile
- Radius of Planet

MARINER MARS '71
- Extended Topographical and Thermal Mapping
- Figure of Planet
- Internal Mass
- Atmosphere Regional
  - Seasonal Variation
  - Influence of Solar Winds
  - Vertical Profiles
  - Clouds
  - Dust Storms
- Wave of Seasonal Darkening
- Potential Landing Sites

TITAN MARS '73
- Comprehensive Mapping
  - Topographical
  - Thermal
  - Surface Moisture
- Surface Liquid Water
- Atmosphere Composition
  - Horizontal
  - Surface
  - Trace Constituents
  - Moisture
  - Particles
- Influence High Energy Particles
- Surface Composition
- Surface Imagery
- Soil Analysis
  - Water
  - Organic Compounds
- Life Detection

borrowed from Lunar Orbiter technology. Additional orbital missions could be performed in 1973 to provide coverage of Mars under different seasonal conditions and in different orbits. Photographic coverage will naturally take into account reconnaissance performed by earlier Mariners. By using a Titan class vehicle we could eject from these orbiters landers that will make direct measurements of the atmosphere during entry. After landing they could provide our first photographs on the surface and make preliminary measurements of the environment and the physical and chemical properties of the surface.



MARINER 1969
INSTRUMENTS FOR VIEWING MARS

With the knowledge provided by such missions, we could develop more sophisticated surface laboratories for later missions. These laboratories might very well have a mobile capability to allow simple "Lewis and Clark expeditions" of exciting regions of this new world. These vehicles would allow surveys of the topography and environment of Mars; they could conduct analysis to provide answers to questions on the suitability of the planet for life.

In order to accomplish these large surface laboratory missions, a Saturn V launch vehicle would be required. This launch vehicle could be used to place landed payloads of approximately 5,000 to 10,000 pounds onto the Martian surface in 1975 or 1977. In addition, a growth version of this payload of approximately 10,000 to 20,000 pounds landed weight could be made ready for the 1977 encounter. This would include the capability to return the first samples of Martian soil to the Earth for detailed analysis. This heavier payload would be launched with a Saturn V/NERVA launch vehicle and would serve as a combined developmental test of both the launch vehicle and mission concept. The accumulated experience from these 1975-1977 missions would provide a sound scientific and technological base for a major exploitation of mission possibilities, using the same basic spacecraft and the Saturn V/NERVA launch vehicle at the 1979 and subsequent encounter opportunities.

Naturally, planning for the late seventies and early eighties becomes hazy; we simply cannot factor into today's thinking the surprises and new information sure to be obtained by the next few missions. This strategy, however, would seem to provide a direction for developments most likely to produce effective returns so that the early steps outlined here can be taken with some assurance that they will not become obsolete before they are carried out. On the other hand we must be prepared to modify *any* plan after each mission provides new knowledge.

VENUS

On the assumption that Mars deserves major emphasis after the Moon, Venus falls at this time into the category of continuing exploratory studies on a relatively smaller scale. However, missions should be carried out in the early 1970's to find out more about Venus and to help determine clearly whether this priority is appropriate or whether emphasis should shift to Venus. The two flyby missions in 1962 and 1967 plus the information obtained from the Russian Venera IV have given new data about Venus currently being studied by many scientists.

Orbital missions in 1972, with longer-term observations than can be afforded by a flyby, and with instruments devised to study the atmosphere and topographical features in detail, could provide important clues for successive steps. It seems scientifically important that during the 1973 opportunity Venus should be used to provide for a combination swingby mission to Mercury. On this mission atmospheric probes should be dropped off to provide longer-term and direct measurements in the atmosphere of Venus.

Data from flyby, orbit, and atmospheric probes should give a base in 1973 from which detailed evaluations could be made to determine the course for future Venus exploration. Discoveries from this combination of missions might well serve to modify the plan outlined here for the overall exploration of the planets. But until such missions are undertaken, it is difficult to design an intelligent follow-on effort.

OTHER PLANETS

Although the similarities between Mars, Venus, and Earth make the study of these planets very important to our knowledge of Earth and its place in the solar system, it is also true that glimpses of the other bodies, each of which appears to have characteristics of its own, will serve to improve our perspective. In 1973, for about the same energy required to go to Venus, a spacecraft can be accelerated by Venus' gravity and velocity in orbit so that it can also swing by Mercury and obtain knowledge of this exciting planet that is closest to the Sun. Detailed design studies and trade-offs have clearly shown the feasibility of this mission; the scientific returns from this two-for-one shot appear tremendous. It can readily be accomplished with modified Mariner spacecraft and the Atlas-Centaur or Titan class of launch vehicle.

Based on our experience with Pioneer, which has successfully explored interplanetary space between the orbits of Venus and Mars, it appears relatively straightforward to extend the use of this spacecraft and send Pioneers outward on trajectories passing through the asteroid belts and to the vicinity of Jupiter. In traveling through interplanetary space toward its rendezvous with Jupiter the probe would provide measurements of the solar atmosphere, the asteroid belt, and both solar and galactic cosmic rays. In the vicinity of Jupiter the spacecraft would explore the nature of its environment, the composition of its atmosphere, its electric disturbances, its magnetic field, the characteristics of its trapped radiation belts, and other significant scientific questions. Such studies are not only important for the knowledge of Jupiter itself but may well relate to our knowledge of the Sun if hypotheses are correct that Jupiter misses being a star by being slightly under critical mass.

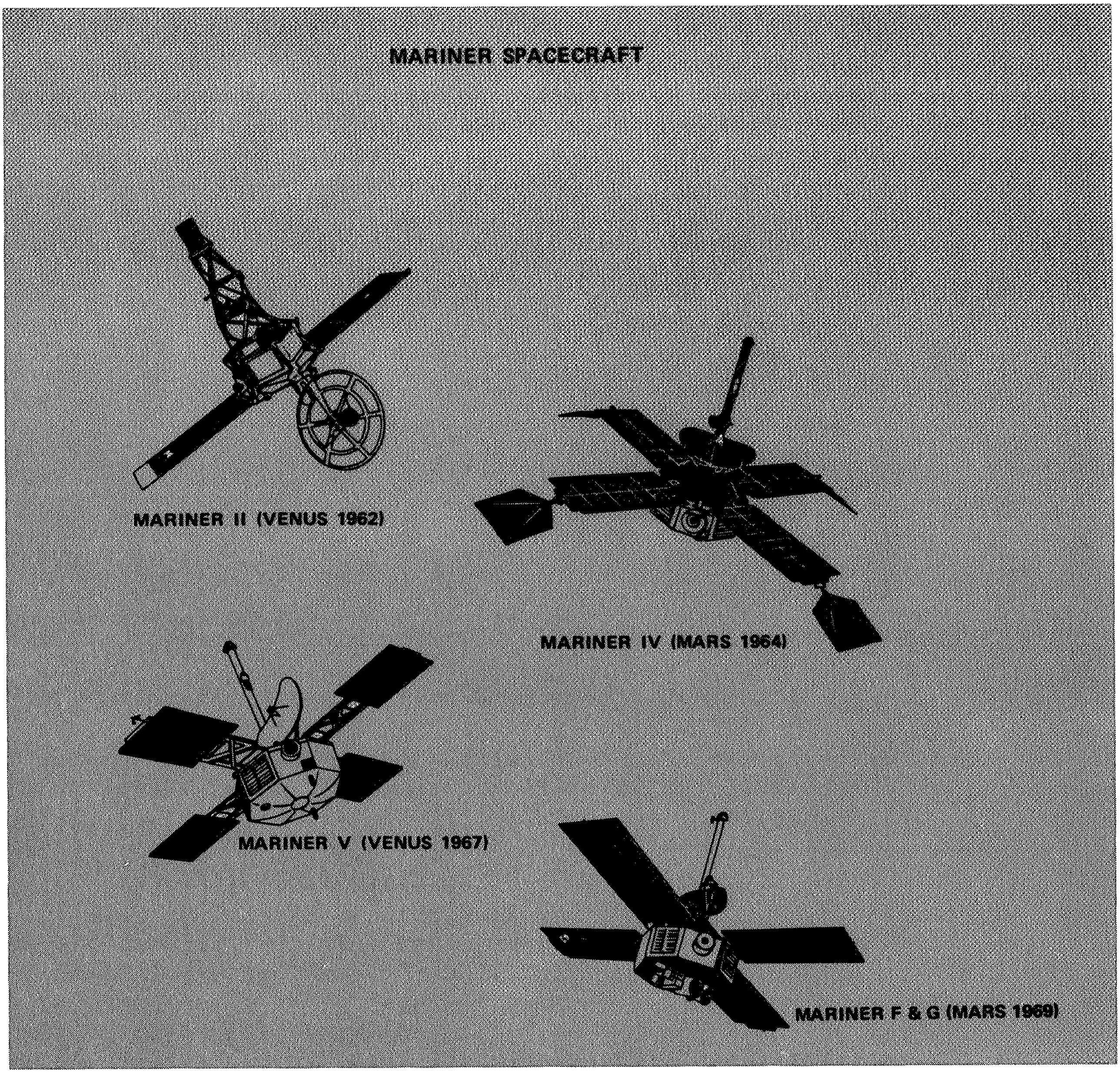
In 1977 and 1978 a rare opportunity is afforded for multiple planet-flyby missions. Jupiter's large mass, (some 318 times that of the Earth) and its orbital velocity about the Sun provide a means for accelerating a spacecraft directed to its vicinity into an orbit that swings close to Saturn, Uranus, and Neptune. This opportunity is afforded only once about every 175 years when these planets align themselves favorably. It seems extremely important scientifically to prepare for this opportunity and make an economical reconnaissance of these other major planets in our solar system. For this reason, at least two missions in 1977 and 1978 should be planned. Such spacecraft will face environments more stringent than any heretofore encountered, but it seems reasonably sure that with the use of radioisotope or other nuclear power sources it should be possible to provide the communication link, the thermal control, and the power necessary to allow a spacecraft to operate in the far reaches of space for the required period of up to eight years.

In the intervening periods between probing missions to other planets it is highly desirable to attempt first-hand observations of the wanderers in our solar system, the comets. These objects traverse from the far reaches of our solar system to the vicinity of the Sun and may carry with them interesting information from outer regions, information that may be more effectively obtained by studying the comets than any other way. The comet Encke offers the next favorable opportunity in 1974, and in 1976 the comet D'arrest approaches within our reach. It is not until 1986 that the famous Halley's comet will return to Earth's vicinity. We surely should prepare for the detailed study of this object; preliminary information from relatively modest missions to two smaller comets before that opportunity occurs would contribute meaningfully to this planning.

The thirty known moons of other planets, especially the two of Mars and the twelve of Jupiter (one of which has an atmosphere), are of high scientific interest and may become worthy of closer exploration in the seventies. Some photographs of Phobos and Deimos, the two small moons of Mars, may be obtained from the Mariner missions in 1969 and the early 1970's. No attempt is made at this time to outline plans for exploring these bodies.

Pluto, while interesting because of its orbit and its mass, is so far from Earth that we are relatively very ignorant of it. Because of this and the difficulty in examining it from a spacecraft, it may likely not become the subject of exploration until a subsequent decade. Advances in the next few years may make this observation unduly conservative, but at present no reasonable priority can be set for its exploration.

The missions being planned for the 70's will enhance our concept of the solar system, and tell us about the possibility of life on other planets. The opportunities to visit these planets are very limited and distances are far, but we have developed a national capability which has already been highly successful in delivering payloads to the planets. The program developed has been designed to capitalize on this capability and to maintain the U.S. position at the frontier of outer space.


MARINER SPACECRAFT
MARINER II (VENUS 1962)
MARINER IV (MARS 1964)
MARINER V (VENUS 1967)
MARINER F & G (MARS 1969)

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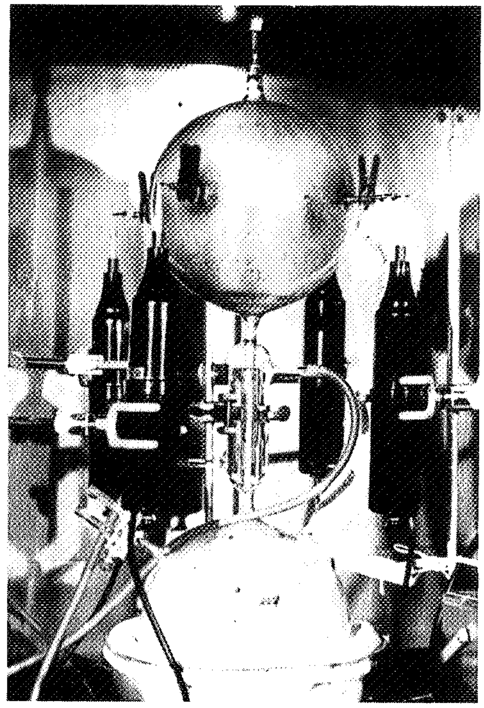

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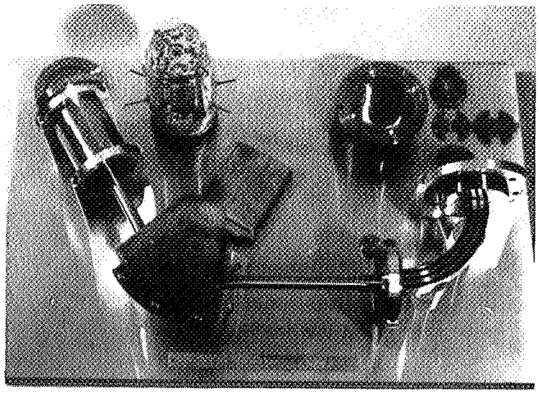

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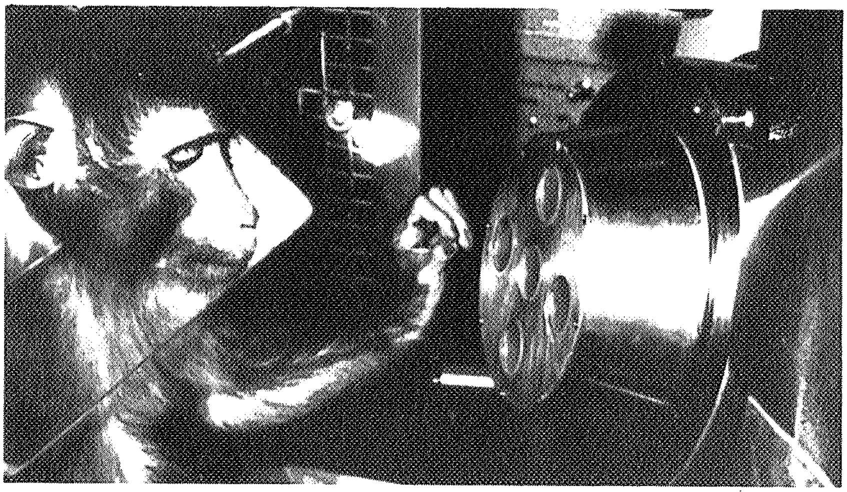

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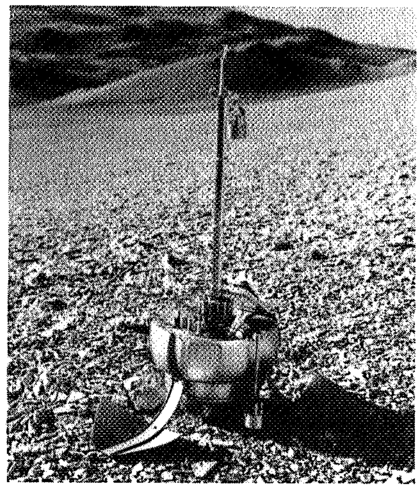

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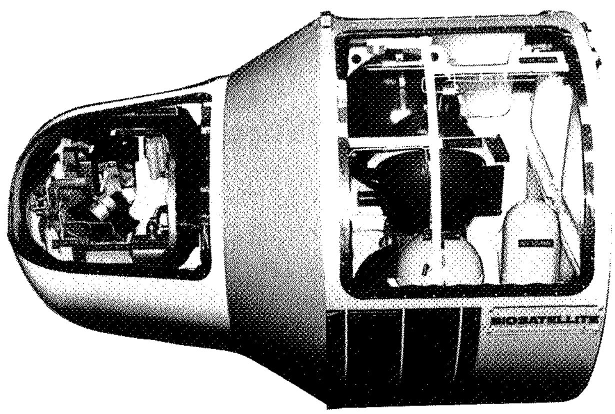


1. MINIATURED MASS SPECTROMETER
2. LABORATORY SIMULATION OF PRIMITIVE ATMOSPHERE
3. PRIMATE PERFORMING TASKS ON BIOSATELLITE TEST PANEL
4. AUTOMATED BIOLOGICAL LABORATORY
5. BIOSATELLITE/30 DAY

strategy for bioscience

GROUND-BASED RESEARCH

Experiments in space are expensive, so the fundamental strategy in NASA's Bioscience Program is to use flight experiments as the culmination of exhaustive ground-based research.

For example: one of the major mysteries in space biology is the role of weightlessness in the intimate proccesses of living cells. Some of the effect of weightlessness can be duplicated on Earth with a device called the clinostat. This device rotates living samples so that the force of gravity acts alternately in opposite directions. The clinostat make it possible to test simple gravity effects in organisms that ordinarily are oriented to gravity in a single direction. Thus, clinostat research makes it possible to focus more sharply the flight experiments on weightlessness.

A related example: the effects of radiation on living cells are different in a condition of weightlessness. Biosatellite II experiments showed mutation rates 400 percent greater with fast-growing cells. Surprisingly the effects of radiation on slow-growing cells actually were reduced significantly. Follow-on, ground-based research will use clinostats to the limit of their usefulness. Then in later Biosatellite flights, this provocative phenomenon will be explored further and with still greater precision.

A third example: the search for life beyond the Earth begins with fundamental research on the origins of life on Earth. Study of primitive life forms is necessary in order to identify the elemental signs of life wherever they may be found. Scientists in universities across the nation are contributing information on the conditions that appear to be necessary for life, the conditions that might transform non-living chemicals into self-duplicating living organisms. NASA sponsored studies in theoretical biology are advancing man's understanding of the fundamental nature of life itself.

A fourth: living plants and animals, including man, have cycles in their life processes that are related to the period of rotation of the Earth. How are the cycles controlled? The answer to this question not only bears on the performance of astronauts, it is of great practical significance to all of us in an age of jet transportation. How can a man function effectively when it feels like three o'clock in the morning to him? Space research is necessary to determine whether *circadian rhythms* are governed purely by habit or whether geophysical forces have a role. But first, before space flight experiments, NASA is conducting research to define the questions more narrowly.

In additon to the ground-based research on fundamental scientific questions, as typified by the examples above, NASA conducts ground-based research to provide control data for flight experiments. Still another category of ground-based research is development of flight experiment procedures and equipment.

Biosatellite Flight Experiments

The current flight research program involves a series of *three experimental packages.*

The first, represented by Biosatellite II flown in September 1967, consisted of experiments on the effects of weightless and radiation—together and separately - on the metabolism, growth and reproduction of relatively simple plant and animal tissues. The life forms used for the experiments were selected because a great amount of information was available on their life processes. Therefore, abnormalities could be identified with precision. The flight of Biosatellite II revealed a greater and more significant interaction of radiation and weightlessness than previously known.

In 1969 and 1970 a pair of 30-day flights are planned, using elaborately-instrumented monkeys as the experimental subjects. The primate experiments will study the performance and reactions of the central nervous, cardiovascular, metabolic and hemodynamic systems during weightless conditions.

The following year Biosatellite experiments will focus again on the more intimate, cellular-level effects of the space environment. Human tissue cultures, rats and small flowering plants will be the experimental subjects in 21-day flights. The human tissue cultures should provide a sharply drawn picture of the response of single human cells to weightlessness. Eight rats will be flown to study the effect of weightlessness on total body composition and to investigate circadian rhythms in orbit where a "day" shrinks to 90 minutes. The flowering plant experiment will study the growth and morphology of the plant subjected to weightlessness during its entire life span.

Biosatellite Spacecraft

The Biosatellite spacecraft used in the presently approved flight series is especially designed for small, automated experiments. It can carry a payload of approximately 135 pounds in a 200 nautical mile orbit for 30 days. The spacecraft is launched by the thrust-augmented Improved Delta vehicle. It makes a parachute descent after re-entry and is recovered by aircraft in mid air. Follow on flights using this same spacecraft design are being considered for experiments after completion of the approved series in 1971.

Improved Biosatellite

An improved Biosatellite is under study as a later extension of the Biosatellite program. The spacecraft would be of almost the same design as the present Biosatellite but it would incorporate modest modifications permitting an experiment payload up to 300-pounds and a flight duration of 60 to 90 days. This series is intended as a companion program for the manned space flight program. The experiments to be flown on the Improved Biosatellite would be those that do not require the presence of an astronaut and are inappropriate to the manned space flight platforms because of special orbit or launch constraints or would be more economically performed in the Biosatellite. Experimental subjects would range from bacteria to higher order mammals.

Bio Explorer

A Bio Explorer is also under consideration to carry experiments not requiring recovery. Controlled rotation of the spin-stabilized vehicle would provide gravity gradient between the limits of 1.2 g and near 0 g to study gravity preference and responses of biological materials at various acceleration levels below 1 g and establish the relative merits of artificial gravity versus the undesirable effects of rotation. The spacecraft would also permit studies of the effects of very low g with 1 g in-flight controls.

Apollo Applications—Biotechnology Laboratory

Several configurations of an Earth-orbital manned laboratory are under consideration. All of these utilize the S-IV-B stage as the basic "workshop" with laboratory facilities installed on the ground prior to launch (S-V workshop), or to be deployed in the spent stage in orbit after it has functioned as a booster (S-IV-B workshop). The manned Earth orbital space laboratory is expected to carry those Bioscience experiments which require the presence of man to insure success of the experiment.

A manned laboratory has special utility for biological research. The living subject matter of biology is intricate and ever-changing. So it is difficult to automate an entire sequence of biological experiments. The results of step one might very well change the approach to step two. However, a resourceful biologist aboard a space laboratory can follow the thread of evidence as it develops.

A manned space biology laboratory seems to be the way to get needed answers relatively quickly and perhaps even more economically. The space biologist can adapt his experiments as needed. We further expect to be able to coordinate the Bioscience instrumentation and space-borne facilities with the needs of the Space Medicine and Technology Programs so that there can be maximum efficiency in the design and use of such a laboratory for all of NASA's life sciences work.

Five major experiment packages Bio A, C, D, E, & F, are being considered for a manned Earth orbital space laboratory to capitalize on these advantages. While all could be flown automated in one or more of the proposed Biosatellite missions, the value of the experiments would be markedly enhanced by the participation of a scientist-astronaut.

Bio A would consist of experiments using monkeys and chimpanzees to make rigorously instrumented measurements of behavior, electrophysiology, metabolism, hemodynamics, and the cardiovascular adaptation during prolonged weightlessness. Each animal would be housed in a separate module. Both restrained and unrestrained animals are being considered in the experiment designs.

Bio C-F are each major experiment packages to extend the survey and in-depth study of the responses of organisms to weightlessness, and other factors in the space environment, evolving from the results gained in the Biosatellite Program. Bio C includes microorganisms, cells, tissues, and very small plants and animals. Bio D includes small vertebrate animals; Bio E & F a variety of plant species and invertebrate animal experiments.

Advanced Biosatellite

As an alternate to the proposed Biotechnology Laboratories, described above, an Advanced Biosatellite is under study. The spacecraft weight at launch is estimated at 4,000 pounds which is within the capability of the Atlas-Centaur launch vehicle. Recovery is required, the recovery package weighing approximately 900 pounds. Life support for three to six months will be needed. Instrumentation will include blood and urine analyses, various implanted transducers psychomotor test apparatus, fluorometric and radioisotope devices, photography, and television.

Some complex and unique new technology will be required both for the experiments and for the long-term life support system.

Removal from Earth Environment—Bio-Pioneer

A plan is being developed to use the Pioneer spacecraft to carry experiments on biological rhythms into heliocentric orbits. In deep space they will be isolated from Earth's geophysical factors and cyclic cues. The Bio-Pioneer experiments could provide important answers to the puzzle of circadian rhythms.

Lunar Bioscience

The lunar surface might contain organic matter or other biological traces. Accordingly, a series of analyses on returned samples is planned in the Apollo Program, aimed at the identification of particular organic molecules or groups of molecules, as well as microscopic and submicroscopic evidence of biological entities. Analysis of lunar material is expected to help us understand many aspects of chemical evolution. For example, a sample of organic matter on the Moon might exhibit a stage in chemical evolution which is not preserved in terrestrial sediments. An analytical study of a lunar sample would thus provide important information on the path of chemical evolution and the origin of life on Earth. In addition to serving as a repository for living or once living organisms which could be compared to terrestrial organisms, the Moon might even contain evidence of an extraterrestrial life form.

Studies will be performed on returned lunar samples when available. A broad spectrum of analytical organic chemical techniques will be applied to aseptically collected samples, as soon as possible after collection. The search for organic molecules of biological significance (amino acid, fatty acids, carbohydrates, purines and pyrimidines, etc.) will be stressed. Microbial studies will be made in an attempt to isolate viable organisms. Electron microscopy will be used to search for fossil organisms.

Eventually, studies will be made *in situ,* in areas considered too dangerous for early astronaut exploration (e.g., areas where gas emissions are prevalent) since these areas might be of even greater interest from a chemical point of view. Volatile organics emitting from within the Moon would be of great significance to the biologist and organic geochemist. Long term analyses, and also those which are susceptible to astronaut contamination, will have to be automated.

Exobiology

The emphasis in Exobiology has been in the direction of: (1) Development of techniques for *in situ* measurements during search of extraterrestrial bodies, (2) Measurements on returned extraterrestrial samples as well as ancient terrestrial sediment for evidence of life's origin and evolution.

Current and future efforts in exobiology are distributed among three areas of research: chemical evolution, biological adaptation, and life detection.

In *Chemical Evolution,* work has continued on the synthesis of biologically significant organic molecules under pre-biotic conditions. The list of molecules so synthesized now includes porphyrins, previously thought to be certain evidence of biological activity. It thus appears likely that all biologically significant molecules can be produced synthetically.

Further studies of organic matter in ancient terrestrial sediments have demonstrated amino acids in 3.1-billion-year-old rocks. This suggests that life arose on Earth early in its history—perhaps within the first billion years.

New techniques are being devised for the extraction and identification of amino acids and carbohydrates from rocks and fossils, both for use on terrestrial rocks and for ultimate application to returned lunar, planetary, and interplanetary samples.

A prototype of a micro-amino acid analyser with volume reduced by a factor of 150—yet with higher sensitivity—has been built. Automatic reaction steps include acid hydrolysis of samples and separation of resulting amino acids from contaminating metal compounds.

A standard gas chromatograph and a compact relatively simple quadrupole mass spectrometer have been combined in a single instrument. It has demonstrated reliable analyses of compounds of mass below 150, and promises results with compounds of up to 500 atomic mass units.

Biological Adaptation studies are in process to evaluate extraterrestrial-type environments and their ability to sustain terrestrial organisms. There are two general emphases to this work–(1) an assessment of the likelihood that terrestrial organisms will either survive or grow on another planet, thus both threatening an indigenous biota and serving as contaminants for future life detection probes, and (2) to provide clues about ecological niches in which life might succeed on another planet. Of interest have been the halophilic bacteria, particularly the obligate halophiles requiring practically saturated salt solutions for good growth. Salt deposits represent one way in which water might be bound on planets like Mars.

For *Life Detection* a variety of techniques is being designed to be used first with automated and ultimately, perhaps, with manned probes. These techniques include the search for those attributes of living systems which are generally considered primary and most universal–(1) Chemistry, (2) Metabolism, and (3) Growth. These techniques will lead to breadboard and ultimately to flight instruments. The gas chromatograph-mass spectrometer combination is one such instrument which is being studied and miniaturized for pre-flight testing.

Other devices for metabolic and growth detection are evolving toward flight systems. Visual imaging systems are also being developed. The essential components of these instruments will be integrated for flight on limited-payload early missions. More sophisticated systems will be used on later missions. A logic for sequential analyses on a planet is being developed so that measurements relevant to biological activity will be made in an appropriate order for meaningful and unambiguous interpretation. All of this technology is also being studied for application to returned samples as well.

Planetary Quarantine

Prevention of contamination of the planets by terrestrial life can be guaranteed only if there are no flight missions to the planets. When missions are flown it becomes a matter of probability of contamination. NASA policy is to maintain less than one chance in a thousand of infecting a planet of biological interest. This will be accomplished by sterilizing the landing hardware and use of the trajectory deflection mode to insure that non-sterile hardware does not land.

Dry heat is the method of choice for sterilization, but this procedure degrades, to a certain extent, the reliability of the mission and will add to its cost. Therefore, the minimum time and temperature will be used that will accomplish the purpose. To lighten the burden, advantage will be taken of techniques for ultra clean assembly, die-away of organisms before launch and in flight and the retention of organisms inside solids. The sterile landing capsule will be protected from recontamination by a hermetically sealed container until it has reached outer space.

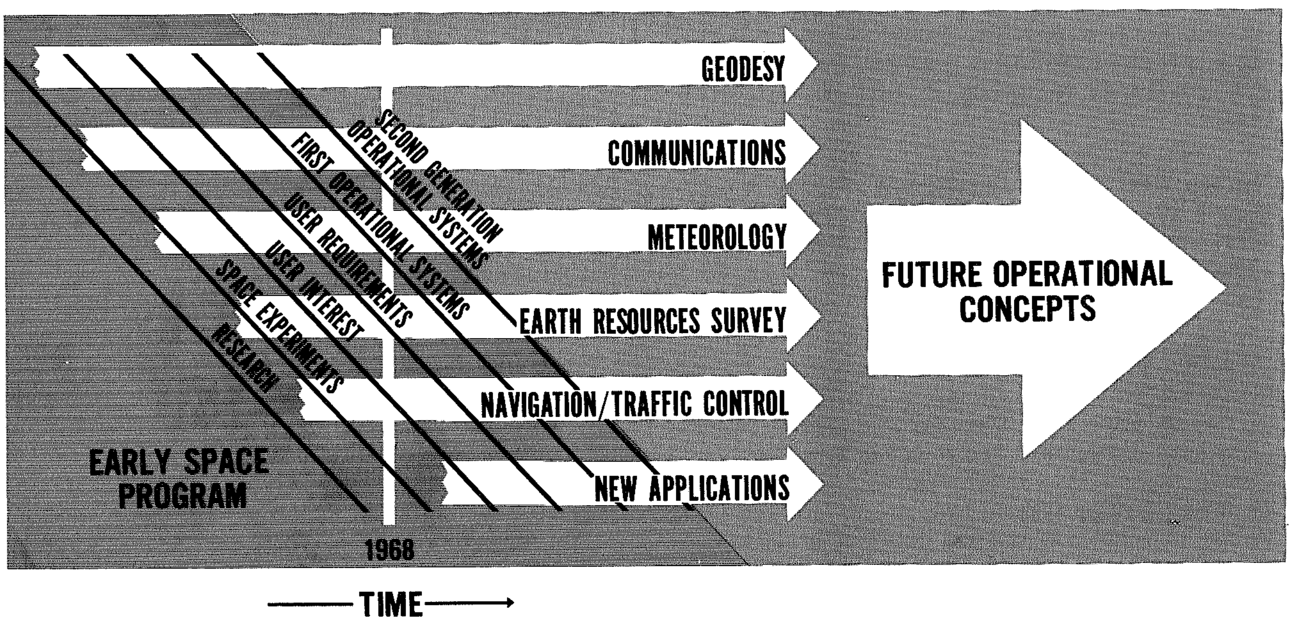
strategy for space applications

GENERAL DISCUSSION

In the development of economic space applications, as in the development of the space sciences, the first step in the long process is research, both basic and applied. As the chart above indicates, all the present systems such as those in meteorology and communications had their roots in research. The chart suggests schematically how operational systems evolve and how, at any given time, different applications disciplines are in different stages of development. All the ultimately differentiated systems stem from a common reservoir of knowledge and experience; and all are subjected, to some degree at least, to a selection process entailing flight experimentation, exposure of early models to potential users, and the establishment of operational requirements before they finally emerge as systems.

The vertical line through the chart represents the present, at which time working systems already exist in geodesy, communications and meteorology. Other transitions to operational status are within sight. It must be emphasized that the establishment of an initial operational system does not signal the end of further research in any of these areas. Quite to the contrary, further research will improve those systems, permitting the development of more efficient and more useful second generation operational systems. Significant improvements in systems now being developed depend heavily on research studies in sensors, techniques, stabilization systems, data handling and analysis, and increased lifetime. Also, unless history is ignored entirely, one must expect that new systems, now undefined, will eventually take shape as a result of the

PHASED EVOLUTION OF SPACE APPLICATIONS



Supporting Research and Technology of today and tomorrow.

An idea—even a demonstrated capability—is far from a useful space application. The achievement of widespread utility is often a long process involving most or all of the ten steps shown below:

STEPS IN THE REALIZATION OF SPACE APPLICATIONS BENEFITS

- BASIC RESEARCH
- SCIENTIFIC EXPLORATION
- APPLICATIONS R & D
- NASA-USER COOPERATION
- TECHNOLOGICAL DEVELOPMENT
- APPLICATIONS FLIGHTS
- USER INTEREST/REQUIREMENTS
- OPERATIONAL PROPOSALS
- PROTOTYPE DEVELOPMENT
- OPERATIONAL SYSTEMS

NASA's scientific activities play an important role in the accumulation of new knowledge represented by the first two steps. Basic research and exploration are absolutely essential to progress in the subsequent development of technology.

The Space Applications Program is most deeply concerned with the next four steps. Applications research and development builds directly on the more general fundamental research which has gone before. Very early in the process, every effort is made to inform and seek the active participation of potential users. With its experience in space research, systems design, and space flight operations, NASA has a unique ability to develop and demonstrate technology in areas of major public benefit.

Moving down through the last four steps, primary responsibility shifts increasingly to the users—still in close cooperation with NASA—as they discover how space applications can help them reach their particular objective.

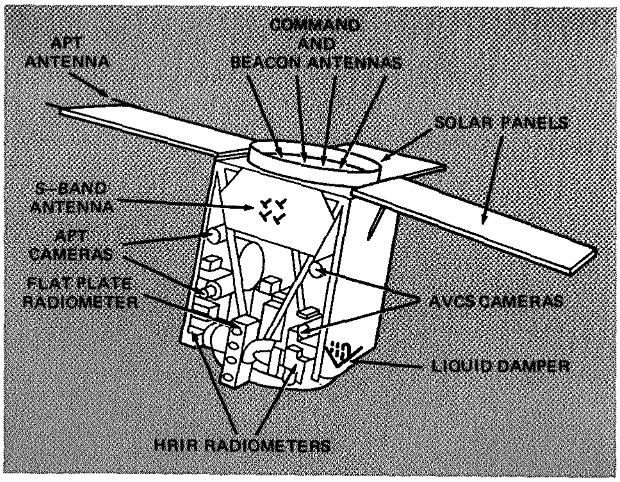
Unlike the space sciences program, where the primary objective is basic new knowledge and understanding *per se,* the development of economic applications of space to ultimate operational and in some cases commercial systems depends on a different kind of "user interest." We are developing systems here that will provide information to serve the practical needs of mankind on a direct and even daily basis. In some cases, a space capability will permit us to meet these needs more cheaply or more effectively than other "conventional" techniques could do. In other cases, we will meet needs that can be met by no other existing technology.

NASA currently has active space flight programs underway in the discipline areas of meteorology, geodesy, communications, data collection, navigation, and traffic control; the latter three areas are currently the subject of experiments only on our Applications Technology Satellites. There are other disciplines such as Earth resources survey to which we have not thus far devoted single purpose satellites. Earth Resources Surveys can logically be grouped into two major classifications: (1) observing the Earth directly from space for its gross characteristics and fine detail, and (2) using satellites to collect environmental information from remote sensors placed in difficult-to-reach locations all over the globe, for delivery to the users centrally located data acquisition stations.

Now that our general approach to the strategy of the development of space applications has been explained, we can proceed to discuss individually the discipline areas and the projects that make them up.

Meteorology

In this area, we see a typical example of the evolution of operational systems as well as the need for second and later generation improvements on those systems. We are currently involved in all the steps mentioned earlier, ranging from basic research and truly research and development flight projects, satellites, such as Nimbus, to the TIROS Operational Satellite (TOS) built and launched by NASA and operated by ESSA. These are launched as needed to maintain a daily view of the Earth's cloud cover during daylight hours. In consultation with the user agency, ESSA, we determined what sensors and imagers were needed for major improvements in that coverage and initiated development of the next generation operational prototype: TIROS M. This satellite will incorporate both APT (Automatic Picture Transmission), a system for direct readout of high resolution cloud cover pictures by local users with their own inexpensive receivers, and AVCS (Advanced Vidicon Camera System), a system for storing high resolution pictures for readout on special equipment at the user agency's data acquisition facilities. In addition it will include a high resolution scanning radiometer to provide global cloud cover data at night as well as surface and cloud top temperature. We foresee a need for development of a third generation operational prototype in the mid-seventies, based on new sensors and techniques developed on our series of NIMBUS R&D satellites.



TIROS M (IMPROVED TOS)

The NIMBUS series of satellites has provided and continues to provide us with a relatively low altitude (600 n.mi.) laboratory or "test-bed" for proving out, evaluating and optimizing our research sensors, imagers, and other systems. We foresee a need for continuing the series of NIMBUS R & D satellites at least through the mid-1970's to pursue the program of instrument development and optimization.

The response of the world community to the results of our black and white and, more recently, color pictures of the Earth from the higher *synchronous* or geostationary altitude (19,300 n.mi.) on ATS satellites convinces us that in the near future, perhaps as early as 1970, we should start the development of a first generation prototype synchronous operational meteorological satellite. In the meantime we will continue to fly some experimental meteorological sensors on the ATS series of synchronous satellites. Ultimately, we foresee the day when a combination of standard applications satellites, using both low and synchronous orbits will supply the needed test platforms for space qualification and testing of sensors for ultimate incorporation into the operational prototypes of the late seventies and beyond.

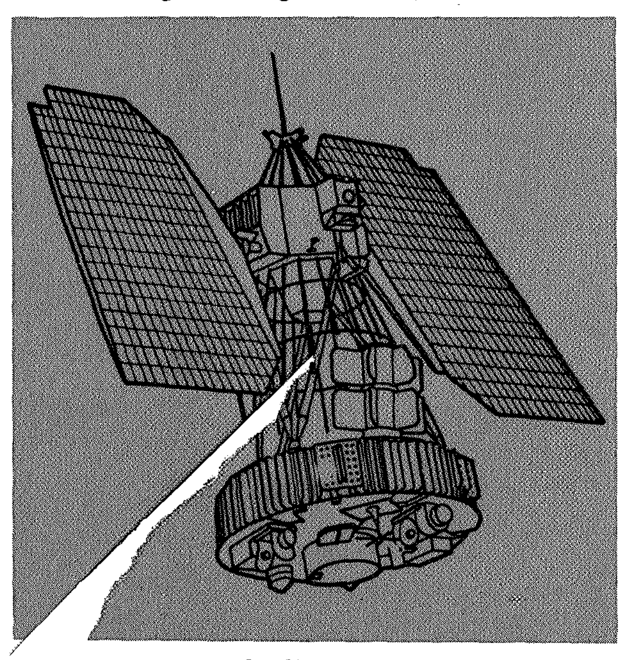
A portion of the meteorology effort is the continuing Meteorological Sounding Rockets program through which we make direct measurements of the meteorological characteristics of the atmosphere between altitudes of 20 and 60 miles—altitudes that are not accessible to satellites because of excessive air drag, but altitudes which are of great meteorological importance because of the energy exchange phenomena that occur there. U.S. and foreign facilities for obtaining routine meteorological rocket soundings provide inter-hemispheric coordinated observations for meteorological research.

Earth Resources Survey

In the area of Earth Resources Survey, we foresee promise, undoubtedly great promise, based on very preliminary results. Already, we have found that pictures taken by our *Gemini* astronauts with their hand-held cameras revealed heretofore unrecognized geological features of interest to the geological and minerological communities. NIMBUS and TIROS satellites have returned images that include detail about ocean currents and geologic faults of potential commercial interest to our fishing and mining industries. In fact, a major question facing us today is not simply one of how to gather the data, but in addition, once the data is collected, how to transfer that data to the using community. We can foresee tremendous practical returns from exploitation of the *synoptic* view of the globe that is possible from space and only from space.

In laying out a flight program for Earth resources survey from space, we realize that aircraft will play a major role in developing the needed technology. Preliminary tests of instruments from aircraft will be cheaper than from space. Also, by flying over known areas, where the conditions have been determined through ground exploration, the aircraft flights will provide a means of "calibrating" and selecting the instrumentation for subsequent space missions.

With this background, let us examine the Earth Resources Survey program we have laid out, recognizing that developments and breakthroughs may accelerate this conservative forecast. We believe that the first R&D satellite in this discipline area could fly in the early seventies using a TAT/Agena or TAT/Delta/TE364. This


NIMBUS "B_2"

small observatory class satellite and its immediate successor would depend on passive and possibly one active remote sensor. Electronic telemetry would be used for return of all data to Earth. For limited-objective missions in which we would test a smaller number of sensors, we could use smaller spacecraft and appreciably cheaper launch vehicles, such as the time-proven Scout or Delta. We also foresee the potential need for testing recoverable payloads using film as the recording medium.

The design of the first generation Earth Resources Survey systems test spacecraft would be based on the results of R&D spacecraft: the Earth Resources Technology Satellites (ERTS-A&B), and the limited-objective missions using the small Applications Technology Satellite. As is the case in the meteorology area, this would serve as proof of both concept and design and would be followed by operational satellites as needed, and funded by user agencies.

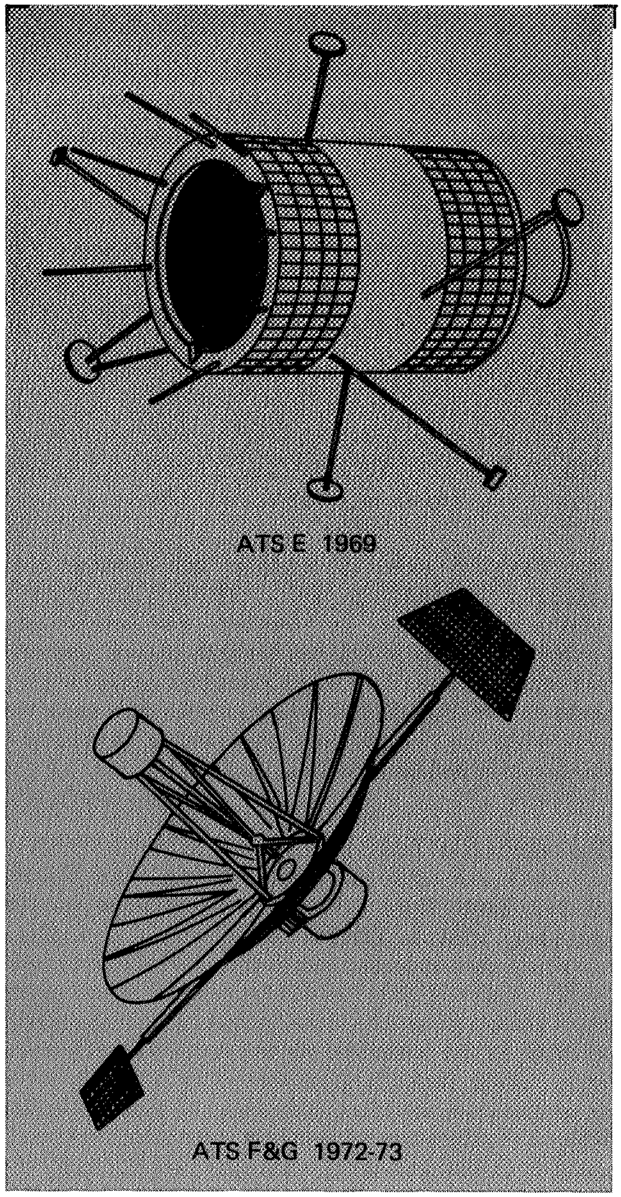
Communications

Our strategy, as applied to improved space communications capabilities is illustrated on the next page. Here we are developing most of our capabilities through advanced Applications Technology Satellites (ATS) in the areas of small capacity multiple channel simultaneous ("multiple access") communications, improved frequency utilization, and community TV broadcast, and satellite-borne tracking and data acquisition and relay aids to other missions. This pattern of multiple uses of ATS satellites to develop required space technology in communications will be followed in achieving the other objectives such as direct-to-home TV broadcast and data relay aids to NASA missions whenever it is feasible to do so. As in other discipline areas, these communication experiments are based on initial research and space development, and they are responsive to user requirements.

In the area of satellite aids to other missions (Data Relay Satellite System – DRSS) we forsee the need beginning in the mid-1970's for operational satellite systems for data relay, probably combined with tracking functions.

Geodesy

In geodesy, we have almost completed the flight program necessary to meet the first objective of the National Geodetic Satellite Program (NGSP), namely, establishment of a world-wide network of geodetic control points, with the successful launch of Geos II in January 1968. One more satellite, Geos C, may be required to provide the remaining observations necessary to complete this goal. Reduction and analysis of all the data may well take an additional year or two.



The second objective of the NGSP—description of the Earth's gravity field and its anomalies down to a size of 600 miles—is being met largely through observing the orbital perturbations caused by those anomalies on various satellites that are already in orbit.

Certain anomalies, however, can only be studied by observing perturbations to orbits of very specially selected inclination, altitude, eccentricity, and period. Providing the opportunity to observe satellites in those specialized orbits will be the role of Geos D and Geos E, under study for launch in the early seventies. These satellites will permit completion of the primary objectives of the NGSP.

Over and above these objectives, however, we have identified other important roles that advanced geodetic satellites can play in supporting various Earth related sciences. These include various contributions: in marine sciences, for example, determination of the mean sea level (the ocean geoid) and the motion of ice masses; in earth dynamics, the solid earth tides and motions of the poles; and earth structure, both internal and atmospheric, through mass, drag and station location measurements.

Navigation and Traffic Control

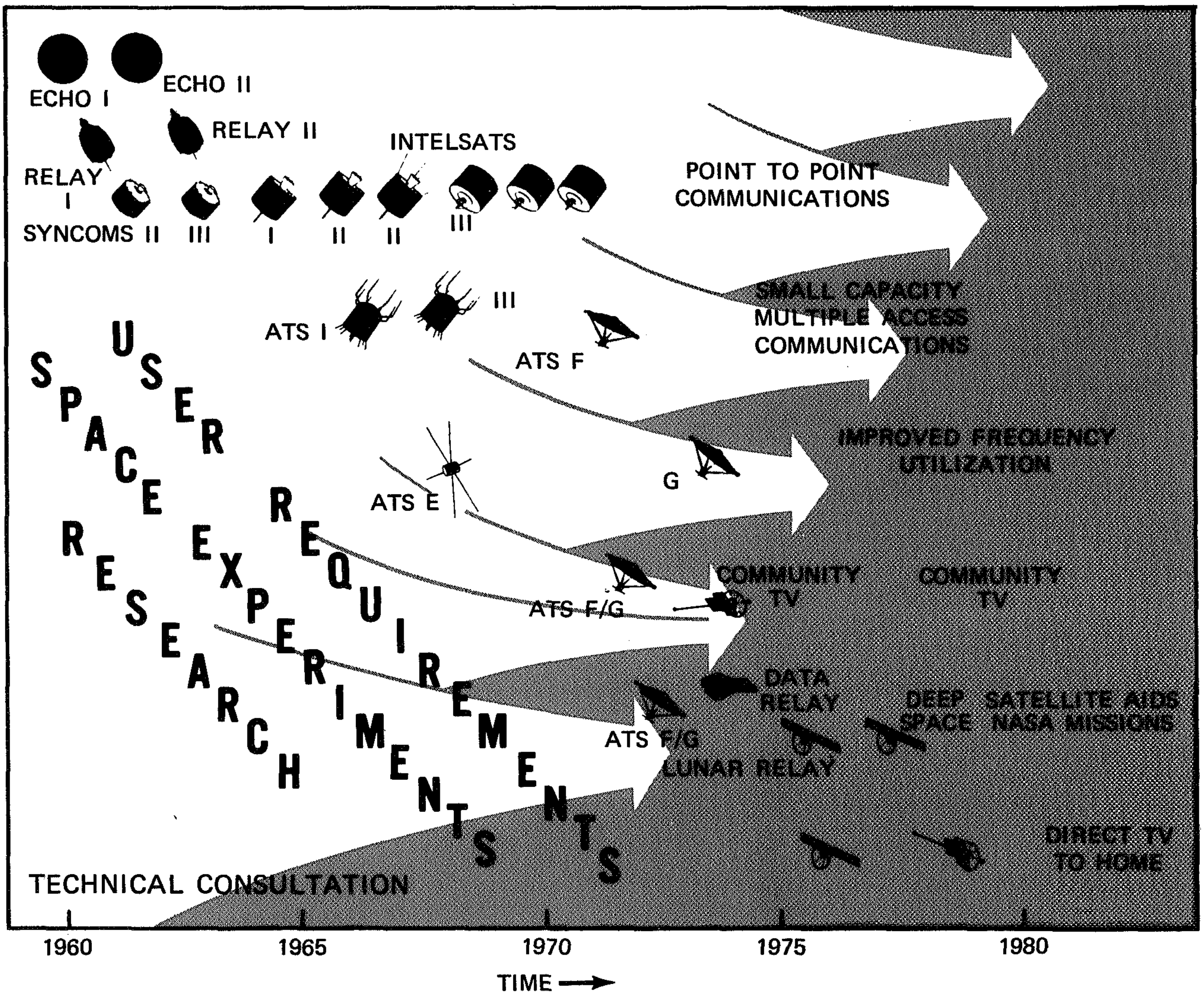
Our strategy in the navigation and traffic control area is almost identical to that in the communications satellite area: conduct of advanced applications experiments on ATS satellites, and development of committed operational prototype satellites. In this case, the identified needs of the maritime and commercial airline communities may demand an early launch of a prototype spacecraft.

Standard Applications Satellites

As these programs in individual disciplines develop, work proceeds concurrently as a vigorous supporting research and technology effort on sensors and techniques and on the Applications Technology Satellites (ATS), the precursors of eventual standard applications satellite missions which will bring together diverse satellite capabilities to meet the many varied requirements in the most economical and effective way possible.

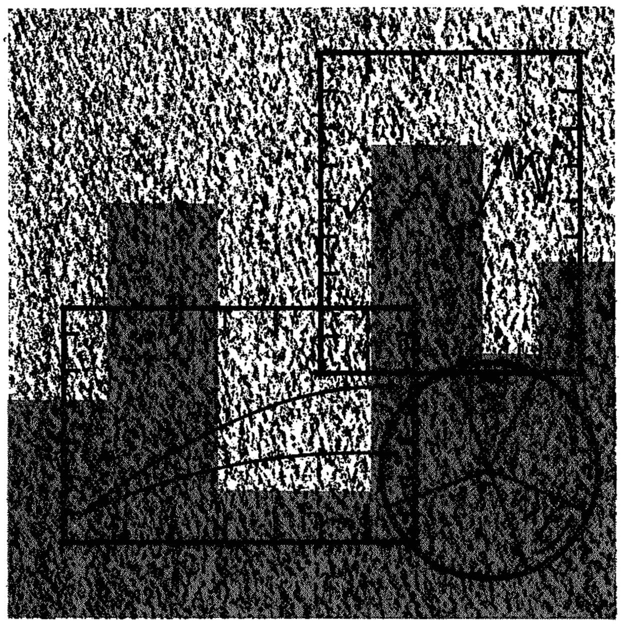
The description of the role of the Applications Technology Satellites (ATS) in the foregoing sections has already made clear our basic near-term strategy.

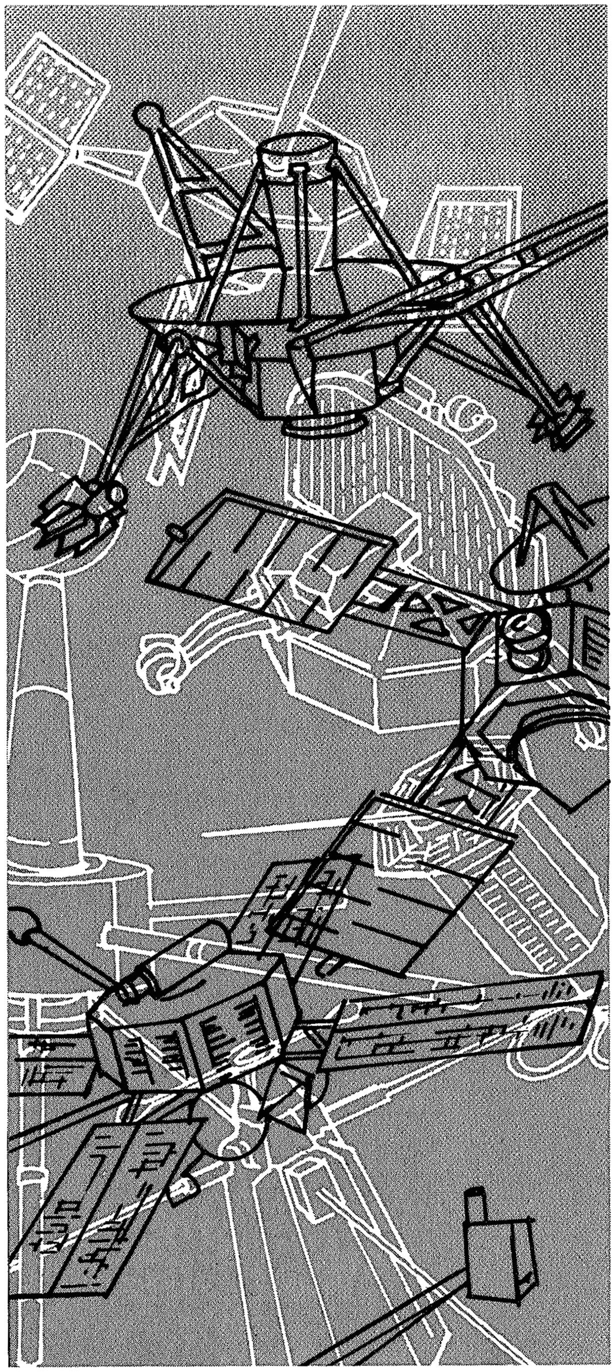
EVOLUTIONARY COMMUNICATIONS PROGRAM



We foresee in the more distant future the possiblity that several economic applications of satellite technology can be combined on a few, if not a single, multiple-purpose satellites, thus achieving economy through the sharing of many basic spacecraft systems such as power, structure, antennas, and data transmission systems. One fact that is abundantly clear, however, is that the ever-growing national technology base must not remain compartmented. What we learn in communications, meteorology, Earth resources, basic spacecraft systems such as stabilization and control, data processing and dissemination and many other fields must be shared. All government agencies and many sectors of the business community must strive to be broadly familiar with scientific progress and technological advances in many disciplines, and must be willing to share their capabilities across organizational boundaries. We in NASA are committed to this objective.

5 fiscal year 1969 program additions





This section presents the new projects and major studies being initiated with FY 1969 funds. The section is organized by programs, with each set of projects and project studies preceded by a chart designed to place them in context with each other, and with program objectives.

SPACE PHYSICS

PROGRAM	APPROVED & UNDER WAY	APPROVED TO BEGIN FY-1969
Space Physics	ORBITING GEOPHYSICAL OBSERVATORY (OGO-F) A standardized, altitude-stabilized spacecraft capable of accommodating a large number of experiments. Conducts interdisciplinary, correlative, investigations of geophysical and solar-terrestrial phenomena for a fuller understanding of Earth-sun relationships and of the Earth as a planet. PHYSICS EXPLORERS A class of relatively small spacecraft placed in low Earth orbit by Scout or Delta class rockets and carrying a relatively few compatible scientific experiments, primarily in geophysics. PIONEER D & E A class of small spacecraft carrying experiment payloads up to 100 pounds on interplanetary flight. Early missions investigated space relatively near Earth frequently making simultaneous measurements at widely separated locations in space. SOUNDING ROCKETS A family of inexpensive single and multiple stage rockets used to carry light weight, generally single, scientific experiments to altitudes up to 1500 miles, obtaining data on ascent and descent. Used extensively for Earth atmosphere science, and geophysics. Characterized by simplicity, and multiplicity of launch locations world wide including from ship. BALLOONS Very high altitude balloons used to carry experiments to altitudes where observations can be made above most of the Earth's atmosphere, as with early space astronomy experiments.	PHYSICS EXPLORERS An extension of the present Explorer class to include a relatively inexpensive very small solar probe to be launched into heliocentric orbit by a Scout class launch vehicle. The first of these missions, called Sunblazer, is to solar corona studies—monitor solar proton events—study the magnetosphere.

PHYSICS EXPLORER–SUNBLAZER

Objectives:

Using a relatively inexpensive solar probe–perform solar corona studies by radio propagation techniques, magnetosphere studies, chemical releases, and emergency monitoring of solar proton events.

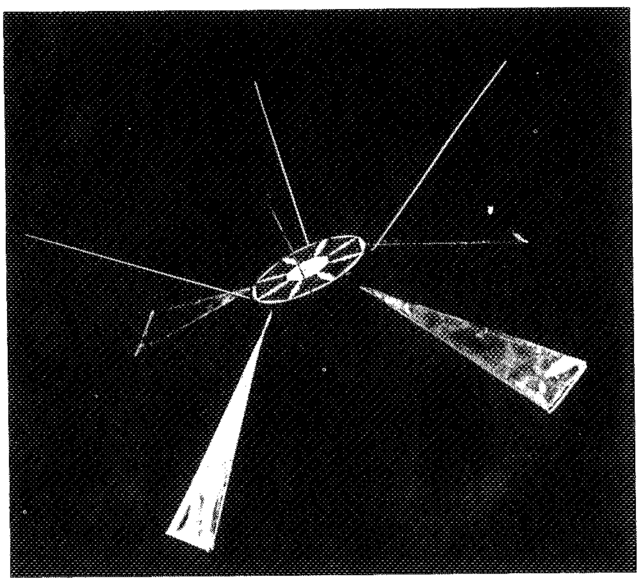
Technical Data:

Orbit:	0.4 to 1.0 astronomical units, heliocentric
Launch Vehicle:	5-Stage Scout
Launch Site:	Wallops Station
Technology Required:	Solid state transmitter having a modest bit rate with small band width but high power.

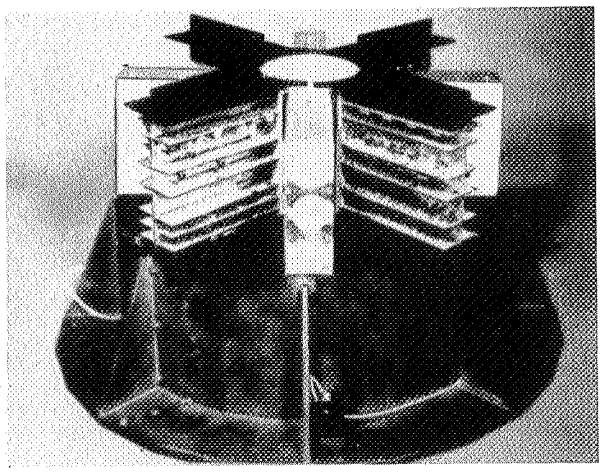
Status:

The launch of the first missions (Sunblazer) are planned for CY 1970 with two launches planned each for CY 1971 and 1972.

LAUNCH CONFIGURATION



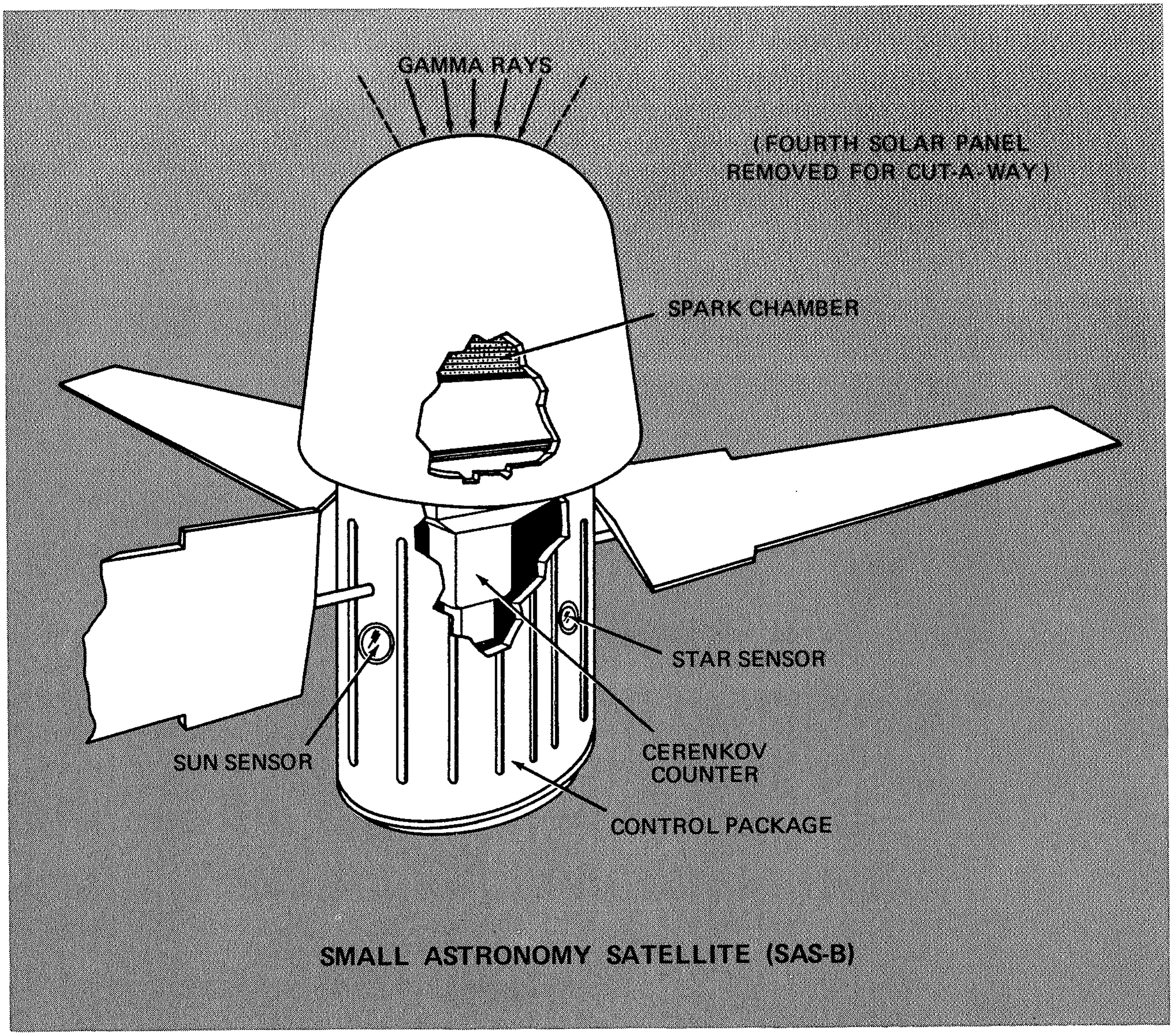
FLIGHT CONFIGURATION



ELECTRONICS

ASTRONOMY

PROGRAM	APPROVED & UNDER WAY	APPROVED TO BEGIN FY-1969
Astronomy	ORBITING ASTRONOMICAL OBSERVATORY ($OAO-A_2$, B, C) The first sophisticated astronomy observatory in space. Will perform intensive, long-duration, precision observations of the full range of celestial objects and phenomena in the infrared to gamma-ray spectral regions using photometry, polarimetry, and high resolution spectroscope techniques. These observations should produce new, previously unavailable data for interpretation and understanding of major astronomical problems. ORBITING SOLAR OBSERVATORY (OSO-G,H) Obtains high resolution spectral data (within 1 Å - 1250 Å range) from the pointed solar experiments in the spacecraft during the major portion of one solar rotation, and adequate operational support of the spacecraft subsystems including raster scans of the solar disc to carry out the acquisition of these scientific data. Also obtains useful data from the non-pointed experiments; and to obtain data from the pointed solar experiments during more than one solar rotation. APOLLO TELESCOPE MOUNT (ATM-A) To examine the problems and develop the techniques for manned astronomy in space—carries the most advanced Solar Physics Experiment to perform studies of the structure and dynamics of the solar corona, chromosphere, and photosphere. A later ATM will perform a low spatial and spectral resolution survey of the celestial sphere in the ultraviolet, X-ray, and γ-ray spectrum. Knowledge gained would contribute to our understanding of solar phenomena and the celestial sphere and will permit evaluation and development of man's ability to perform astronomical observations and operations in the space environment. ASTRONOMY EXPLORERS A class of small spacecraft to perform broad surveys of stellar radiation sources. The first of this class, the small Astronomy Satellite (SAS-A) is an all sky survey for X-ray sources to produce an X-ray source catalog; to search for temporal variations in X-ray source intensity over periods of minutes to months; and to measure the angular diameter of X-ray sources if greater than a few arc minutes and to identify those sources.	ASTRA Study The primary Advanced Study effort in FY 1969 will be a preliminary analysis of ASTRA. This project is intended to provide the next step in space astronomy by combining long-term automated precise observations with the availibility of man to service the telescope, replace instruments, or recover film. The primary telescope system would employ diffraction-limited optics and improvement in resolution and pointing accuracy over OAO. ASTRONOMY EXPLORERS A second Small Astronomy Satellite, (SAS-B), to perform broad surveys of stellar gamma ray radiation sources.



ASTRONOMY EXPLORER (SAS-B)

Objectives:
Perform broad survey of sources radiating in the gamma ray region both inside and outside our galaxy.

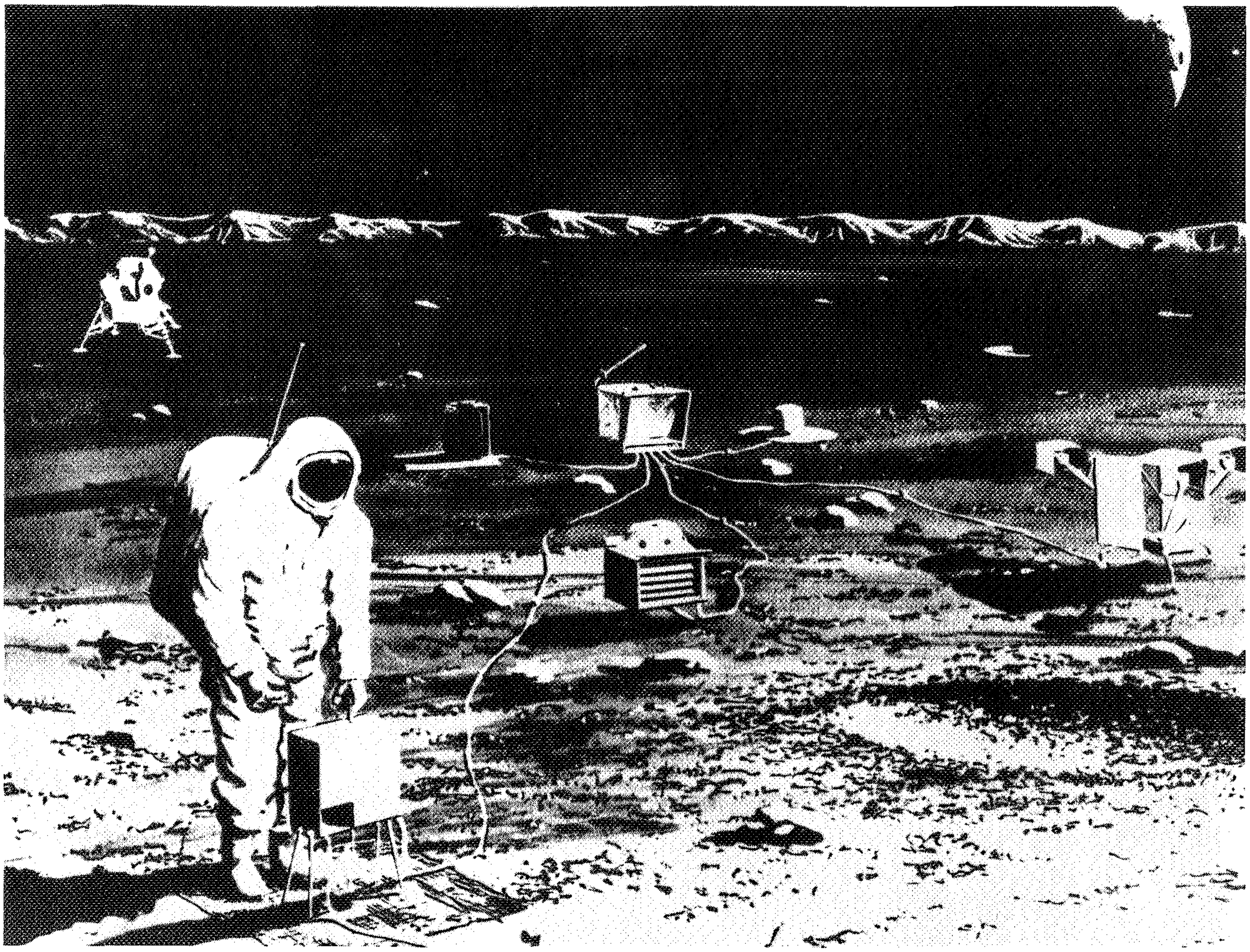
Technical Data:

Spacecraft:	360 lbs total with 180 lbs of experiments
Orbit:	300 to 500 nautical mile equitorial orbits.
Launch Vehicle:	Scout
Launch Site:	San Marco Platform off Kenya, Africa

Status:
Launch would be for mid-1971.

LUNAR EXPLORATION

PROGRAM	APPROVED & UNDER WAY	APPROVED TO BEGIN FY-1969
LUNAR EXPLORATION	APOLLO The first landing of man on the Moon to collect Lunar material for return to Earth, emplace geophysical instrumentation for long-term observations and conduct field geology investigations.	Planning for extended Lunar exploration operations which are to be centered around augmented landed payloads, greater mobility on the Lunar surface, and longer stay times on the Moon largely for scientific observation



EARLY POST APOLLO MISSIONS

Earlier engineering studies were conducted to define modifications to the basic Apollo Lunar configuration which would permit a modest increase in the payload for scientific instrumentation, the extension of stay time on the lunar surface to two or three days, and the opportunity to land in areas of high scientific interest.

The goals of these missions in the early 1970's are to provide an early increase in the ability to conduct exploration of the Moon.

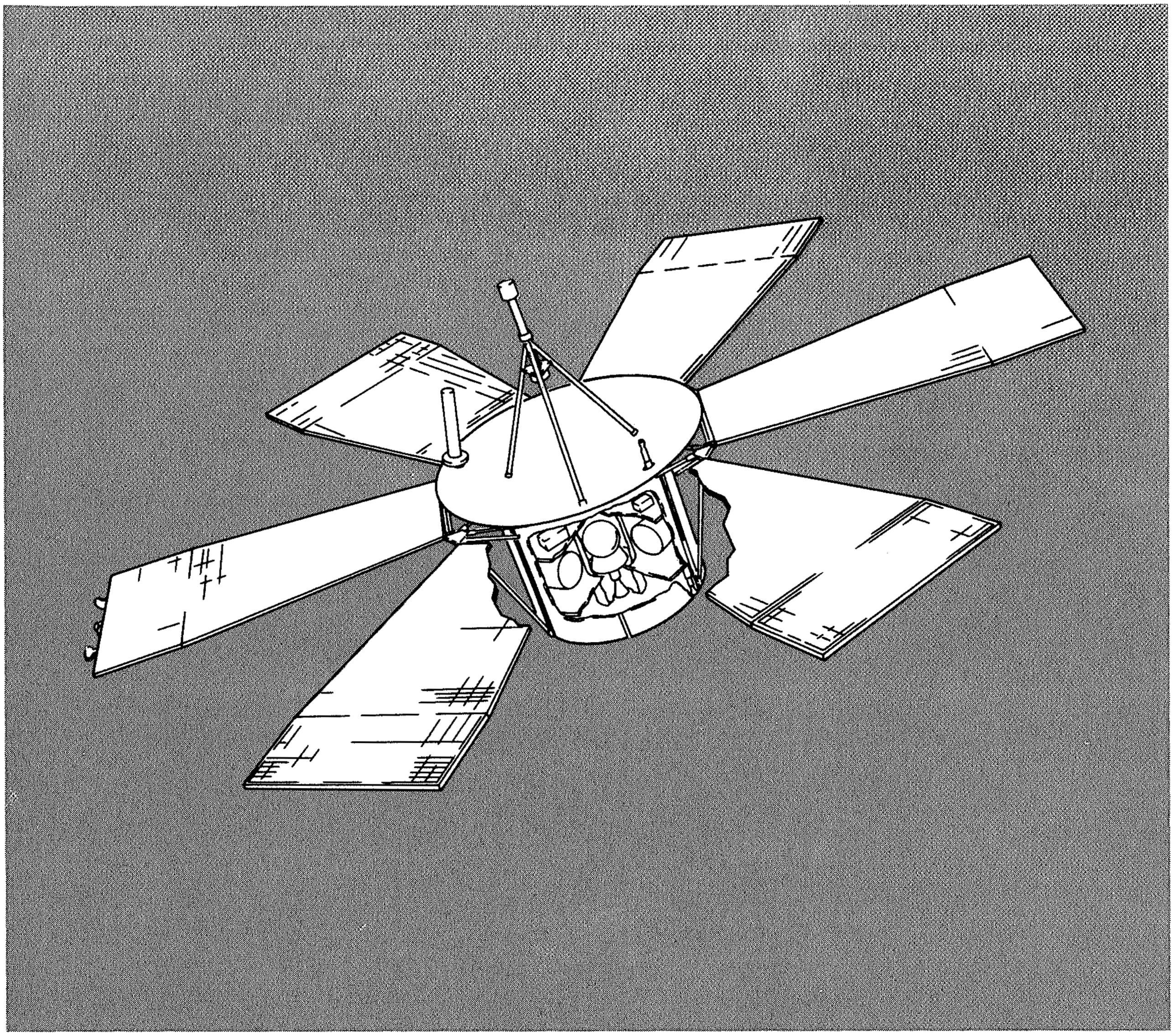
By modifying an Apollo Lunar module to take advantage of operational experience and predicted growth potential, a Lunar mission with the following capabilities is possible:

- three-day staytime by two astronauts.
- An accessible landing area increase from less than 5% of the visible face of the moon to more than 50%.
- Landing scientific or contingency payloads of up to 1,000 pounds.

Current studies to define the lunar missions immediately following the first successful Apollo landing, contemplate one to three-day astronaut stay time on the Moon during which limited reconnaissance and experiments would be performed. Under development for several years, automated instrumentation called—the *Apollo Lunar Surface Experiments Package (ALSEP),* as discussed on page 4-15, is to be left behind on the Moon after the astronauts have returned to Earth and is designed to perform a variety of geophysical, geodetic, and particles and fields measurements.

PLANETARY EXPLORATION

PROGRAM	APPROVED & UNDER WAY	APPROVED TO BEGIN FY-1969
Small size spacecraft (25-75 lb payload		**PIONEER F&G** A mission to make early gross measurements of the Astroid Belt and Jupiter environment, develop long duration flight technology and measure interplanetary phenomena.
Medium size spacecraft (100-250 lb payload)	MARS 1969 (FLY-BY) To make an exploratory investigation of Mars which will set the basis for future experiments, particularly those relevant to the search for extraterrestrial life and to prove the environmental data to support succeeding missions and further to develop the technology need for these missions. The Mariner-Mars 1969 mission is to flyby within 3000 kilometers to the planet and increase our understanding of the planet's surface and atmospheric characteristics over that obtained from Mariner IV. The mission will examine the Martian atmosphere in IR and UV and radio wavelengths, and extend Mariner IV photo-imaging coverage of the Martian surface to new areas and at higher resolution.	MARINER-MARS 1971 Using a Mariner size spacecraft to exploit the 1971 Mars opportunity—these missions will build on the results of the 1964 and 1969 Mars fly-by missions will orbit Mars, record and transmit data for an extended period. Mars 1971 is to observe the daily and seasonal variation of the planet leading to an evaluation of its dynamic characteristics and processes. This evaluation is essential to the understanding of Martian biology. Topographical and thermal mapping of the Martian surface is also to be included. This mission will develop the necessary technology for long-term planetary orbital observations. In terms of scientific data return, the data return from the 1971 orbiter will be over 10 times greater than that of the 1969 Mariner-Mars flyby. TITAN-MARS 1973 The 1973 Orbiter and Lander combination would significantly extend our growing knowledge of Mars derived from the 1969 flyby and the 1971 Orbiter. Detailed knowledge of the Martian atmosphere and surface and the improved technology utilized will also make major contributions to the ultimate goal of landing surface laboratories for detailed Martian investigation.



PIONEER F & G

Objectives:

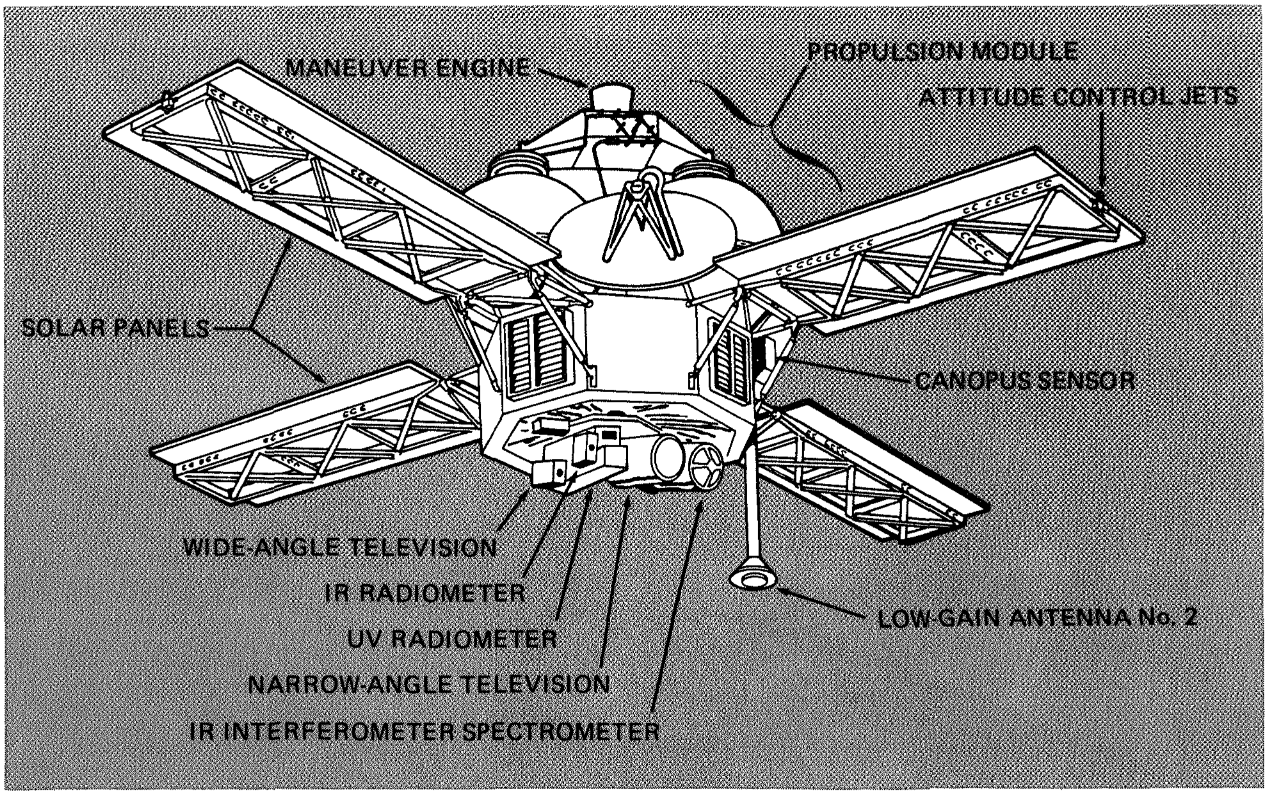
To obtain precursory scientific information beyond the orbit of Mars with the following relative emphasis: (1) Investigation of the interplanetary medium; (2) The nature of the Asteroid Belt, both scientifically and as a hazard to the space flight; and (3) Exploration of the magnetosphere and atmosphere of Jupiter. The secondary objective is to develop the technology for long duration flights to the outer planets.

Technical Data:

Orbit:	Heliocentric to about 5 AU
Launch Vehicle:	Atlas/Centaur/TE 364
Launch Site:	Eastern Test Range
New Technology:	Source of electrical power at 5 AU

Status:

Preliminary studies are underway to determine the proper power source: Solar or RTG powered. Flights are planned for CY 1972 and CY 1973.



MARINER-MARS 1971

Objectives:

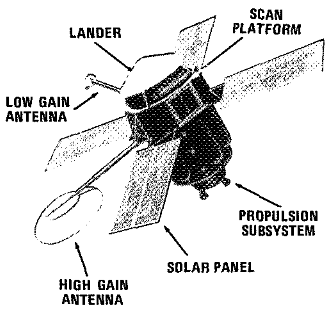
To observe, from an orbiting spacecraft, the daily and seasonal variation of the planet leading to an evaluation of its dynamic characteristics and processes. This evaluation is essential to the understanding of Martian biology. Topographical and thermal mapping of the Martian surface is also to be included. This mission also is to develop the necessary technology for long-term planetary orbital observations. In terms of scientific data, the return from the 1971 orbiter would be over 10 times greater than that of the 1969 Mariner-Mars flyby.

Technical Data:

Launch Vehicle: Atlas/Centaur
Launch Site: Eastern Test Range
New Technology: Improved orbital operations technology and increased telecommunications capability.

GROSS WEIGHT	2000 POUNDS
INSTRUMENT WEIGHT	120 POUNDS
TYPES OF INVESTIGATIONS BEING CONSIDERED:	
TELEVISION	UV SPECTROMETER
IR RADIOMETER	S-BAND OCCULTATION
IR SPECTROMETER	CELESTIAL MECHANICS
POWER	350-400 WATTS
STABILIZATION	3 AXIS
DESIGN LIFE	180 DAYS CRUISE 90 DAYS ORBIT
MISSION	MARS ORBITER
LAUNCH	MAY, 1971

Status:
Mission design studies underway. Flight planned for CY1971.



	ORBITER	LANDER
Useful Weight In Orbit	900-1200 Pounds	1700 Pounds
Instrument Wts	160-200 Pounds	16 Pounds (Entry) 23 Pounds (Surface)
Types of Investigations Being Considered	Television IR Radiometer IR Spectrometer UV Spectrometer S-Band Occultation Celestial Mechanics	**Entry:** Accelerometers Pressure Temperature Atm. Composition **Surface:** Camera Atmospheric Composition Soil Organic Analysis Life Detection Water Detection
Power	400-500 Watts	
Stabilization	3 Axis	
Design Life	180 Days Cruise 180 Days Orbit	3 Days Min.– 90 Days Max.
Mission	Mars Orbiter	Lander
Launch	July, 1973	

TITAN-MARS 1973

Objectives:

To allow additional and extended observations of the dynamic characteristics and processes of the planet Mars during a different opportunity and under different seasonal conditions than the 1971 Mars Orbiter and to permit more and improved orbiter instrumentation. The Lander is to allow direct measurements of the Martian atmospheric pressure, temperature, and composition for the first time in the history of our planetary exploration program and to give us our first look at the surface, initiate the direct search for extra terrestrial life, measure surface moisture, and determine elementary composition of the surface.

The 1973 Orbiter and Lander combination would significantly extend our growing knowledge of Mars derived from the 1969 flyby and the 1971 Orbiter. Detailed knowledge of Martian atmosphere and surface and the improved technology utilized would make major contributions to the ultimate goal of landing surface laboratories for detailed Martian investigation.

Technical Data:

Launch Vehicle: Titan III D/Centaur
Launch Site: Eastern Test Range
New Technology: Improved telecommunications capabilities
Sterilization
Aeroshell and heat shield technology
Probe technology

Status:

Currently in the mission study phase. The flight is planned for CY1973.

BIOSCIENCE

PROGRAM	APPROVED & UNDERWAY	APPROVED TO BEGIN FY 1969
BIOSCIENCE	BIOSATELLITE (C,D,E,F) Six Earth Orbital Missions, 2 completed, 4 remaining. Experiments on the effects of weightless and radiation—together and separately—on the metabolism, growth and reproduction of relatively simple plant and animal tissues. The primate experiments will study the performance and reactions of the central nervous, cardiovascular, metabolic and hemodynamic systems during weightless conditions. Human tissue cultures, rats and small flowering plants will also be flown to study the cellular-level effects of the space environment. APOLLO Return lunar sample analysis	NO NEW PROGRAMS

SPACE APPLICATIONS

SPACE APPLICATIONS	APPROVED AND NOW UNDERWAY	APPROVED TO BEGIN IN FY 1969
METEOROLOGY	TIROS M Day and night cloud observational capability for local and global readout in a single satellite, to advance the TIROS Operational Satellite (TOS) System. NIMBUS, B-2, D, E, and F Periodic Quantitative observation of the structure of the atmosphere, with improved sensors, upon which to base operational systems for quantitative global measurements for comparison with numerical models of the atmosphere.	No New Programs
COMMUNICATIONS	SR & T Research and development to establish a sound scientific and technological basis for future applications in communications, including systems studies in new mission areas.	No New Programs
GEODESY	SR & T Support of the National Geodetic Satellite Program. Establish one world datum. Improve positional accuracies of geodetic control stations and satellite tracking sites. Better define structure of Earth's gravitational field.	No New Programs
NAVIGATION AND TRAFFIC CONTROL	SR & T Establishment of specific requirements and development of space technology needed to provide position information to ships and aircraft and more reliable means of communication and data transfer which will serve traffic control, traffic coordination and emergency aid.	No New Programs

SPACE APPLICATIONS (Continued)

SPACE APPLICATIONS	APPROVED AND NOW UNDERWAY	APPROVED TO BEGIN IN FY 1969
EARTH RESOURCES SURVEY	SR & T Research and development to determine, in cooperation with potential users, which Earth resources data can be acquired effectively from space. Development of combinations of instruments and subsystems potentially useful for collection and analysis of such data. Remote sensor measurements from aircraft flying over test sites at which "ground truth" has been established.	AUGMENTED AIRCRAFT PROGRAM More frequent flights, with improved sensors and higher capability aircraft. Observations from much higher altitudes. EARTH RESOURCES TECHNOLOGY SATELLITE (ERTS) STUDIES The studies planned for Fiscal Year 1969 are to specify sensor payloads, and determine the potential economic benefits which might be obtainable. These studies are to determine those Earth resources data which may be best acquired from space and to investigate, in cooperation with the Departments of Interior, Agriculture, and Commerce, and NAVOCEANO, technology required for the acquisition and utilization of such data. The ERTS is envisioned as an essential link in the sequence of laboratory, aircraft, and short duration space flight experiments leading to future operational satellite systems.
TECHNIQUES IN SYNCHRONOUS ORBIT	ATS – E, F, & G Geostationary satellites to test gravity gradient stabilization, active 3-axis stabilization, accurate pointing (± 0.1 degree), large space-deployable antennas, high-power phased arrays, communications in new frequency regions, & new meteorological sensors. F & G are second generation spacecraft.	NO NEW PROGRAMS

6 future mission options

Many factors must be considered in selecting the best missions for implementation from among the many technically feasible proposals of great merit. This selection is further complicated by the difficulty of judging the relative national priority of the project objectives, be they in science, technology, or applications of direct benefit to mankind.

In science, for example, there are still many virgin areas where little or no knowledge or understanding exists beyond what can be surmised from ground-based research. Proposals for initial search for knowledge in these areas must be considered on merit against proposals to extend knowledge in areas of science where at least initial, or precursor investigations have been successfully carried out.

Our inability to look very far into the future in many areas of science makes it difficult to forecast the knowledge we will gain from any one or series of space missions. Proposals must frequently be accepted on faith and the instinctive belief, frequently born out, that the greatest advances come in the areas of greatest ignorance.

Our ability to look far into the future is further limited by the difficulty of forecasting technological development. Only a few years ago it would have been difficult to predict our present technological capability, much less to accurately foresee its development in the future. Many of today's technology barriers to attractive space research can be expected to disappear. Experience shows it reasonable to set apparently impossible research goals and to then undertake the technology necessary to achieve them. But it also points out the folly of making too firm or too distant plans. New knowledge is certain to require continuing adjustment and redirection as we progress, and plans must be kept flexible.

In addition to factors of merit, priority and feasibility as discussed above, consideration must be given to social and economic factors and the political process of decision making in our democratic form of government.

The Nation each year reassesses its future goals, the proper means to achieve them, and the relative emphasis that should be placed upon each. This assessment begins with the development of the annual budget by the President for consideration by the Congress and culminates in the appropriation of the funds by the Congress for the President to undertake those parts of the program which it approves. In preparing the budget and enacting the final appropriations the future needs of the country are evaluated in light of today's environment and its projection into the future.

This whole process of assessment determines the relative emphasis the country will place on the exploration of space, solving the problems of the cities, transportation and other needs. No one in the Nation can accurately predict the outcome of such an assessment even for the next few years. In addition, as one looks within the space program it is equally difficult to accurately assess the future of astronomy vis-a-vis space applications vis-a-vis planetary exploration, etc.

Selection must also consider the order, time and pace with which a proposal should or could be implemented. There is a best time, and a span of acceptable times, when a project should be implemented and there is a level of activity, a pace, at which a project should procede to allow exploitation of the results of earlier work. Occasionally, where a project provides needed preliminary knowledge for a later high priority project it may be paced by the follow-on project.

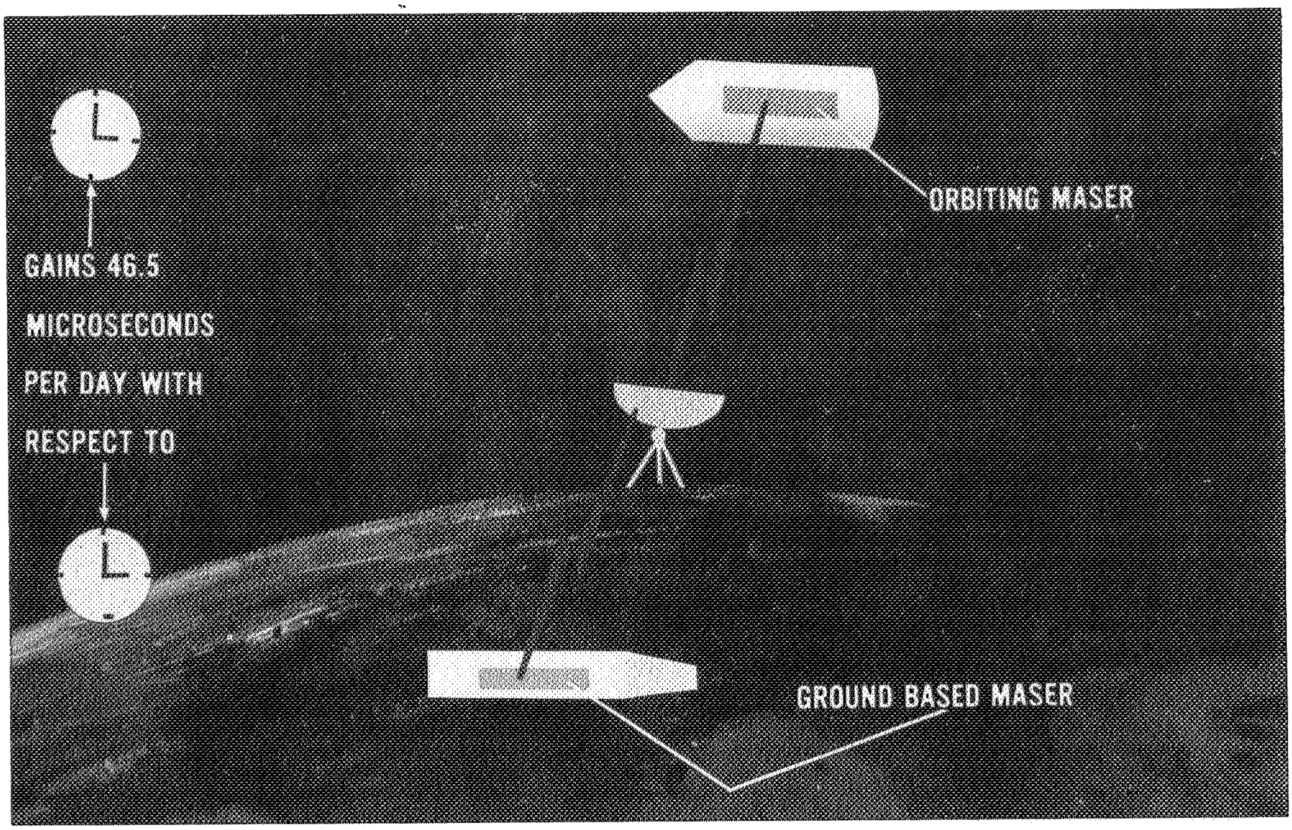
The program which results from the overall selection process must maintain continuity and balance. Management must distribute resources and manage priorities in the space program so as to maintain a viable effort in each area which it plans to continue even while emphasizing those parts of the overall program given greatest priority.

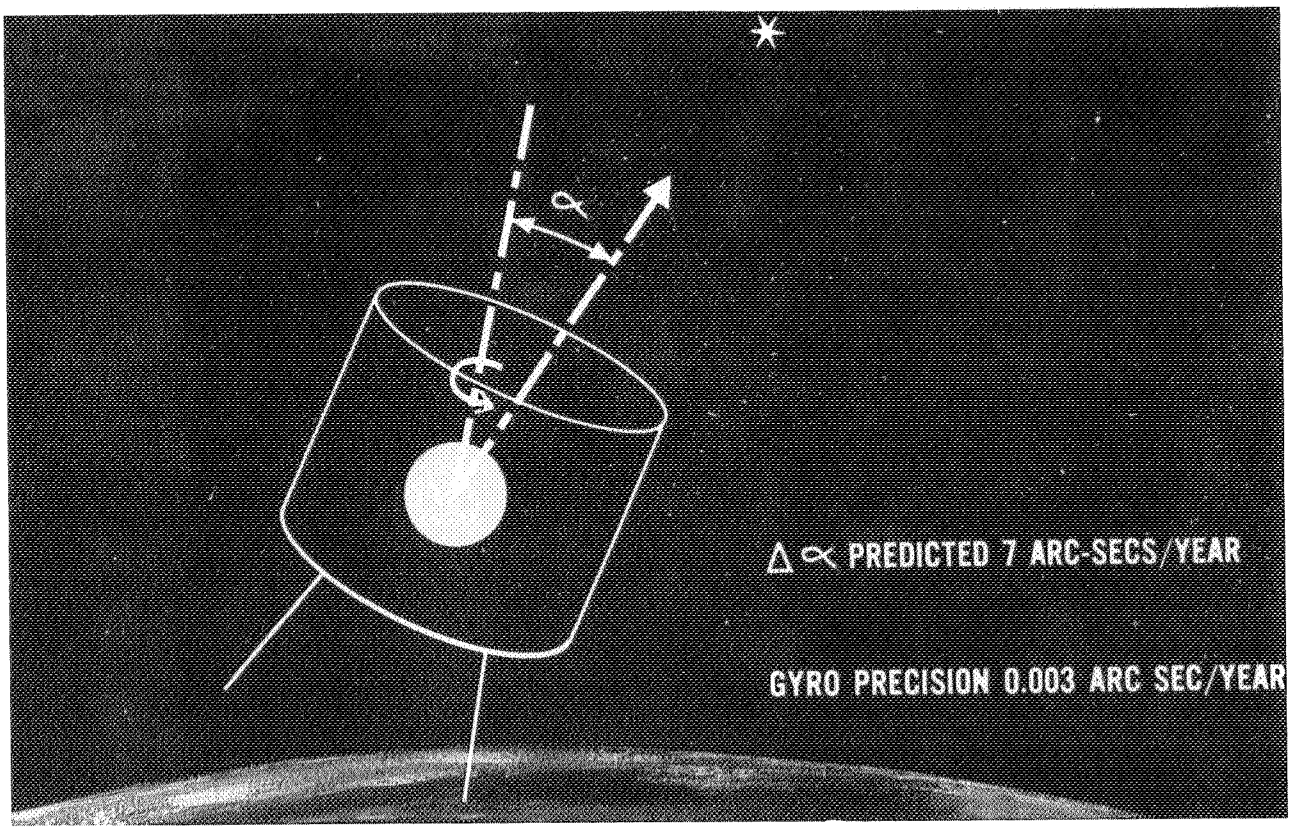
Because of these considerations, the ability to look into the future and predict with high confidence the programs and the missions that will be undertaken is indeed limited. However, at this point in time, it is possible to discuss some of the possibilities for future space exploration that are presently under study. The material in this section attempts to indicate some of the possibilities that are under consideration for future implementation building upon the present program and the ones initiated in FY 1969.

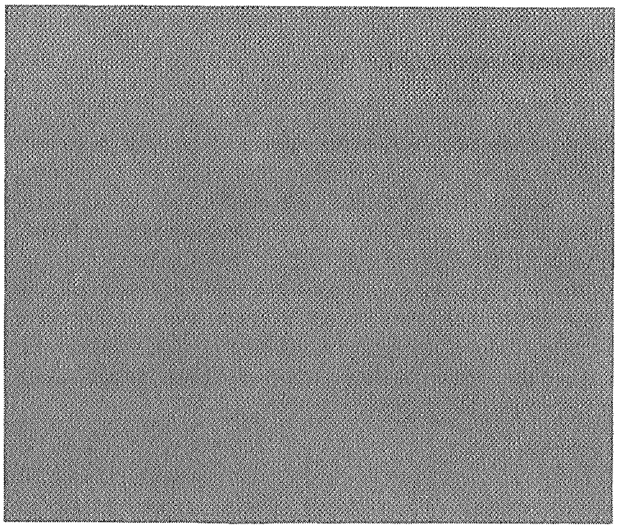
SPACE PHYSICS

PROGRAM	APPROVED & UNDER WAY	APPROVED TO BEGIN FY-1969	PLANNED FOR INITIATION IN EARLY 1970's	
Space Physics	ORBITING GEOPHYSICAL OBSERVATORY (OGO-F) PHYSICS EXPLORERS PIONEER D & E SOUNDING ROCKETS BALLOONS	PHYSICS EXPLORER–SUNBLAZER	RELATIVITY EXPERIMENT Two alternate missions are being considered to test the general theory of relativity; one flying a hydrogen maser on a large spacecraft in synchronous orbit, the other flying a very accurate gyroscope on a Delta size spacecraft in circular orbit about 300 nm high. PHYSICS EXPLORERS Advance class of Delta launched spacecraft missions stressing: Onboard propulsion for low altitude orbit maintenance and orbit changes for studies of the atmosphere, Computerized control of selective measurements within the magnetosphere and interplanetary environments. Scout launched spacecraft for correlative studies of specific Earth environment phenomena, e.g. measuring the composition, size distribution and influx of meteoric particles in Earth orbit. Missions to explore the region of the solar system from 0.1 Au out through the Asteroid Belt and out of the plane of the ecliptic. Particular emphasis would be given to the particle population in the Asteroid Belt but would also obtain data on the character of solar particles and the solar wind in this region.	CLUSTERED SATELLITE A grouping of several satellites maintained in close proximety to one another in order to obtain the high spatial resolution needed for investigating dynamic phenomena in the Earth's magnetosphere. MANNED EARTH ORBITAL SPACE LABORATORY Exploitation of manned orbital capability to conduct physics experiments of value not feasible on Earth.

BEING CONSIDERED FOR FY 1970 AND BEYOND







RELATIVITY EXPERIMENTS

HYDROGEN MASER

Objectives

To test the general theory of relativity by measuring the relativistic effects of gravity and of motion on time.

The relativity theory of gravitation predicts that a clock in a circular synchronous orbit will gain 46.5 microseconds per day with respect to an identical clock on the surface of the Earth. The present hydrogen masers have a stability of 3×10^{-13} or better and with such stability the effects of the gravitational potential on time should be measurable to an accuracy of 0.05 per cent which is a factor of 20 improvement over the best present measurement. It is expected that this experimental precision can be increased by additional advances in hydrogen maser technology.

Technical Data

Orbit:	Synchronous
Launch Date:	The experiment can be ready for launch in 1973
Launch Vehicle:	Not determined
Launch Site:	Eastern Test Range

Status

Working masers exist; prototypes are being designed and associated equipment is being fabricated. The development of a model of the maser coordinated with that of the electronics will be tested together as a clock system.

GYRO:

Objectives

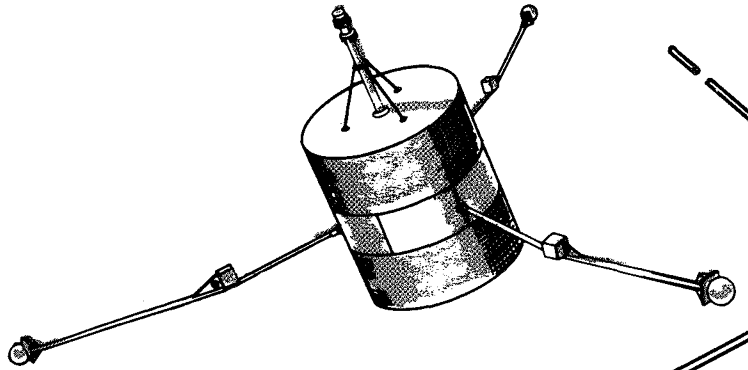
To test the general theory of relativity by measuring the precession (about 7 arc-seconds per year) of the axis of a very accurate orbiting gyroscope with respect to a stellar inertial coordinate system.

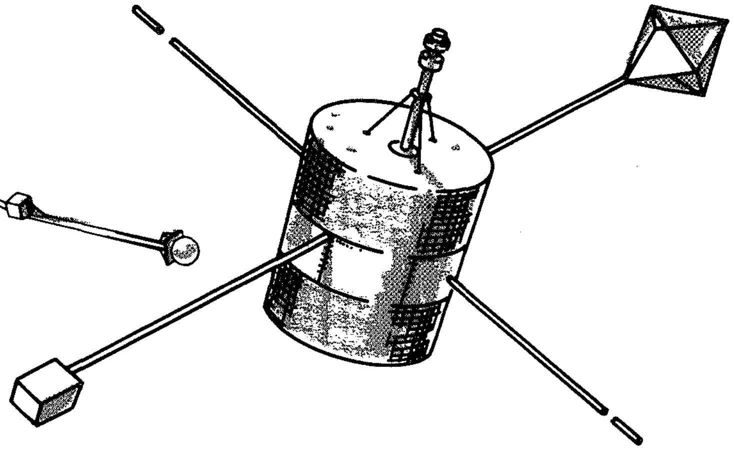
Technical Data

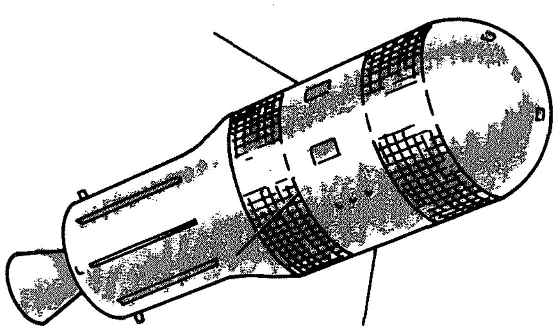
Orbit:	300 n. m. circular
Launch Date:	about 1975
Launch Vehicle:	TAT/Delta
Launch Site:	Eastern Test Range

Status:

Completion of gyroscope components design in progress will make possible the assembly and testing of the laboratory model of the experiment. Preliminary testing includes the checking of the levitation system for the gyroscope, functional testing at low temperatures, and gyro helium-gas spin-up to verify the laboratory development.







SPACECRAFT WEIGHT: 200 - 900 POUNDS
EXPERIMENT WEIGHT: 50 - 150 POUNDS

PHYSICS EXPLORERS

Objectives:

Conduct well-defined experiments to provide a clearer understanding of the Earth's environment (including interplanetary space) and the evolution of physical theories (e.g., chemistry of the atmosphere, diffusion processes, atmospheric dynamics, atmospheric heating, wave propagation, particle-wave interaction, plasma instabilities, magnetic field irregularities, collisionless shocks). The clearer understanding would have application in understanding weather, long range communications, and in space travel.

Technical Data:

Orbits: Selected for specific research objective; will range from low altitude to 20 Earth radii and beyond.

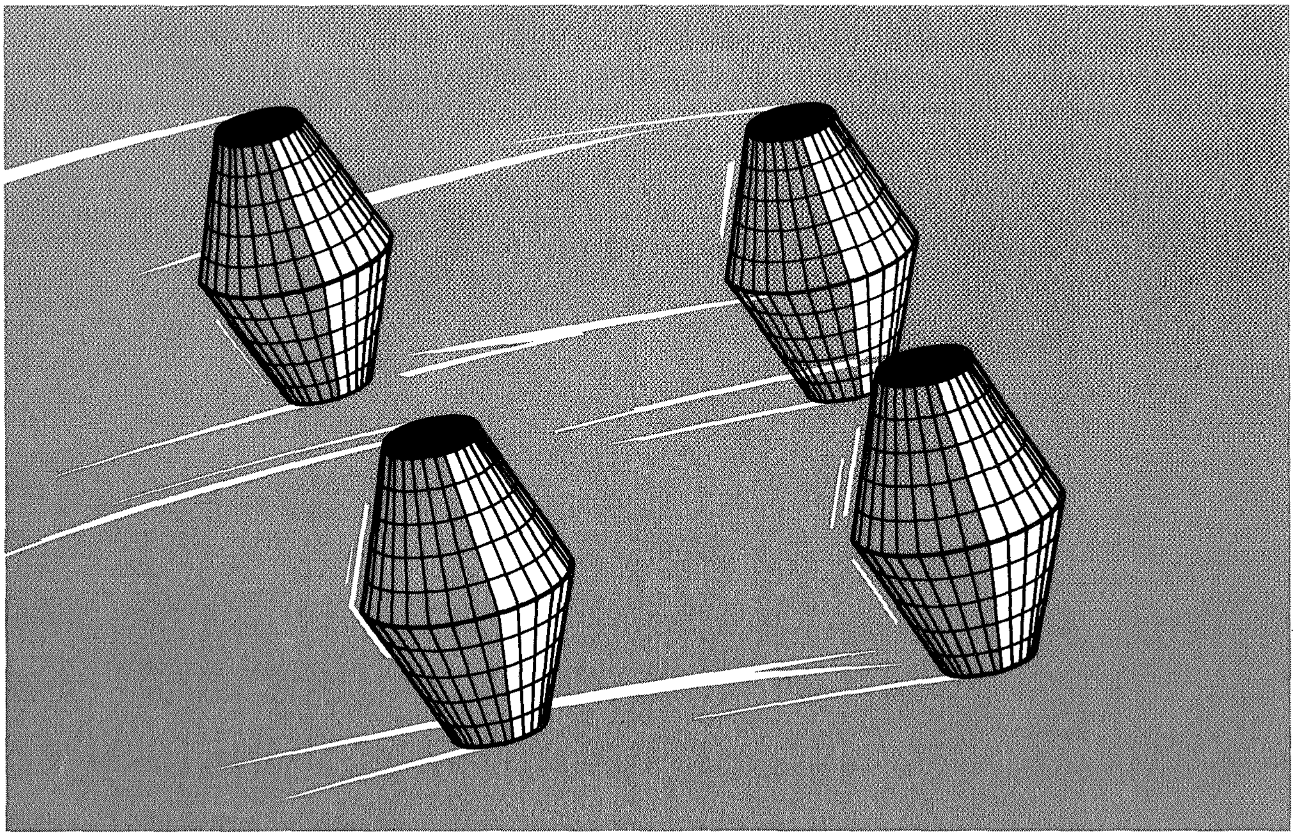
Launch Vehicle: Scout and Delta Class

Launch Site: Eastern Test Range

Technology Required: On-board propulsion for maintenance of low altitude orbits, and minor orbit adjustments. To optimize satellite operations on-board computers would be essential for flexibility in experiment programming and for selective data processing.

Status:

Advanced studies for low altitude missions are completed and design studies have been initiated. Conceptual designs for magnetospheric missions have been evolved. A scientific group has been assigned responsibility for defining scientific objectives for research in specific areas and outlining related mission requirements.



CLUSTERED SATELLITES

Objectives:
Studies of collisionless shock and magnetoshpheric neutral sheet. Simultaneous measurements from several satellites in close proximity (10-1000 km) are required to resolve spatial and temporal effects.

Status:
First flight projected for early 1970's.

System studies are being considered for initiation in Fiscal Year 1970.

Technical Data:

Orbits:	20 Earth radii and beyond
Launch Vehicle:	Delta Class
Launch Site:	Existing sites
Technology Required:	Deployment and station keeping techniques

SPACECRAFT WEIGHT:	**120-150 pounds each**
EXPERIMENT WEIGHT:	**20-30 pounds**

ASTRONOMY

PROGRAM	APPROVED & UNDER WAY	APPROVED TO BEGIN FY-1969	PLANNED FOR INITIATION IN EARLY 1970's	PLANNED FOR INITIATION IN MID 1970'S AND BEYOND
Astronomy	ORBITING ASTRONOMICAL OBSERVATORY (OAO-A_2, B, C) ORBITING SOLAR OBSERVATORY (OSO-G, H) APOLLO TELESCOPE MOUNT (ATM-A) SMALL ASTRONOMY EXPLORER (SAS--A)	ASTRA Study SMALL ASTRONOMY EXPLORER (SAS-B)	ASTRA--Design & Development Perform very high resolution telescopic observation of the sun, planets, stars, and galaxies with a set of large aperture optics and exploit both automated and manned space technology to develop an observatory for manned operation and maintainability prior to the observatories of the future, i.e., the National Astronomical Space Observatory. ORBITING ASTRONOMICAL OBSERVATORY (OAO FOLLOW-ON) As needed to complement the ATM and ASTRA programs; would continue OAO type of activity — ultra-violet observations and in addition include x-ray and infrared capability. Also the introduction of spacecraft devoted primarily to guest observers. OBRITING SOLAR OBSERVATORY (OSO FOLLOW-ON) Continue solar observation but with better spatial, spectral and temporal resolution, provided by improvements which reflect technology advances in pointing, weight carrying, data handling, command control, etc. ASTRONOMY EXPLORERS (SAS-C, D) Small spacecraft to perform broad surveys and special studies of stellar X-ray gamma-ray and ultra-violet sources.	NATIONAL ASTRONOMY SPACE OBSERVATORY (NASO) Very large aperture, highest precision instruments to perform astronomical observations in a variety of wavelengths. Under continuing study towards mission in early 1980's.

ASTRA

Objectives:

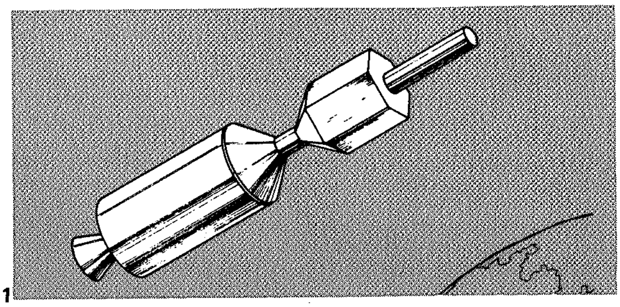
Perform very high resolution telescopic observations of the planets, stars, and galaxies with a set of large apetrue optics and to exploit both automated and manned space technology to develop a stellar observatory for operation and maintainability prior to the observatories of the future i.e., the National Astronomical Space Observatory.

Technical Data:

Orbit: 300 to 350 nautical miles, circular
Launch Vehicle: Atlas/Centaur
Launch Site: Eastern Test Range
Technology Required: Diffraction limited optics with pointing stability to 0.01 arc-seconds for several hours

Status:

Preliminary feasibility studies have been performed. Conceptual studies are planned for FY 1969. Basic technology developed on the OAO and ATM projects is to be adapted. The first flight could be in mid 70's.



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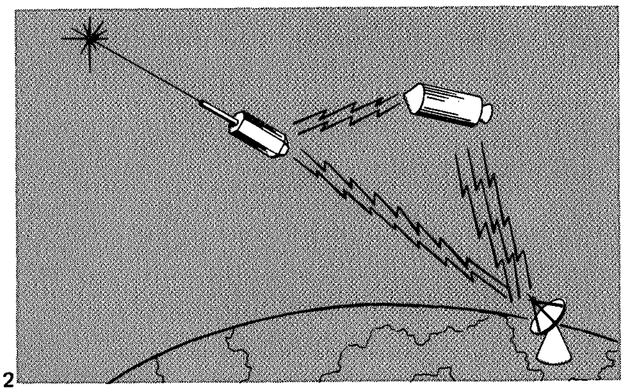

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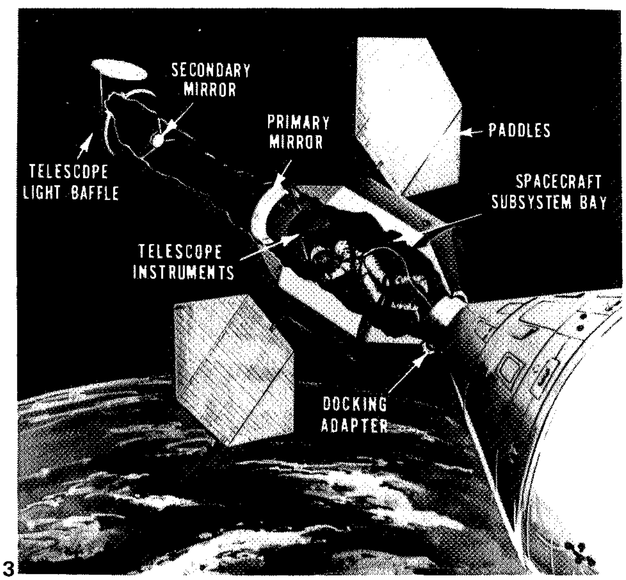
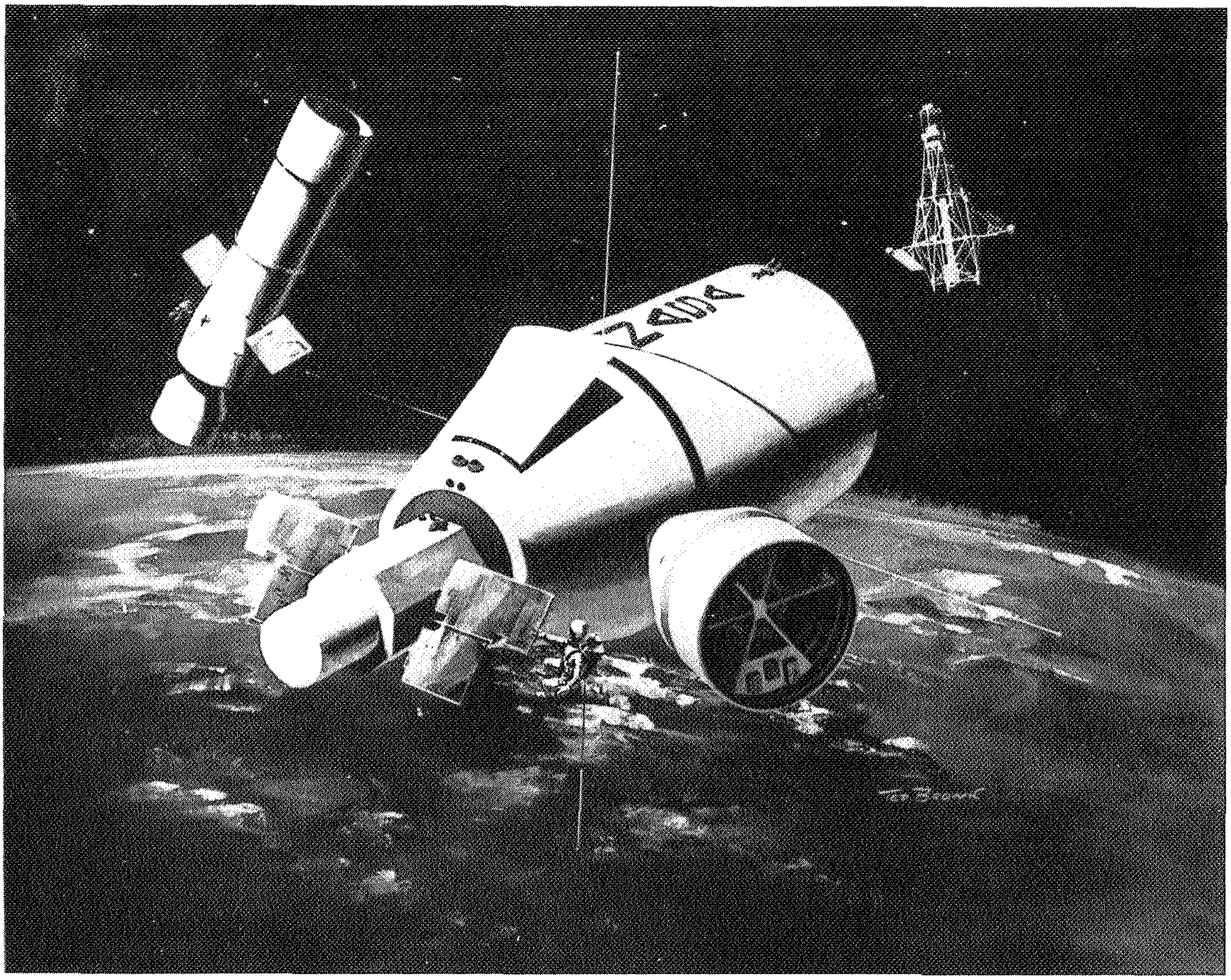


3

1. MAN ATTENDED
2. AUTOMATED
3. SPACECRAFT CONCEPT



NATIONAL ASTRONOMICAL SPACE OBSERVATORY (NASO)

Objectives

A national astronomical observatory in space would consist of very large aperture, highest precision instrumentation to conduct a wide variety of astronomical observations in wavelengths ranging from hard gamma-rays to long wave radiowaves. Celestial objects and detail far beyond current ground-based capabilities would be observed. These large instruments of discovery, thus, would be directed toward answering man's fundamental questions about the structure, origin and evolution of the universe.

Technical Data:

Orbit: Synchronous or low orbit
Launch Site: Eastern Test Range
Technology Required:

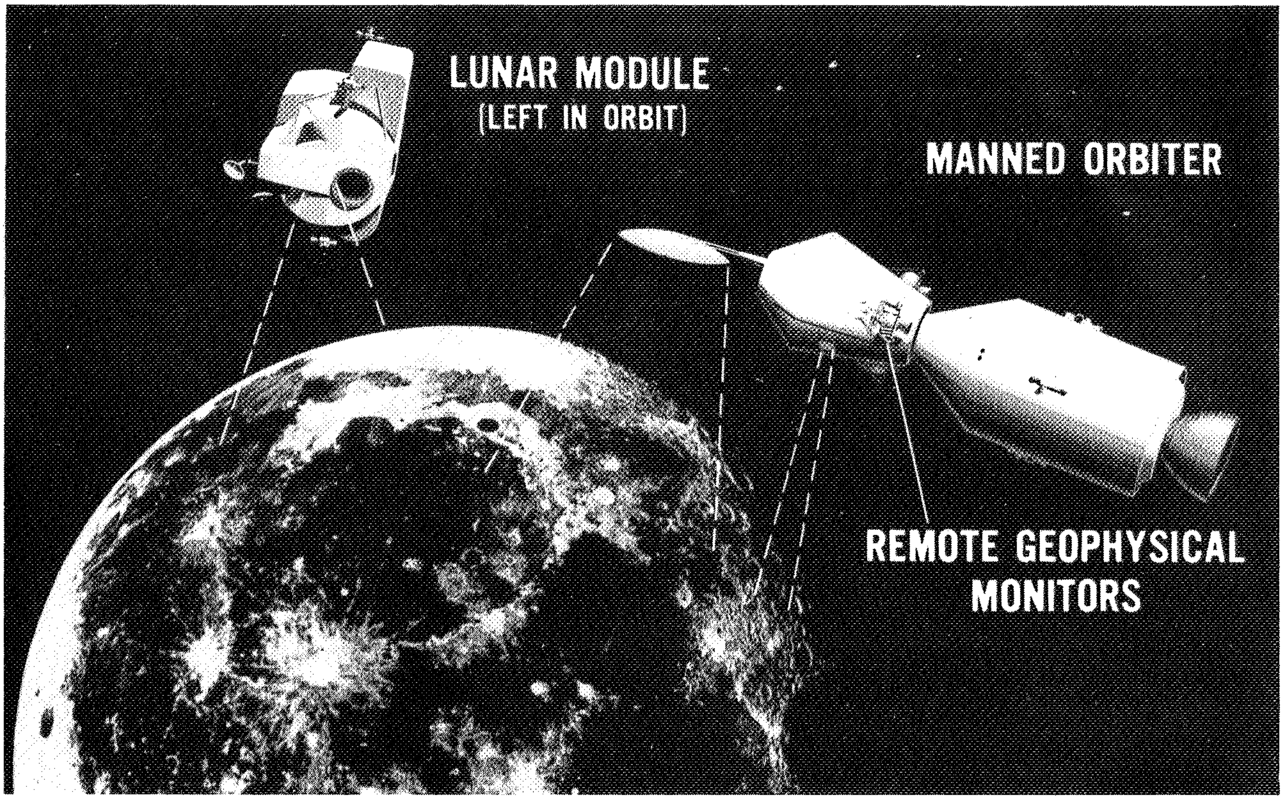
- Improved mirror materials and construction for long term, high precision stability.
- Mirror surfaces to provide high UV reflectivity, precision of figure and freedom from scattering and polarization.
- Methods of rapidly evaluating mirror figure and system alignment under normal and zero gravity.
- Methods of generating and maintaining diffraction-limited mirror quality and performances in space.
- Development of techniques and procedures for maintenance in orbit.
- Development of attitude control systems to 0.003 arc seconds stability.

Status:

Initial conceptual studies have been performed. Advanced component research in progress. Program planning directed toward initial mission in early 1980's.

LUNAR EXPLORATION

PROGRAM	APPROVED & UNDERWAY	APPROVED TO BEGIN FY 1969	PLANNED FOR INITIATION IN EARLY 1970'S
LUNAR EXPLORATION	APOLLO The first landing of man on the Moon to collect lunar material for return to Earth, emplace geophysical instrumentation for long-term observations and conduct field geology investigations.	Planning for extended Lunar exploration operations which are to be centered around augmented landed payloads, greater mobility on the Lunar surface and longer stay times on the Moon largely for scientific observations.	The character and projects for the Post Apollo Program for Lunar Exploration is currently under intensive study. The projects presently being considered include: Advance Lunar Orbital Missions CSM Science and Subsatellites Remote Geophysical Monitor Lunar Flying Unit Lunar Roving Vehicle Lunar Drill Advance Alsep (Surface Science)



ADVANCED LUNAR ORBITAL MISSIONS

Lunar orbital missions should be sequenced so that:

Orbital surveys precede landings at selected sites. Since the high resolution imagery which has been acquired is not adequate for a sustained Lunar exploration program, additional flights which return Lunar Orbiter-type data are needed early in the flight schedule. Twelve to eighteen months are required to turn photographs into mission design data and detailed maps of target areas.

Remote sensors are not ready for operational flight. Several instruments can be flown in feasibility tests using the orbiting CSM during manned Lunar surface missions. Metric mapping requiring film return and high resolution photography are ready for flight on the CSM in the late Apollo time period. However, the low latitude location of sites for initial surface missions will keep the orbiting CSM which has delivered the astronauts to the surface from higher latitude sites which are desired for later missions.

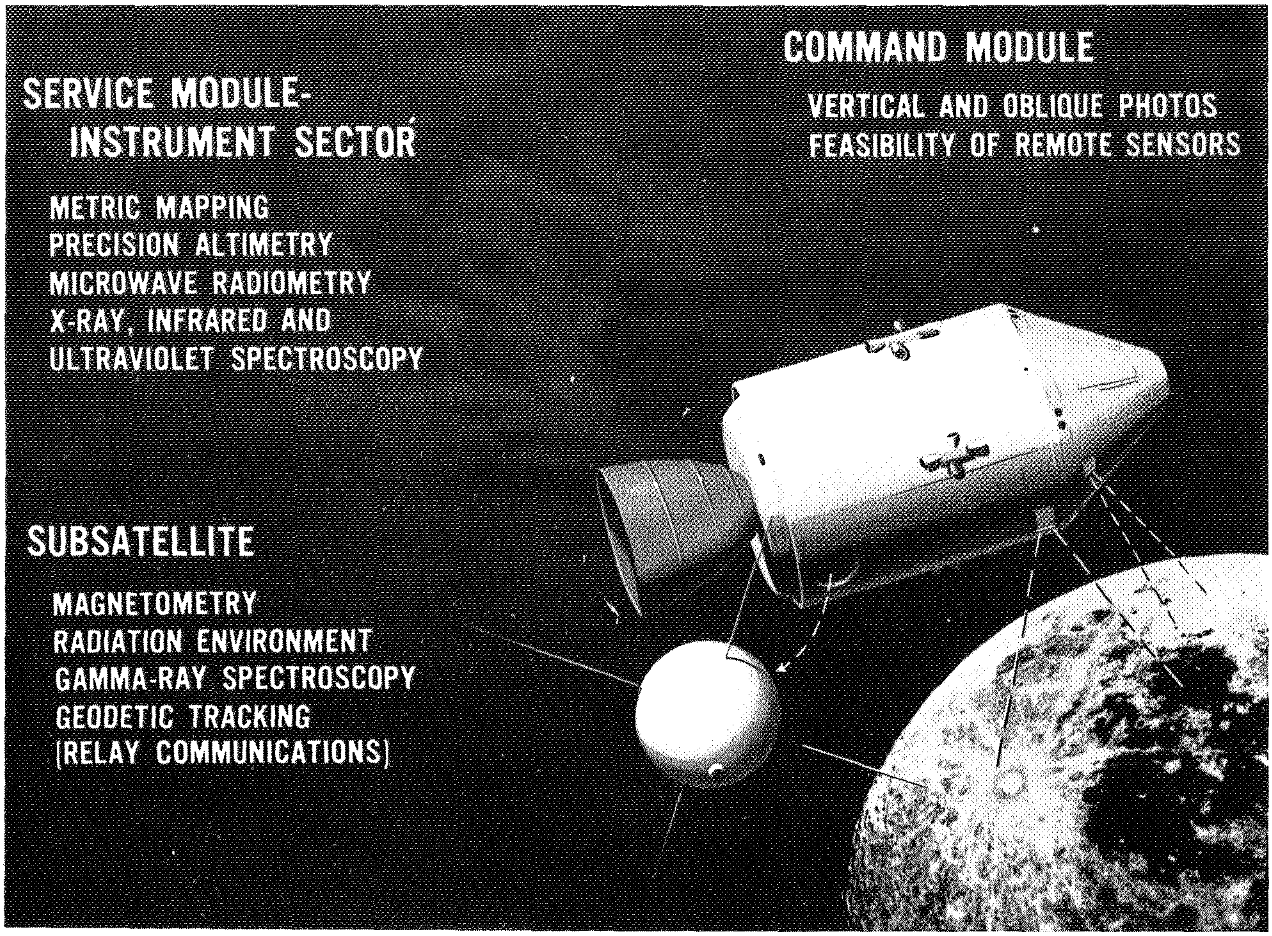
If remote sensing techniques prove feasible for survey of the Lunar surface, and heavy payloads of sophisticated instrumentation must be flown simultaneously to acquire data from multiple sensors, then manned Lunar missions for orbital purposes or automated spacecraft designed for advanced remote sensing may be required late in the Exploration phase.

Lunar orbital missions should be programmed in three phases:

- Early, automated, high resolution imagery of the present Lunar Orbiter type for selection of landing sites and traverse routes,
- Use of the orbital portion (CSM) of manned Lunar missions for metric mapping and feasibility testing of remote sensors, and
- Possible flight(s) of manned Lunar orbiters late in the program with heavy payloads of sophisticated, second generation remote sensors of proven feasibility.

Flights of manned Lunar mission solely for orbital purposes, and flights of advanced Lunar Orbiters are *not* included in the latest Lunar exploration plan.

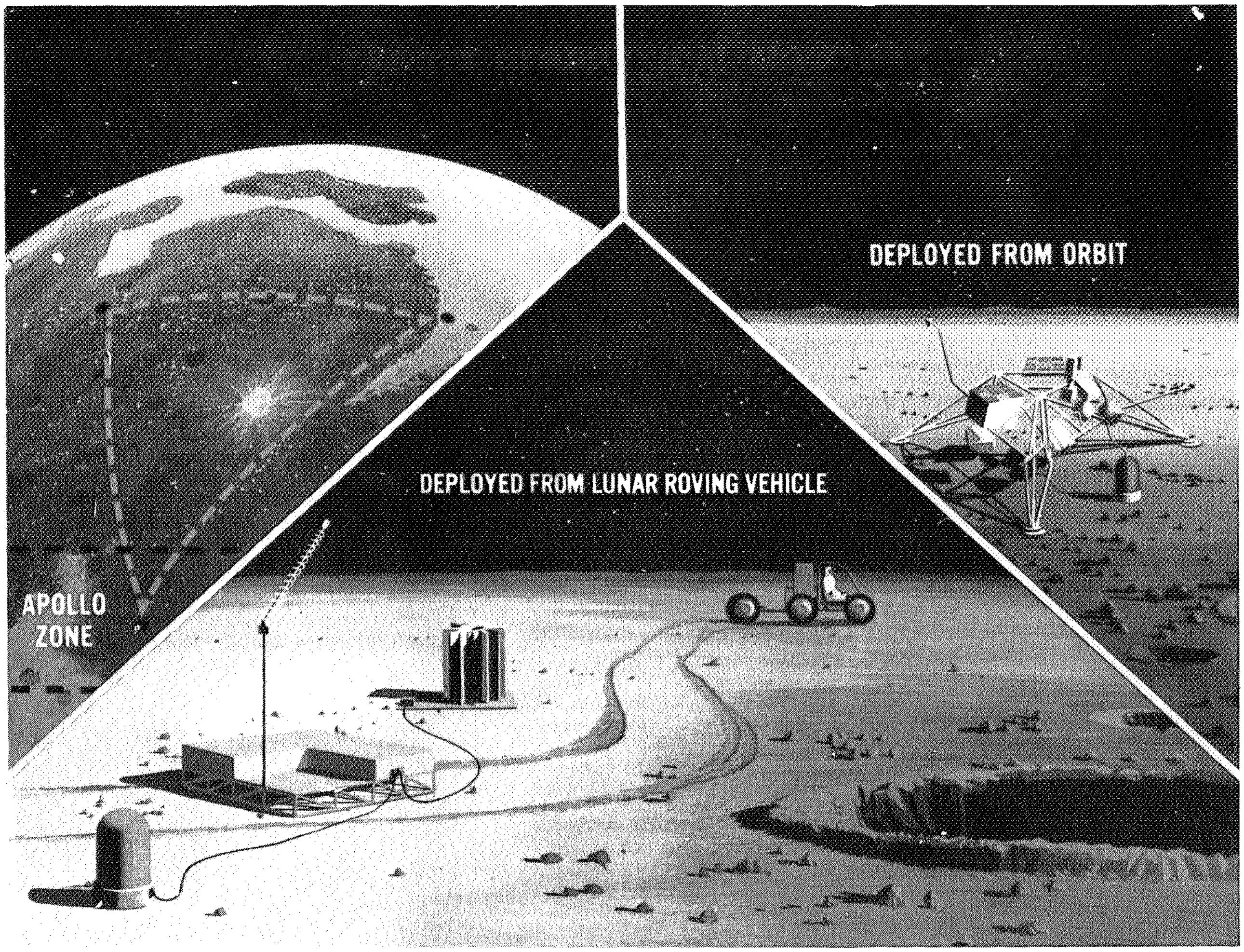
BEING CONSIDERED FOR FY 1970 AND BEYOND



COMMAND AND SERVICE MODULE AND SUBSATELLITE

Experiments in Lunar orbit will use science packages in the Command and Service Module and Subsatellites. The *Command and Service Module Package* and *Subsatellite* are related. As discussed on page 4-18, the objectives are to survey the surface of the Moon from Lunar orbit by vertical and oblique photography and precision altimetry; to obtain radiometric and spectroscopic measurements of the Lunar surface; and to measure the near-lunar environment, e.g., magnetic fields, nuclear particles, and density.

BEING CONSIDERED FOR FY 1970 AND BEYOND



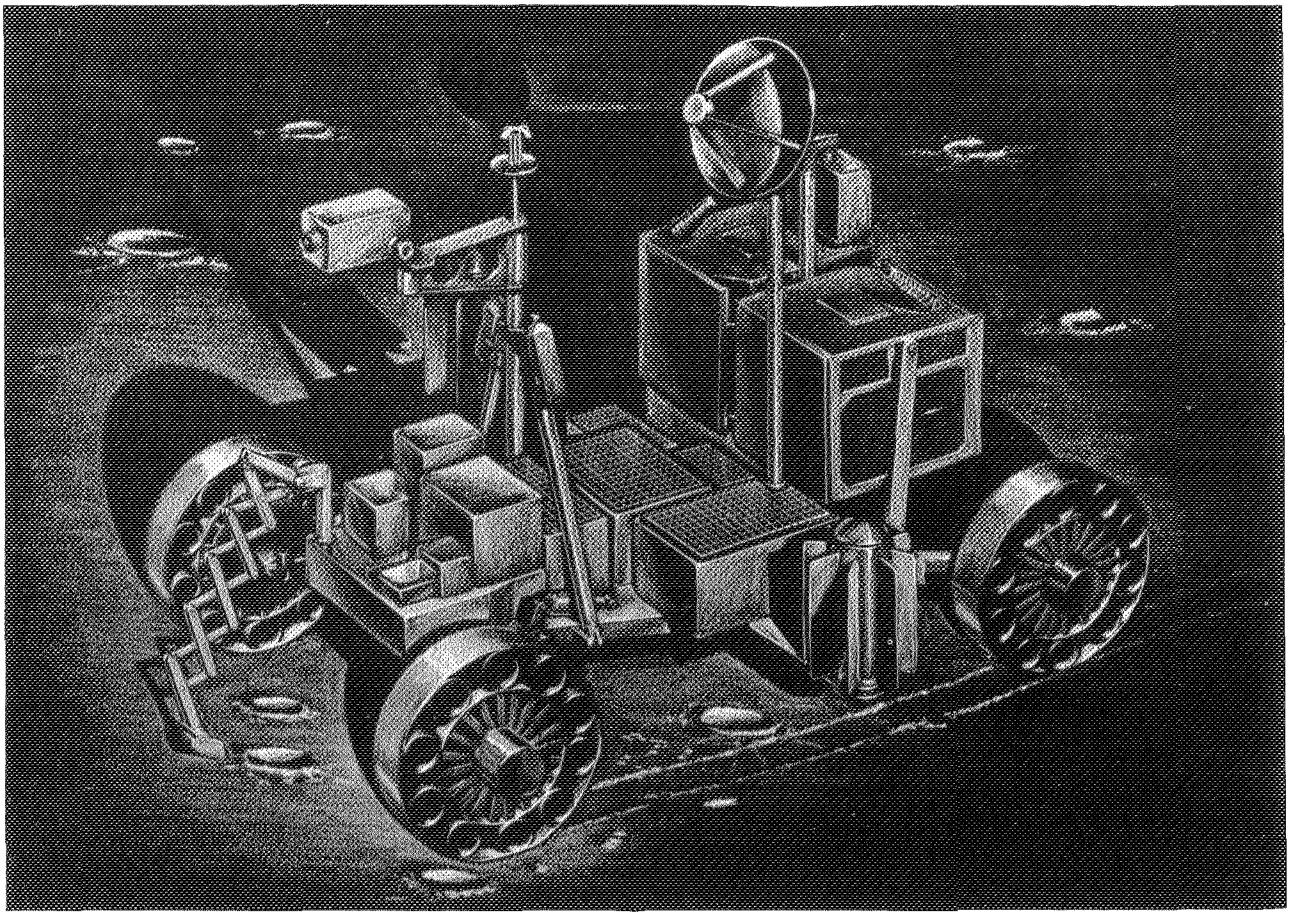
REMOTE GEOPHYSICAL MONITOR

As discussed on page 4-18, the objective of the *Remote Geophysical Monitors* is to establish a widely-spaced net of seismometers and gavimeters over the face of the Moon in conjunction with Advanced ALSEP deployment by manned landings. The Remote Geophysical Monitor would provide a network of many widely-spaced units with a minimum lifetime of two years operating simultaneously to allow detailed study of geologic, geophysical, and geodetic information. Data from seismometers and gravimeters deployed over the lunar surface would be the fundamental means of understanding the interior structure and the evolution of the Moon.

LUNAR FLYING UNIT

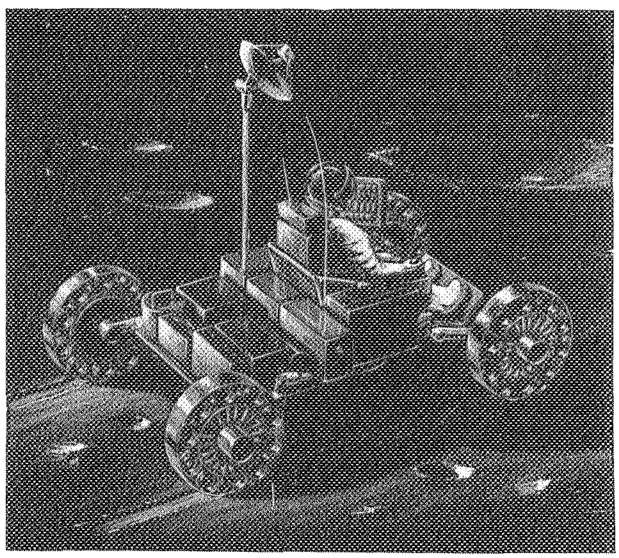
The Santa Cruz conference urged that a *Lunar Flying Unit* be developed immediately for later Apollo flights. The astronaut's increased mobility range would allow exploration of lunar surface features such as large craters and their environs as far as seven miles away from the landing site.

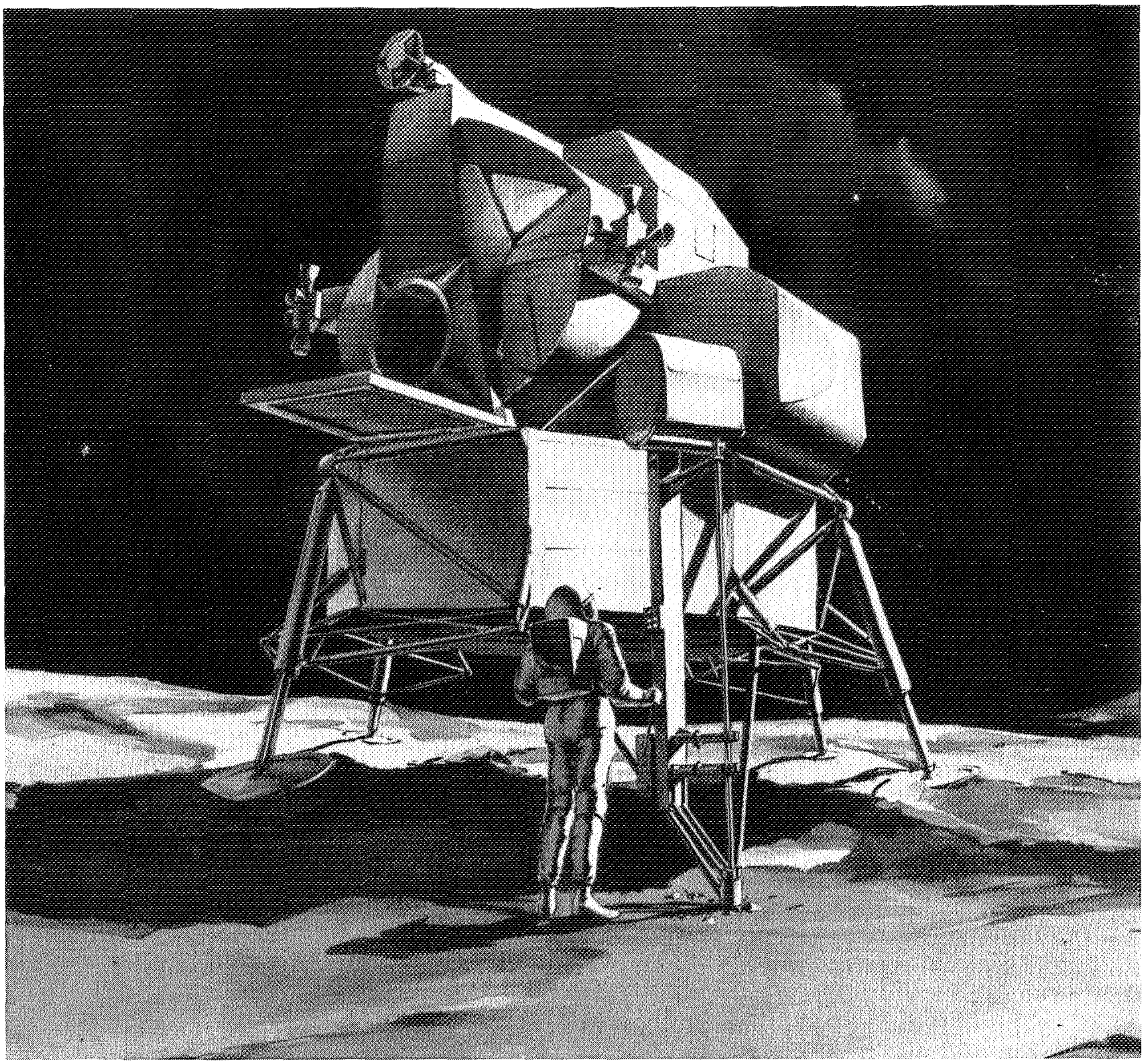
The *Lunar Flying Unit (LFU)* has been selected as the most promising means of providing astronaut mobility during Extended LM missions. Two of these 180-pound units would be carried on each Extended LM mission so that a rescue capability will be present. Residual descent stage propellants would fuel the LFU. Since each fueling requires up to 300 pounds of fuel and approximately 1,000 pounds of residuals may be available, at least three LFU sorties may be planned. The radius of operations with a LFU is dependent on a combination of factors, including safety and communications capabilities. Initial use would probably be limited to a radius of a few kilometers of the Extended LM. The LFU is currently in the definition phase.



LUNAR ROVING VEHICLE

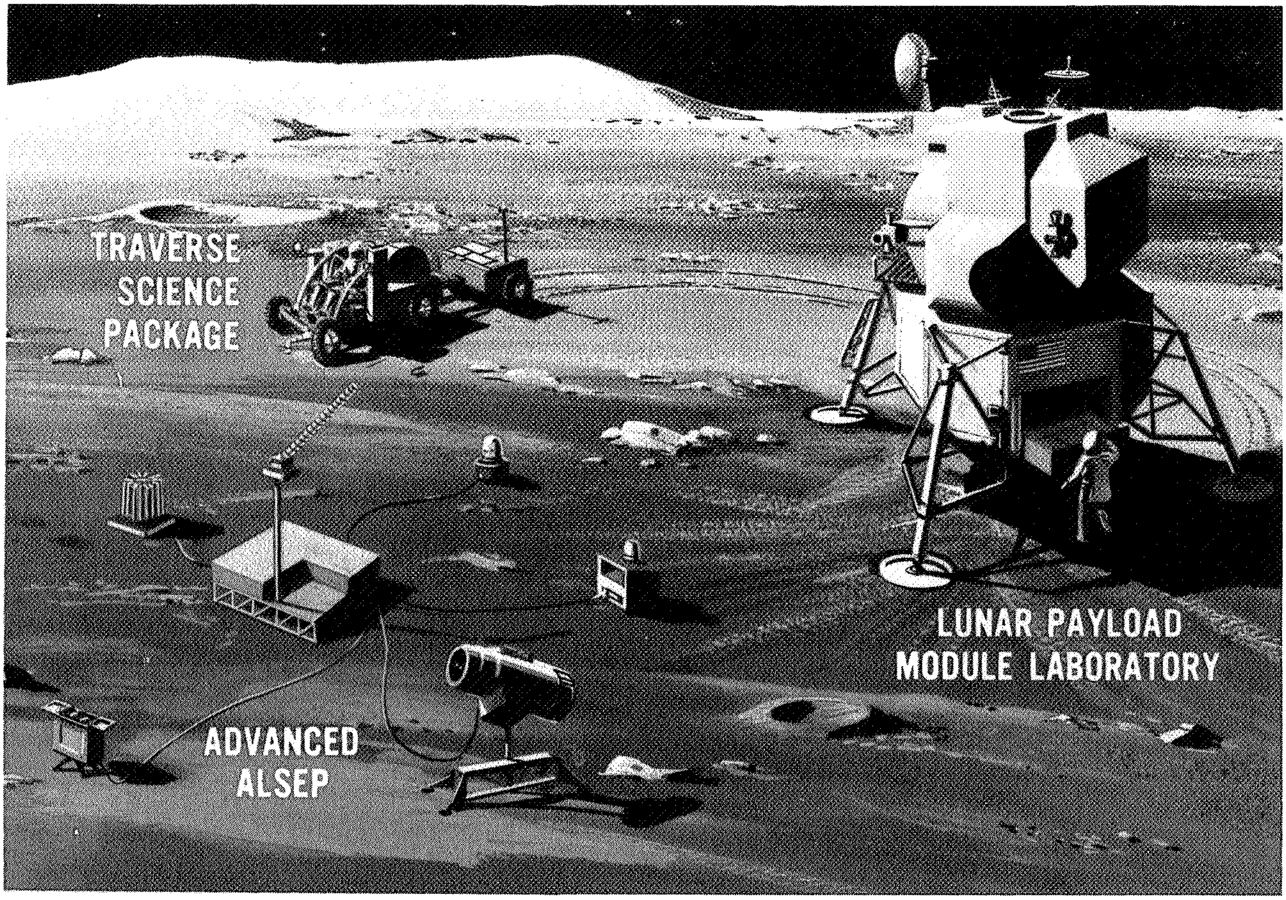
In addition to manned flying mobility, there is under study the concept of a Lunar Roving Vehicle, a further evolution of a concept earlier proposed as Field Assistant. This roving vehicle would be designed for long-range (up to 1200 miles) scientific traverses on the Moon operating in either an automated mode or carrying two astronauts. Operations of the automated LRV and its instrumentation would be controlled from Earth in the same manner as the Surveyor television camera and surface sampler. The vehicle would observe Lunar features and collect specimens, delivering its samples to rendezvous points for return to Earth by manned missions. At these manned landings sites, the LRV would locate rock outcrops and define scientific activities for the astronauts. The vehicle could evolve into one which is capable of being driven by the astronauts. A Titan/Centaur system could be the launch vehicle as well as the Saturn IB-Centaur and would also carry an automated science station as part of a lunar-wide geophysical monitoring network.





LUNAR DRILL

The Lunar drill is a modification of conventional terrestrial core drills designed so as to operate in the Lunar environment. It is a light weight, low powered, semi-automatic device that would be attached on the outside of the descent stage of the LM. This device would be able to drill a 2-inch diameter hole at least 100 feet deep into Lunar subsurface and recover a core from these rocks throughout this depth. In addition to the core which would be brought back for later study by scientists, the drill hole would support scientific investigations by the emplacement of heat-flow probes and geophysical logging devices, and possibly small explosive charges for seismic investigations.



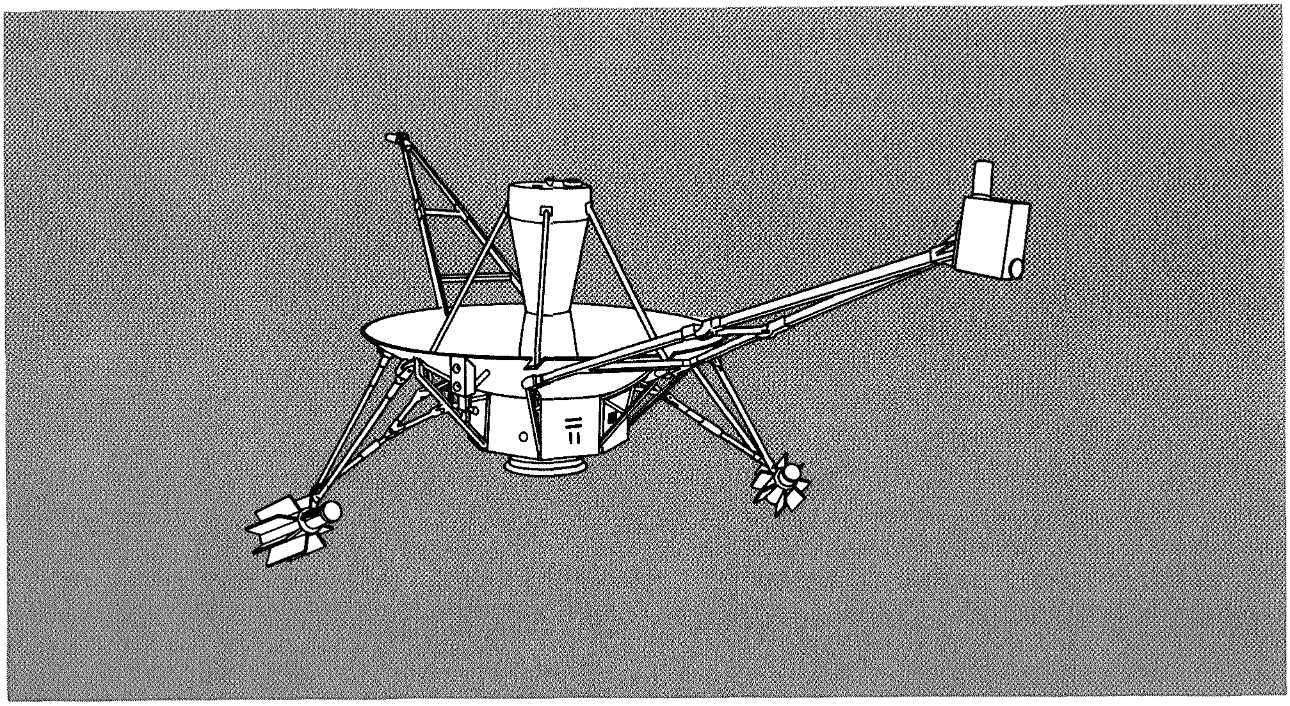
ADVANCED ALSEP

The *Advanced Apollo Lunar Surface Experiments Package (Advanced ALSEP)* is to be a growth version of ALSEP designed to carry additional experiments and to have greater interchangeability of instruments. As discussed on page 4-18 the objectives of the Advanced ALSEP's are: to measure and monitor the internal energy regime of the Moon, interaction of solar and cosmic environment with the Lunar surface, and response of the Lunar mass to gravitational forces exerted by the Earth and other solar system bodies; to investigate suitability of the Lunar surface for future studies; and, to search for evidence of organic or proto-organic materials.

Advanced ALSEP's would continue the physical properties measurements of initial missions and include instruments of other scientific disciplines such as biology and astronomy.

PLANETARY EXPLORATION PROGRAM

PROGRAM	APPROVED & UNDER WAY	APPROVED TO BEGIN FY-1969	PLANNED FOR INITIATION IN EARLY 1970'S	PLANNED FOR INITIATION IN MID-1970'S & BEYOND
Small size spacecraft (15-75 lb payload)		PIONEER F&G	JUPITER FLYBY A Mariner class mission to provide the first comprehensive investigation of the atmosphere and surface of Jupiter, including TV imaging and spectrometric analysis. PLANETARY EXPLORERS (A-E) Small orbiters to monitor the environment of Venus and Mars, measuring particles, fields and atmospheric properties.	Under Study
Medium size spacecraft (100-250 lb payload)	MARS 1969 (FLY-BY)	MARINER-MARS 1971 TITAN-MARS 1973	VENUS/MERCURY 1973/75 By using a gravitational swingby maneuver at Venus, these missions would provide an early opportunity to observe Mercury's surface characteristics and to detect any tenuous atmosphere. VENUS MARINER FLYBY/ATMOSPHERIC PROBES 1973/75 These multiple probes would investigate the cloud composition and atmosphere characteristics at several locations around the planet.	Multiplanet FLY-BY 1977 and 1978 A unique opportunity exists in 1977 and again in 1978 to send a spacecraft to the vicinity of four planets (Jupiter, Saturn, Uranus, and Neptune) with a single mission.
LARGE SIZE spacecraft (Greater than 250 lb payload)			MARS 1975/77 A mission to place large surface labs on the surface with Saturn V or Saturn V/Nerva launch vehicle. This latter launch vehicle would permit the return of samples of Martian soil to the Earth.	MARS 1979 & BEYOND



JUPITER FLYBY

Objectives:

This mission would be the first flight of a new Mariner-class spacecraft designed to explore the outer planet. This flight would provide the first comprehensive investigation of the atmosphere and surface of Jupiter, including TV imaging and spectrometric analysis. Moreover, this mission would be utilized to improve the reliability and operation of spacecraft for the Multi-planet Flyby in 1977 and 1978.

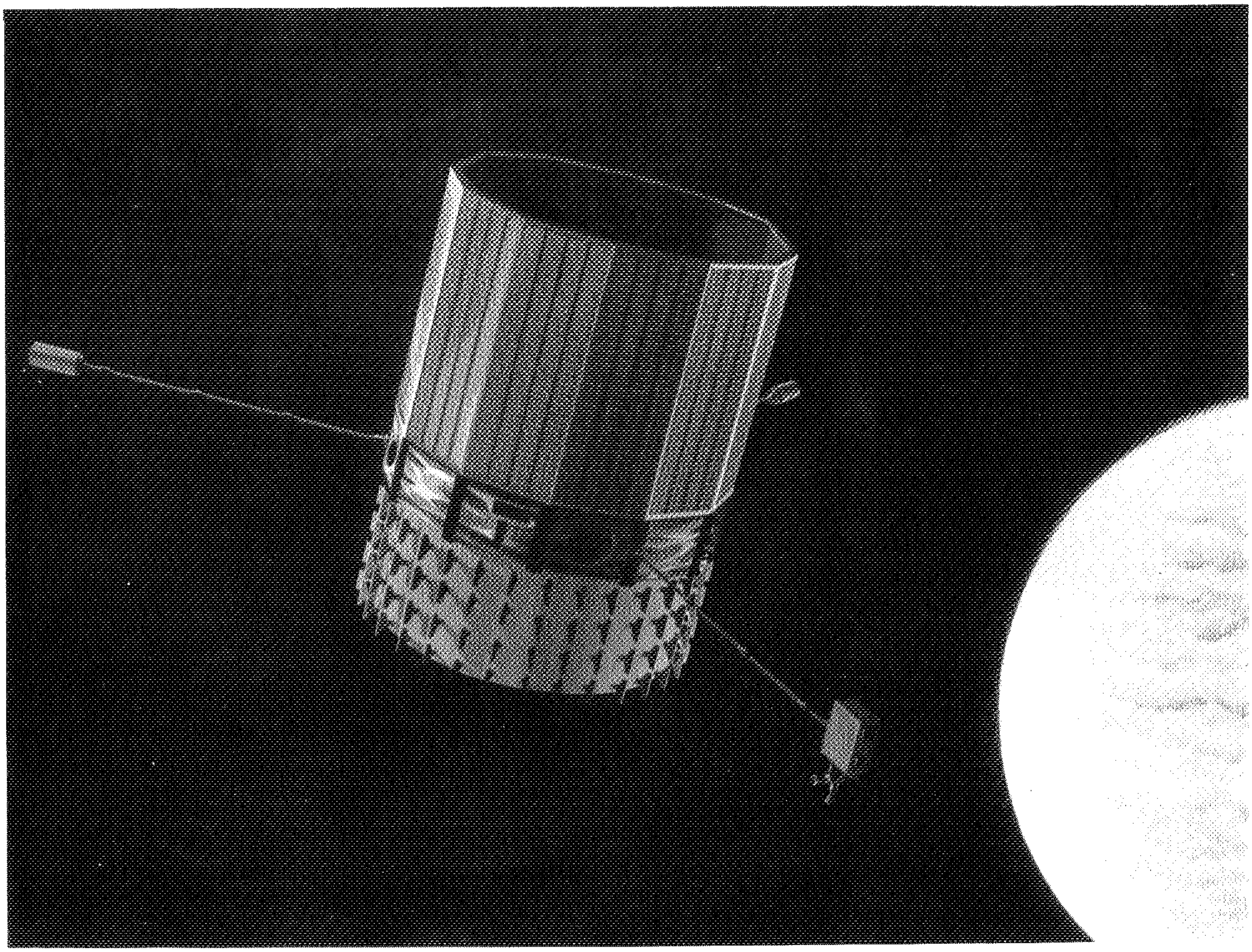
Technical Data:

Launch Vehicle: Titan 3D/Centaur/Burner II
Launch Site: Eastern Test Range
New technology: Source of primary electrical power, increased telecommunication capability, improved guidance accuracy, on-broad electrical propulsion.

Payload Range: 50-100 lbs.

Status:

Preliminary studies are underway with the objective of planning flights in the 1973-75 time period.



PLANETARY EXPLORERS (1972-1975)

Objectives:

Place in orbit around Venus and Mars low-cost, long life, Explorer-type spacecraft to continue and extend the scientific investigations of the planetary environments and interplanetary space. Initial missions would probably obtain scientific measurements in the following areas:

- Magnetic fields
- Solar wind plasma
- Energetic particles
- Exospheric composition
- Planetary EM emission
- Atmospheric structure.

These measurements would provide information concerning the present state of the planetary environment in the Solar System and reflect upon the internal composition and nature of the interior of the planet.

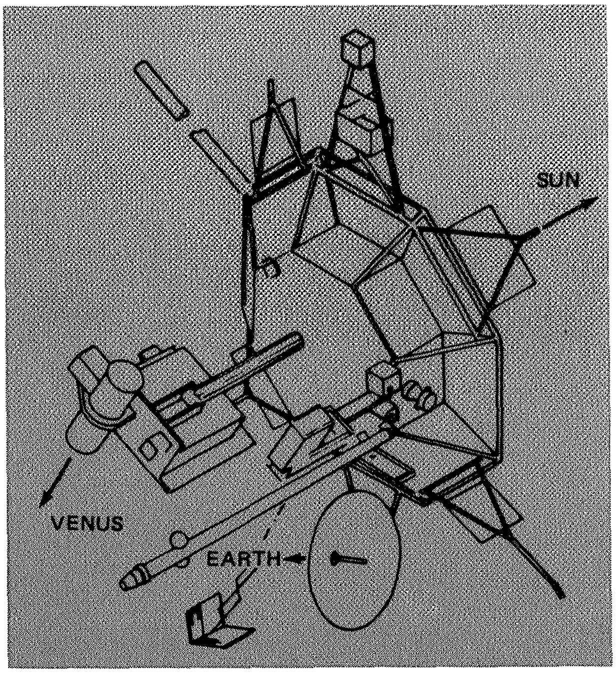
Technical Data:

Launch Vehicle:	TAT/Delta
Launch Site:	Eastern Test Range
New Technology:	Guidance and Control Data handling & storage Improved Telecommunications Capability

Payload Weight: 50 lbs.

Status:

Studies are underway with the objective of planning flights to Venus in 1972, 1973, and 1975 and to Mars in 1973 and 1975.



VENUS-MERCURY FLYBY (1973 & 1975)

Objectives:

Venus flyby probe portion of the mission would investigate the temperature, pressure, composition, and structure of the Venusian atmosphere, and the nature of the planetary surface. Information of this type is relevant to the biological and cosmogonical problems, while at the same time, it is needed to support subsequent missions.

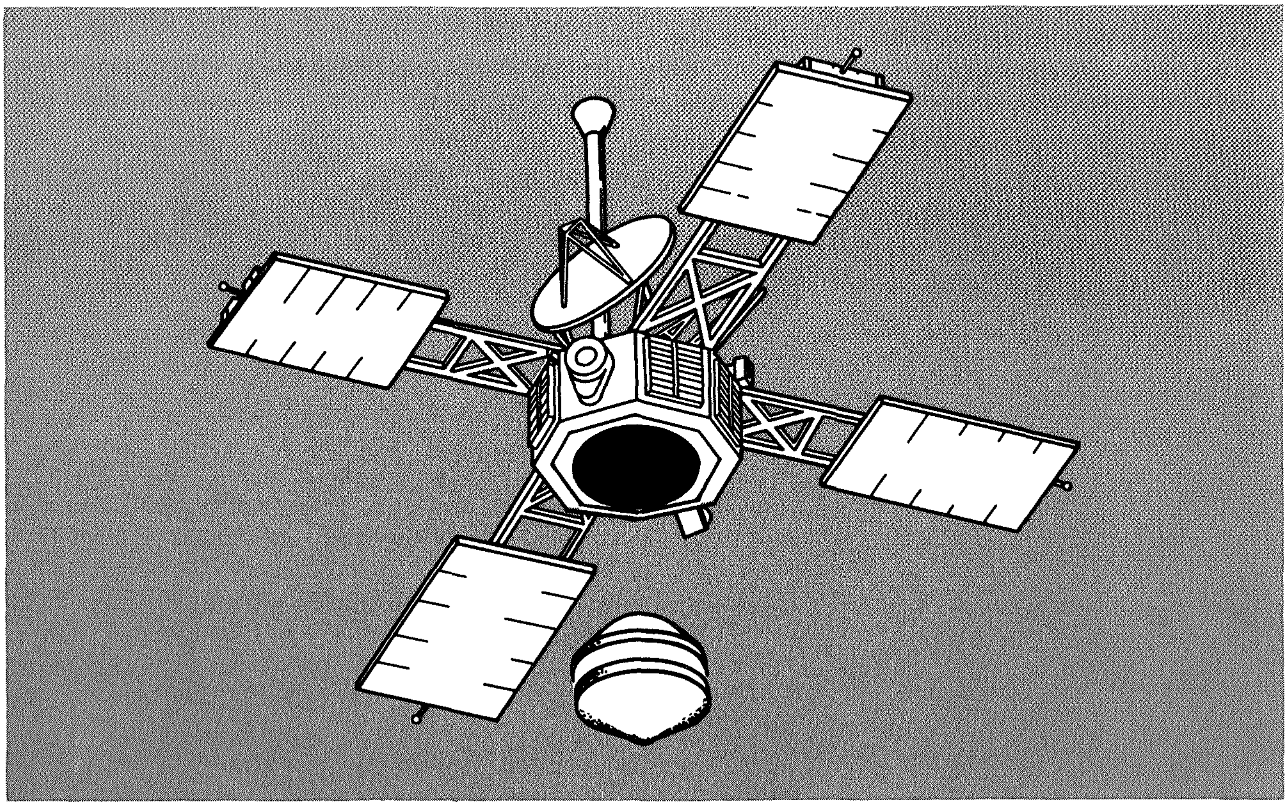
The Mercury flyby portion of the mission would provide visual and thermal images of the planet. These data would be particularly relevant for comparison with the Moon and Mars. Measurements of magnetic fields and charged particles would provide insight into the internal structure and whether a conducting core exists. If an occultation is possible, information would be obtained on whatever atmosphere is present.

Technical Data:

Launch Vehicle: Atlas/Centaur
Launch Site: Eastern Test Range
New Technology: High temperature spacecraft hardware
Thermal control
Improved telecommunications capabilities
Sterilization
Gravity-assist technology
Survivable probe technology

Status:

Upgrading prior mission studies for 1973 and 1975. Reasonable launch opportunities will be October-November 1973 and June 1975.



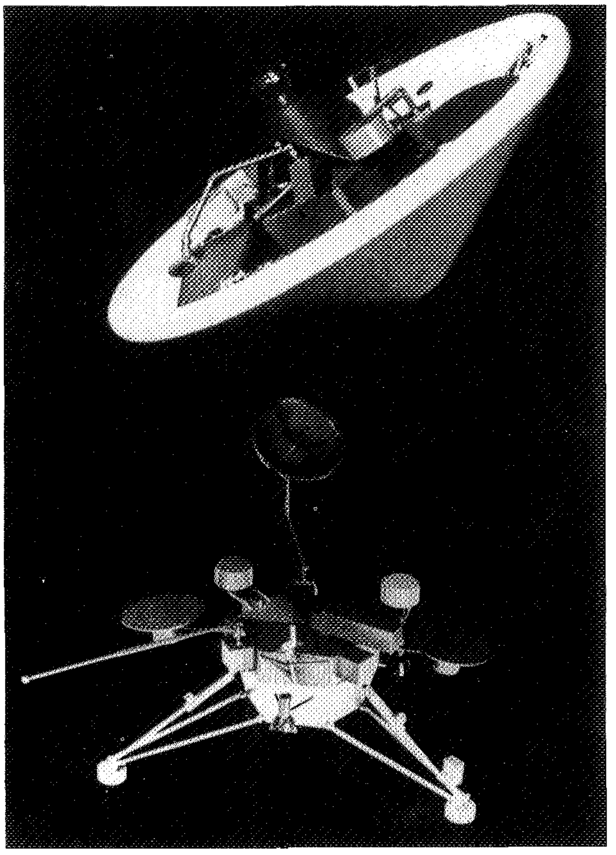
VENUS MARINER FLYBY/ATMOSPHERIC PROBES (1973 and 1975)

Objectives:
Measurements of cloud composition and atmospheric temperature, pressure, composition and density profiles would be made using multiple atmospheric probes. Mariner V flew within 2500 miles of Venus and obtained significant scientific data on the composition and density of the Venus atmosphere and its environment. This mission would increase our understanding of the dynamics of the atmosphere by simultaneously probing the atmosphere at widely separated geographical locations.

Technical Data:

Launch Vehicle:	Atlas/Centaur
Launch Site:	Eastern Test Range
New Technology:	Heat shield technology Entry probe technology High temperature hardware Sterilization Advanced balloon technology Guidance and control

Status:
Presently in the early study phase for the 1973 and 1975 opportunties. As an alternate to the atmospheric probe payload, the entry vehicle could deliver an atmospheric buoyant station.



MARS 1975/77

Objectives:
To obtain additional information relevant to the existence and nature of extraterrestial life, the atmosphere, surface, and body characteristics of Mars, by performing experiments on the surface of Mars and perhaps return samples of Martian soil to the Earth. The surface laboratory study would emphasize biological measurements and also provide additional information on the surface composition, seismic activities and the weather of Mars.

Technical Data:

Launch Vehicle:	Saturn V or Saturn V/Nerva
Launch Site:	Eastern Test Range
New Technology:	Sterilization Improved telecommunications capabilities Long Life power systems Data storage and processing Thermal control Reliable retro systems High performance guidance and control Biological instrumentation Automated rendezvous and docking in orbit around Mars

Status:
Currently under study.

BIOSCIENCE PROGRAM

PROGRAM	APPROVED & UNDERWAY	APPROVED TO BEGIN FY 1969	PLANNED FOR INITIATION IN EARLY 1970'S	PLANNED FOR INITIATION IN MID 1970'S AND BEYOND
BIOSCIENCE	BIOSATELLITE (C,D,E,F) APOLLO Return lunar sample analysis.	NO NEW PROGRAMS	FOLLOW-ON BIOSATELLITE Same spacecraft as present program. Repeat or new experiments IMPROVED BIOSATELLITE Essentially same as present spacecraft with modest modifications for larger payload, and longer orbital duration. BIOPIONEER Pioneer spacecraft with biological payload—Solar orbit—Biological rhythm studies. BIOEXPLORER A small nonrecoverable spacecraft in earth orbit to conduct function, growth, behavioral and biorhythm experiments. BIOTECHNOLOGY LABORATORY (1) A manned orbiting laboratory for Bioscience, Medical and Biotechnology experiments. Five major Bioscience experiment packages are proposed: Bio A, C, D, E and F. The experiments would continue the survey of space environment effects on biological systems and in-depth study of specific recognized phenomena begun in Biosatellite A-F. The packages would carry primates, mircoorganisms, small vertebrates, plants, and invertebrates, respectively.	ADVANCED BIOSATELLITE (1) Major re-design for 4000 pound spacecraft three to six month orbit duration. General biology and animal physiology experiments.

(1) Advanced Biosatellite and Biotechnology Laboratory are alternates.

BIOTECHNOLOGY LABORATORY

The Biotechnology Laboratory is a facility concept for accommodating bioscience, biomedical, and biotechnological experiments. Five bioscience experiment packages are proposed for this facility in the mid-to-late 1970's:

BIO A

Study the metabolic, cardiovascular, neuromuscular, and central nervous functions, adaptation and performance of primates under weightless space flight conditions and determine the onset, rate and extent of physiological changes.

BIO C

Study the growth, reproduction, nutrition, and genetics of mircoorganisms and single cell cultures in the space environment under the condition of weightlessness.

BIO D

Study the metabolism, growth, reproduction, development, behavior and adaptive responses of small vertebrates under the condition of weightlessness and space flight.

BIO E

Study the geotropic responses, morphology, growth, development and biochemistry of plants under weightlessness and with artificial gain space flight.

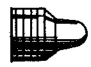
BIO F

Study the same responses of invertebrate animals to weightlessness and space flight as are studied in higher animals for comparative purposes to better understand interspecies relationships and adaptive mechanisms.

Status:

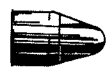
The Biotechnology Laboratory facility and these experiment packages are under consideration f?r the Manned Earth Orbital Space Laboratory in the mid 1970's.

BIOSATELLITES

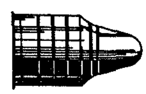


BIOSATELLITE
PRESENT APPROVED PROGRAM

FOLLOW-ON BIOSATELLITE
SAME AS PRESENT WITH NEW EXPERIMENTS



IMPROVED BIOSATELLITE
BASIC DESIGN SAME AS PRESENT, MODIFIED FOR 300 LB. PAYLOAD 60-90 DAYS



ADVANCED BIOSATELLITE
IMPROVED DESIGN – 4000 LB. SPACECRAFT, ALTERNATIVE TO BIOTECHNOLOGY LABORATORY

IMPROVED BIOSATELLITE

Objectives:

This is a continuation of the present Biosatellite with modest improvements to increase reliability and enlarge the payload and orbit endurance. The experiments will be in part suggest by the scientific results of the presently approved flights.

Technical Data:

Launch Vehicle: TAT/Delta (2-stage)
Launch Site: Eastern Test Range

Status:

Under study.

ADVANCED BIOSATELLITE

Objectives:

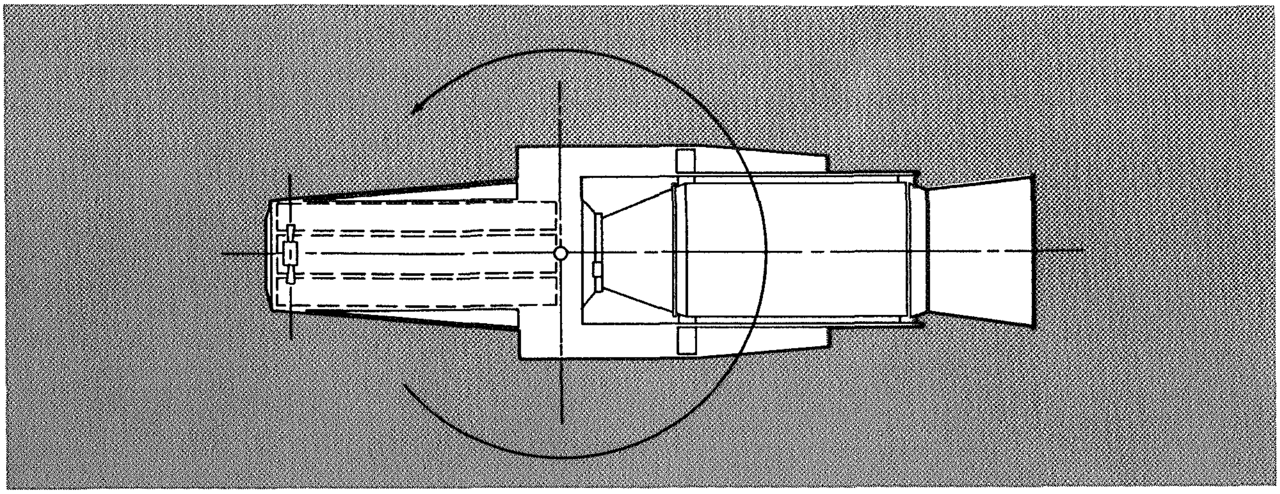
This is an alternate approach to the biotechnology laboratory missions. The purpose is to determine the immediate and long-term effects of the space environment on physiological systems and to determine the time course of change and adaptations.

Technical Data:

Launch Vehicle: Atlas Centaur
Launch Site: Eastern Test Range

Status:

Under study.



BIOEXPLORER

Objectives:

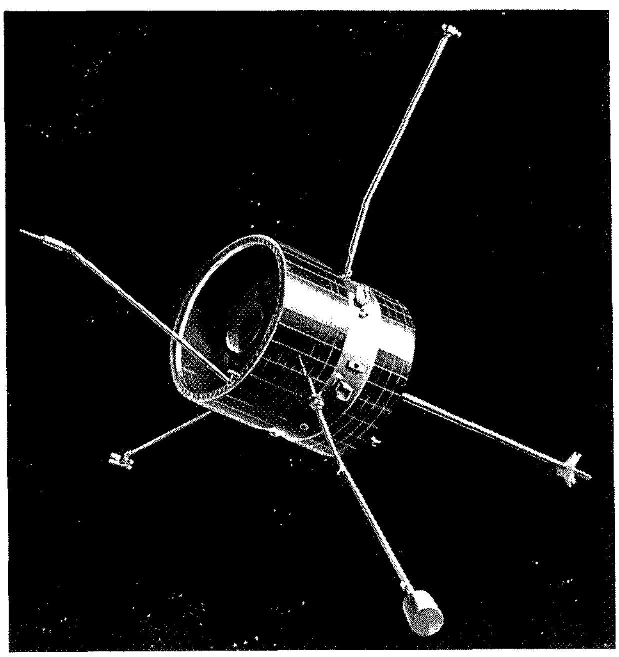
To conduct bioscience experiments on function, behavior and rhythm experiments with small animals and plants which do not require the recovery feature of the current Biosatellites. Will have the added feature of a centrifuge configuration which will permit: determination of minimum gravity requirements of plants and animals; determination of the relative biological merit of artifical gravity versus the undesirable effects of rotation; determination as to whether zero gravity and 1+ gravity are on the same sensory continuum. This configuration also permits the highly desirable option of "control" experiments at 1 g.

Technical Data:

Spacecraft:	Under Study.
Orbit:	Geocentric
Launch Vehicle:	Scout
Launch Site:	Wallops Station

Status:

Under study.



BIOPIONEER

Objectives:

To conduct experiments on circadian biological rhythmicity of organisms removed from the periodic influences of the Earth and its rotation to determine whether or not living organisms are dependent upon the Earth's periodicities for their biological clock or whether these biological rhythms persist when removed from Earth's periodicities.

Technical Data:

Spacecraft:	Same spacecraft used for Pioneer XI but with biological payload.
Orbit:	Heliocentric
Launch Vehicle:	TAT/Delta
Launch Site:	Eastern Test Range

Status:

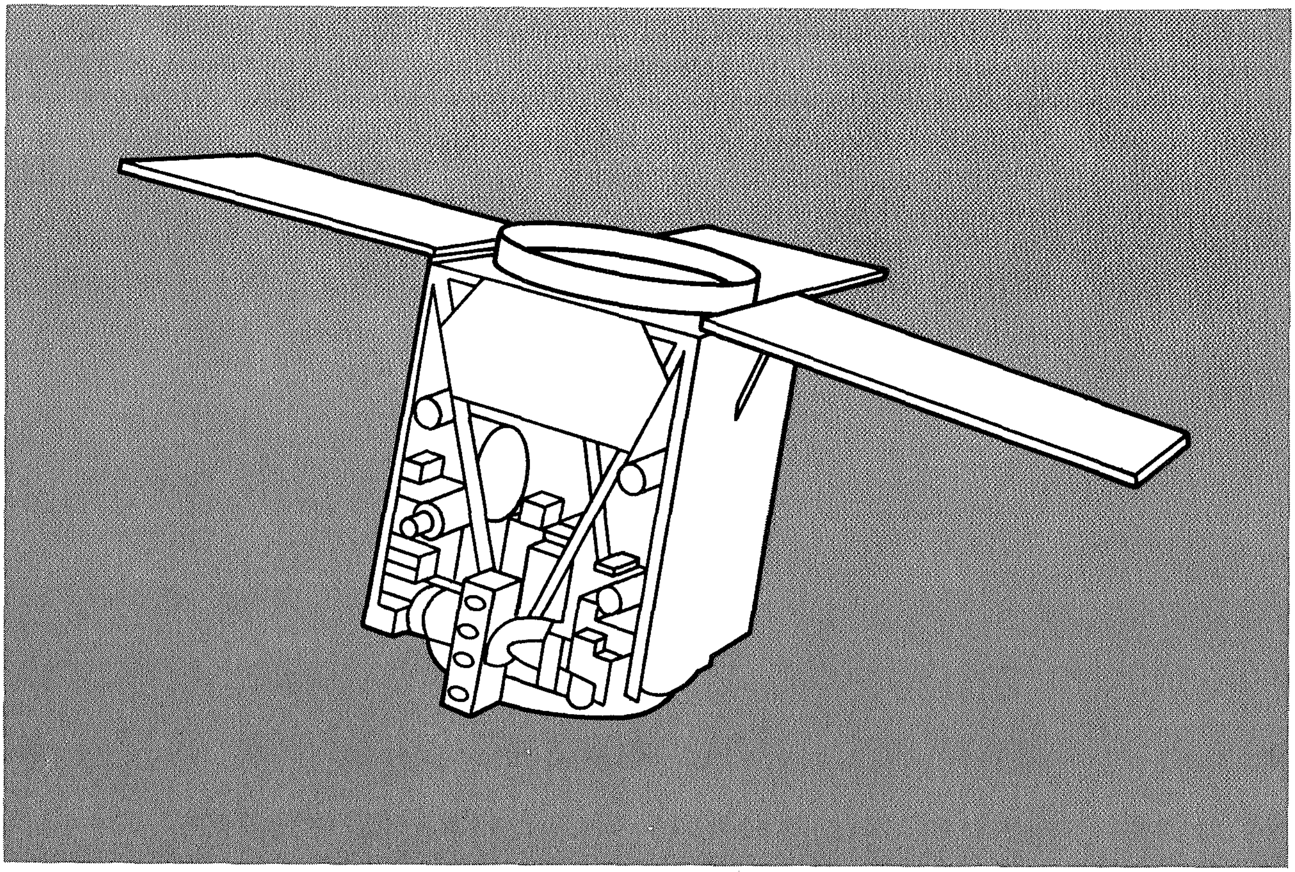
Two flights each are being considered for the 1972-1973 time period.

SPACE APPLICATIONS

PROGRAM	APPROVED AND NOW UNDERWAY	APPROVED TO BEGIN IN FY 1969	PLANNED FOR INITIATION IN EARLY 1970's	PLANNED FOR INITIATION IN MID 1970'S AND BEYOND
METEOROLOGY	TIROS M NIMBUS B-2, D, E and F	No new Programs	Follow-on TIROS effort to develop prototype for advanced polar orbiting spacecraft incorporating the advanced sensors developed under the NIMBUS program. Initiation of effort on Synchronous Meteorological System Test Satellites to support National Operational Meteorological Satellite System. *Follow-on Nimbus* effort to improve sensors, instrumentation, and measurement intercomparison. Support to the World Weather Watch (WWW).	Advanced operational prototypes as required. Experimentation and flight test of subsystems on "standard" satellites. (See "Common Systems" below)
COMMUNICATIONS	SR & T	No New Programs	Advanced applications experiments on ATS (See "Techniques" below) to investigate improved frequency utilization and small terminal multiple access concepts; and to develop capability for broadcasting from space and satellite aids for data relay, e.g., Data Relay Satellite System (DRSS).	Extension of promising improvements into new spectral regions and for new purposes.
GEODESY	SR & T	No new Programs	GEOS C & D Support of the NGSP, completion of the gravimetric objectives, i.e., refinement of the description of the Earth's gravitational field.	Advanced geodetic satellites to support Earth Sciences and monitor the time variations of such fundamental parameters as the geometry of the surface of the solid Earth and the oceans.
NAVIGATION AND TRAFFIC CONTROL	SR & T	No new Programs	Advanced applications experiments.	Initiate design of system test satellites and the required R & D.

SPACE APPLICATIONS (Continued)

PROGRAM	APPROVED AND NOW UNDERWAY	APPROVED TO BEGIN IN FY 1969	PLANNED FOR INITIATION IN EARLY 1970'S	PLANNED FOR INITIATION IN MID 1970'S AND BEYOND
EARTH RESOURCES SURVEY	SR & T	Augmented Aircraft Program ERTS Study	Launch of first ERT Satellites, plus "limited objective" missions to flight test & intercompare specific Earth resources survey satellite-instrumentation. Projects being considered include: ERTS A & B, Small Applications Technology Satellite	Development & test of operational prototype satellite systems as required by user agencies. Also, larger & more sophisticated experimental satellites to explore promising areas of Earth resources survey. Advanced experiments on ATS synchronous missions.
TECHNIQUES IN SYNCHRONOUS ORBIT	ATS—E, F, & G	No New Programs	ATS H, & J Begin definition of third generation spacecraft for launch in 1974 or 1975, to continue advanced application more experiments. Emphasis on more precise (±0.001 degree) pointing of sensors & antennas to make possible new applications in all areas.	Probable transition to synchronous orbit "standard" space applications missions.
COMMON MULTIPLE USE SYSTEMS		No New Programs	Begin definition and design of multiple use spacecraft, probably starting with low Earth orbit class.	Advanced "standard" statellites, both low Earth orbital & synchronous.



TIROS FOLLOW-ON

Objectives:

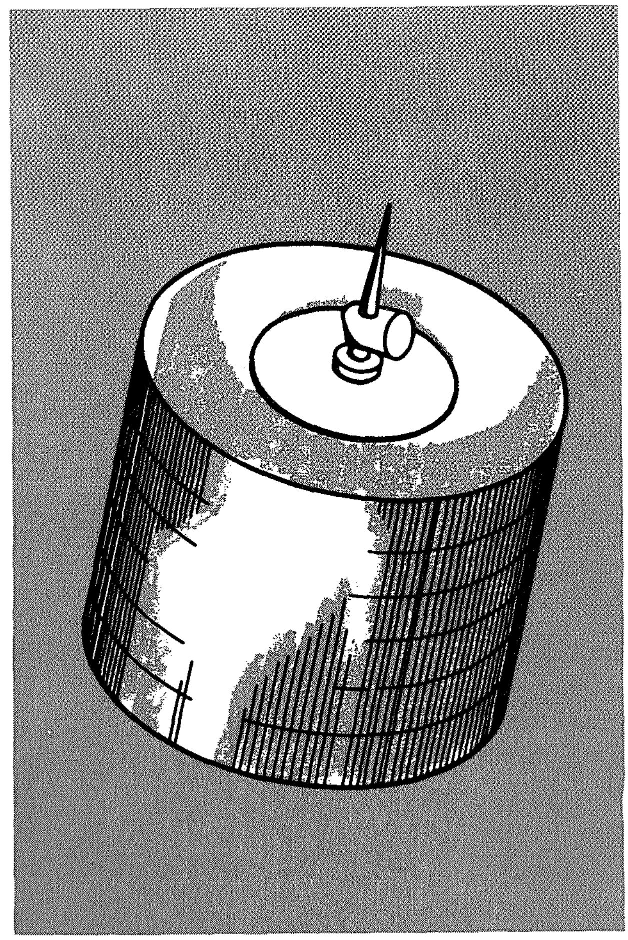
The TIROS Follow-On program is aimed at developing prototypes for advanced polar orbiting operational spacecraft. These will incorporate the state-of-the-art advances in spacecraft technology and sensors achieved in the Nimbus research and development program. Flights are being considered to prove the operational concept of infrared vertical temperature sounders and the operational concept of microwave sounders and other sensors developed on Nimbus E and F. These projects directly affect the National Operational Meteorological Satellite System (NOMSS) and support NASA's responsibilities to other government agencies.

Technical Data:

Launch Dates:	Under Study
Launch Vehicle:	TAT/Delta
Launch Sites:	Western Test Range

Status:

Studies initiated in FY 1969 and being considered for FY 70 will define the program in further detail.



SYNCHRONOUS METEOROLOGY SYSTEM TEST SATELLITE

Objectives:

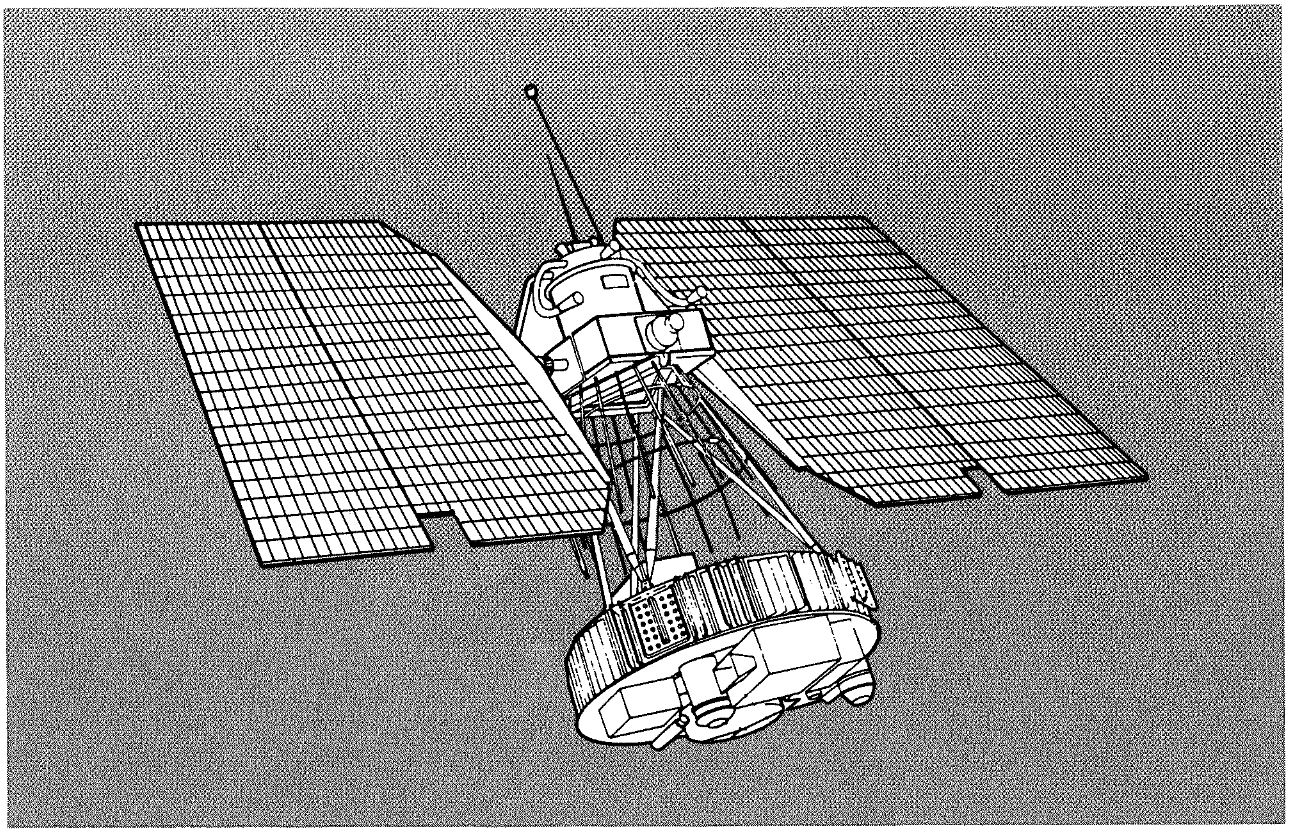
To provide an R&D test of a total synchronous meteorological satellite system to support the National Operational Meteorological Satellite Systems. The intention is to use existing technology to provide this initial capability, much in the manner that TIROS-developed technology was used for the first TOS generation.

Technical Data:

Orbit:	Geostationary
Launch Date:	Under Study
Launch Vehicle:	TAT/Delta
Launch Site:	Eastern Test Range

Status:

Preliminary planning only for flights in 1972-1974 time period. The initial spacecraft would be based on ATS I nd III spacecraft and sensor technology.



WORLD WEATHER WATCH

Objectives:

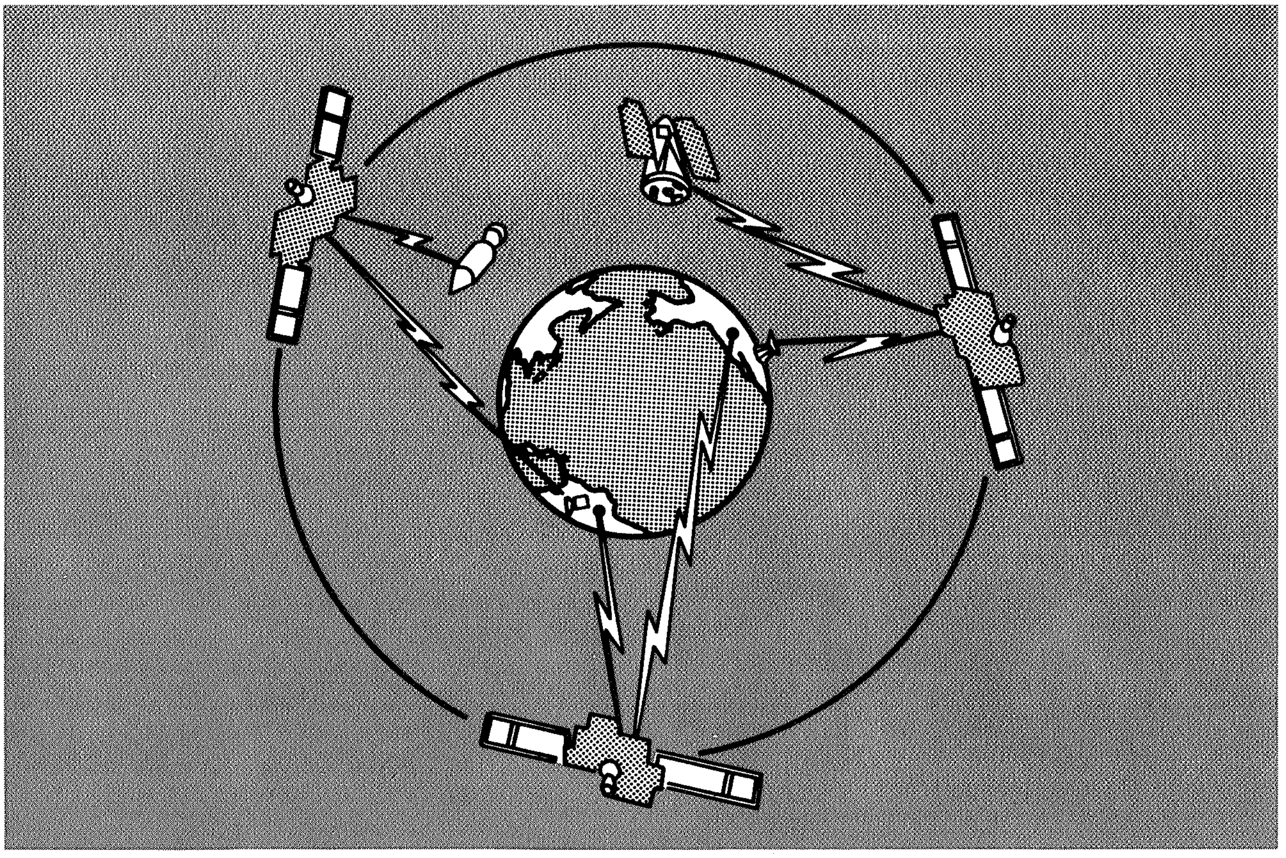
The World Weather Watch (WWW) satellites would be polar orbiting observatories that will provide the global, three-dimensional data on the mass and motion fields of the atmosphere, cloud patterns, precipitation patterns, and surface temperatures required by the Global Atmospheric Research Program (GARP) experiments planned for 1973 and 1976. It should be noted that the Department of Commerce provides a focal point to coordinate the U.S. effort. NASA would develop the space technology required to support GARP.

Technical Data:

Launch Dates:	Under Study
Launch Vehicle:	TAT/Agena
Launch Site:	Western Test Range

Status:

Studies initiated in FY 1969 and planned for subsequence years will insure that the necessary capabilities are provided to meet the U.S. commitments.



DATA RELAY SATELLITE SYSTEM (DRSS)

Objectives:

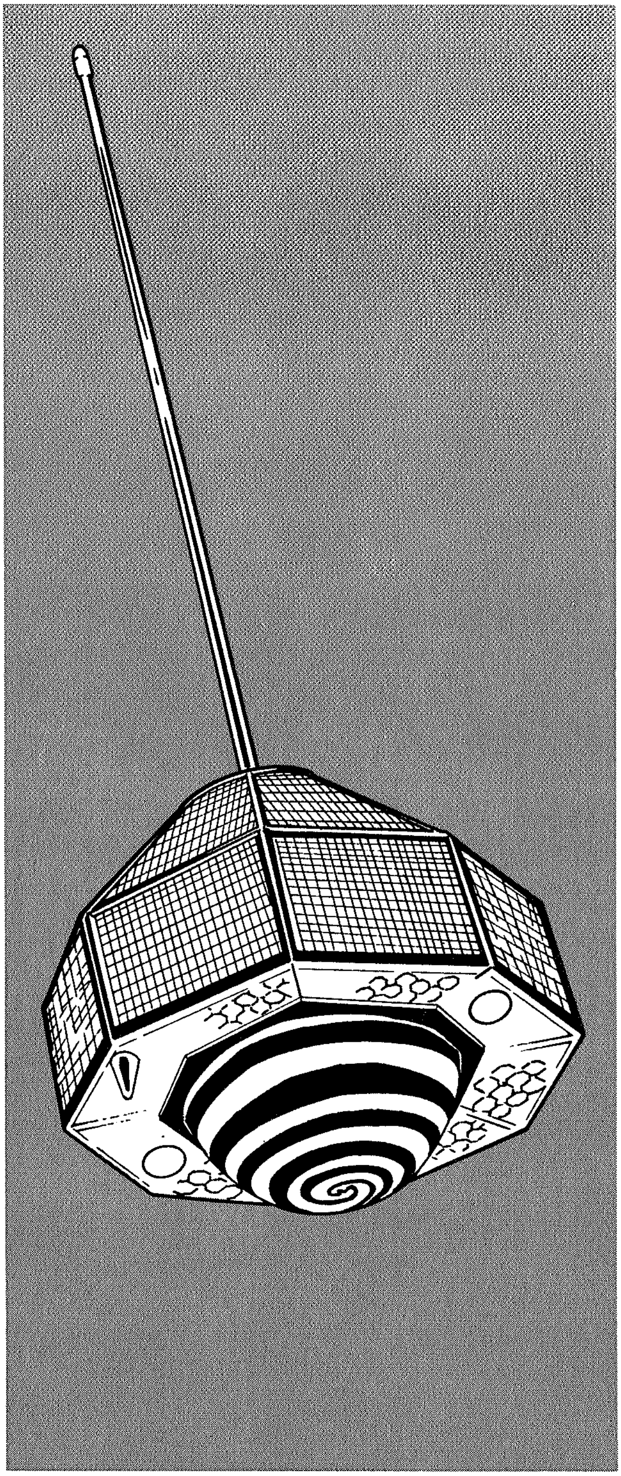
As foreseen, a tracking and Data Relay Satellite System would consist of several synchronous satellites. These would be capable of relaying data from other Earth-orbital mission spacecraft, both manned and automated, which require immediate transmission of information to mission control centers in the U.S., and to allow a means of orbit determination. The implementation of a data relay satellite and compatible subsystems on mission spacecraft would yield three major benefits: (1) it could provide for the first time 100 percent coverage for any mission spacecraft in low altitude Earth orbit (2) it could reduce NASA's dependence on ships, aircraft, and remote ground stations; and (3) it offers the potential for effecting economies in network operations. Three satellites in simultaneous operation are contemplated 120° apart in earth synchronous orbit.

Technical Data:

Launch Dates:	Under Study
Launch Vehicle:	Atlas/Centaur
Launch Sites:	Eastern Test Range

Status:

Studies initiated in FY-1969 and being considered for FY 1970 will define the program in further detail.



GEOS C & D

Objectives:

GEOS-C is planned to be launched into a low inclination (20°), 600 nautical mile orbit to permit the acquistion of the additional gravity data required for the completion of the National Geodetic Satellite Program in the 1970-1972 time period. GEOS-C would be a retrofitted version of the GEOS-B backup spacecraft and would carry a satellite radar altimeter as well as the normal complement of geodetic instrumentation.

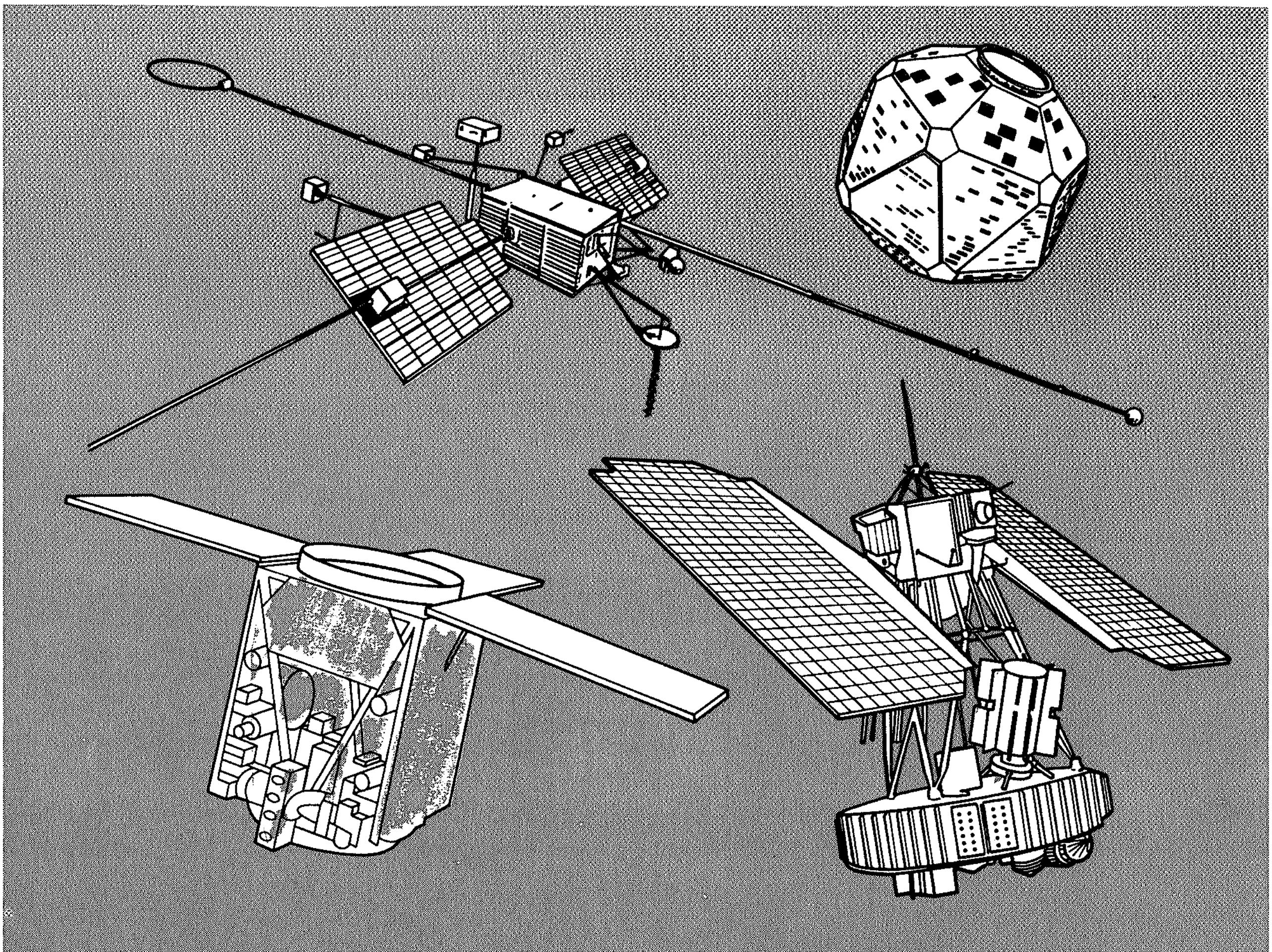
The GEOS-D spacecraft would be developed to provide a full R&D demonstration of a satellite radar or laser altimeter and its validity in providing important measurements of the ocean surface; that is, ocean geoid or mean sea level. It is anticipated that GEOS-D would carry a moderate payload of applications experiments in addition to the altimetric instruments. GEOS-D is planned to be launched into a near polar orbit at an altitude of 600 Nautical miles with a low eccentricity.

Technical Data:

Launch Dates:	Under Study
Launch Sites:	As appropriate to the mission
Launch Vehicle:	TAT/Delta

Status:

GEOS II backup hardware is available for use in GEOS-C. Present plans are to use GEOS technology for GEOS-D. Studies initiated in FY 1969 will form the bases for decisions to initiate later phases.



POSSIBLE SPACECRAFT CONFIGURATION

ERTS A & B

Objectives:

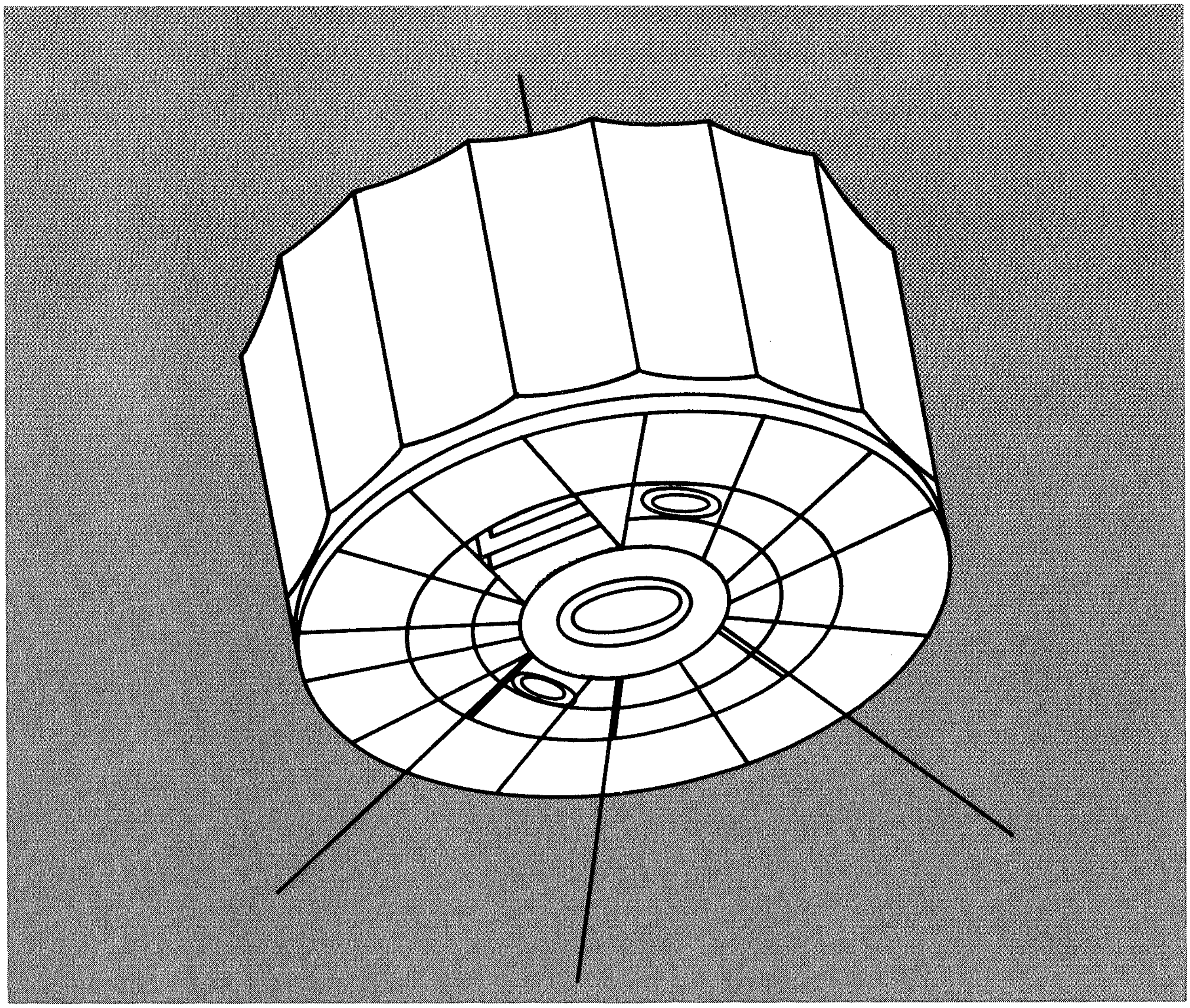
Develop a first generation research Earth Resources Technology satellite to begin to test and evaluate combinations of instruments, sensors, and imaging devices capable of gathering data on the natural and cultural resources of the Earth in such discipline areas as: Agriculture and forestry resources; geology and mineral resources; geography, cartography, and cultural resources; and oceanography and marine resources. Analysis of data from the Tiros and Nimbus satellites indicates that even these satellites, developed for meteorological observations, can provide useful Earth resources data in some of the discipline areas. Instruments have been developed through the Aircraft Program which would be candidates for the ERTS satellite.

Technical Data:

Launch Site:	WTR
Launch Vehicle:	TAT/Delta
Design Lifetime:	2 years

Status:

Preliminary in-house studies completed. Contractor studies to be initiated in FY-69 including economic benefits and trade-offs. Launches are under construction for the early 1970's.



SMALL APPLICATION TECHNOLOGY SATELLITES

Objectives:
To test engineering subsystems and to determine the effectiveness of individual sensor systems, such as TV and film cameras, by obtaining data from sun-synchronous inclination orbitis with mission durations of 14 to 21 days. These satellites would use relatively inexpensive launch vehicles of the Scout class. The first missions would flight test sensors for the Earth Resources Survey Program.

Technical Data:

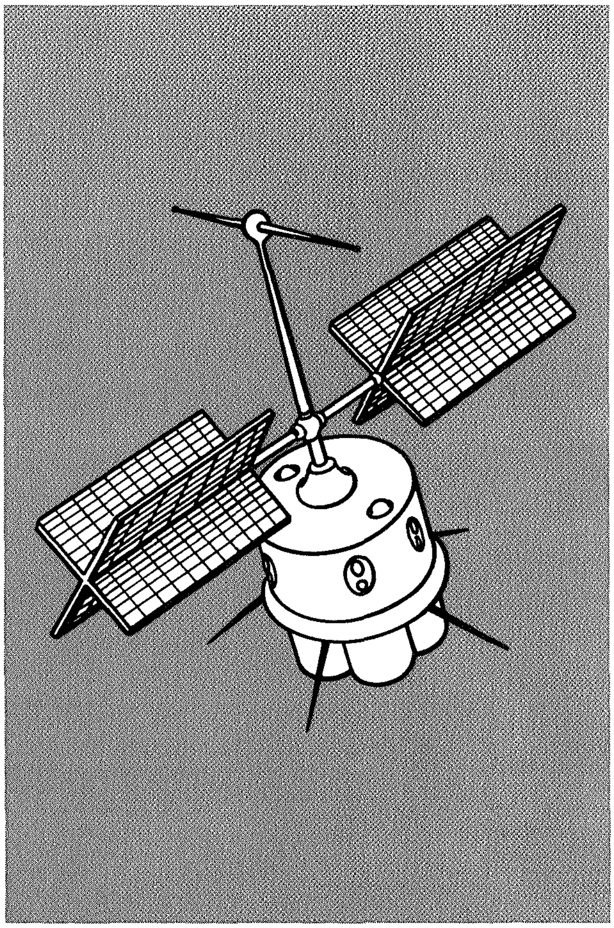
Launch Vehicle:	Scout
Launch Site:	Wallops Station
New Technology:	Sensors, Imagers, Radar Devices.

Status:
Initial planning and studies stage. Launches are being considered for early 1970's.

ATS – H & J

Objectives:
Extend our capability to conduct applications experiments on precisely oriented spacecraft in geostationary orbit: ±0.001° in all three axes.

A need for large weight capability, precisely oriented spacecraft in geostationary orbit during the mid-1970's and beyond is foreseen to permit use of very high resolution imagers for gathering detailed meteorological data on small weather systems such as tornados and thunder storms and for gathering detailed data on small scale Earth resources phenomena, both natural and cultural. This degree of precision pointing may also be necessary to support precise laser altimetry for geodetic purposes and to support experimental millimeter and submillimeter wavelength communications with planetary and interplanetary probes.



Technical Data:

Orbit:	Geostationary
Launch Vehicle:	Titan IIID/Centaur or Atlas/Centaur
Launch Site:	Eastern Test Range
Design Lifetime:	5 years
New Technology:	very precise pointing and stabilization, millimeter and submillimeter communication devices, very high resolution optical images.

Status:
Conceptual studies were initiated in FY 1969 with definition studies being considered for FY 1970.

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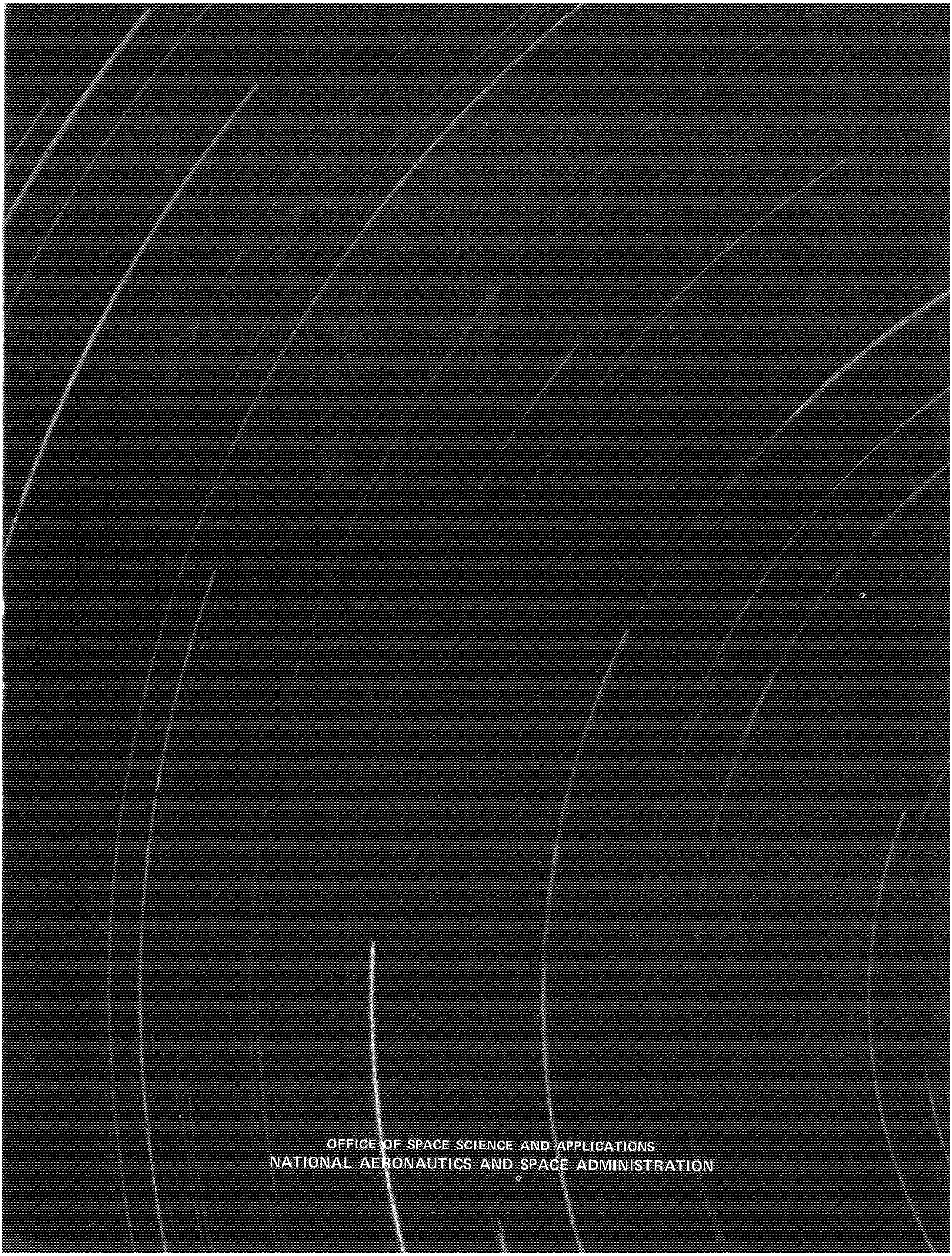

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