DOCUMENT RESUME

ED 059 041 SE 013 151

| | |
|---|---|
| TITLE | Space Station: Key to the Future. |
| INSTITUTION | National Aeronautics and Space Administration, Washington, D.C. |
| REPORT NO | NASA-EP-75 |
| PUB DATE | [71] |
| NOTE | 44p. |
| AVAILABLE FROM | Superintendent of Documents, Government Printing Office, Washington, D.C. 20402 ($0.45) |
| EDRS PRICE | MF-$0.65 HC-$3.29 |
| DESCRIPTORS | *Aerospace Education; *Aerospace Technology; *Astronomy; Earth Science; Instructional Materials; Resource Materials |
| IDENTIFIERS | Space Age; *Space Sciences |

ABSTRACT

The possible applications, advantages and features of an advanced space station to be developed are considered in a non-technical manner in this booklet. Some of the areas of application considered include the following: the detection of large scale dynamic earth processes such as changes in snow pack, crops, and air pollution levels; the development of new industrial processing and technology in space, such as metal foam, growing crystals, and levitation melting; scientific research in astronomy, life science, and physics. The space station design and environment as well as the space shuttle transportation system are described. Many large drawings illustrate the space station and its operation. (PR)

# Space Station: Key to the Future

EP-75 National Aeronautics and Space Administration

Issued by the Office of Public Affairs
National Aeronautics and Space Administration
Washington, D.C. 20546

For sale by the
Superintendent of Documents
U.S. Govern.nent Printing Office
Washington, D.C. 20402

Price 45 cents

# Foreword

The areas of communication and meteorology have demonstrated vividly that space systems can provide unique, direct benefits to man on Earth. In a few short years, these space applications are no longer sources of wonder, they have taken their place in the array of commercial and governmental services that our society now takes for granted. It is easily perceived that applications emanating from current research activities will continue to grow. No one can yet comprehend the full dimensions of the possibilities to which space systems can be placed in the service of man. The most beneficial and most profound results of our activities in space may accrue in areas where the benefits are indirect. These include international relations, management techniques for complex enterprises, and industrial technology. But the most significant results will be in the advance of knowledge, the understanding of the evolution of the universe and the origin of life. This understanding can be expected to progress significantly, and perhaps undergo profound transformations, as the new frontier of space is explored to aid the understanding of the secrets of nature and the universe.

Manned space flight programs have been primarily concerned until now with learning how to operate effectively and safely in space environment while accomplishing missions of increasing complexity and value. The astronauts have been test pilots undertaking experimental flights. Overall, our objective has been to build a manned space flight capability. Now, an increasingly complex set of missions using increasingly complex spacecraft has been completed successfully in the Mercury, Gemini and Apollo Programs. Their success attests to the maturing of that capability. With this capability in hand, we can pay considerably more attention to the scientific objectives that can be achieved by employing men at the scene of the activity. We have established follow-on programs to the lunar landing in which scientifically trained astronauts will employ Apollo space vehicles in programs oriented toward scientific experimentation.

Such a program is the Skylab Program in which the third stage (S-IVB stage) of the Saturn launch vehicle will be fitted out as an orbital workshop to be a precursor to the Space Station. Three astronauts will occupy this Earth orbiting laboratory for continuous periods as long as two months. They will use the equipment installed to conduct scientific experiments, make solar observations and to determine the effects of long space missions on the health of crewmen. NASA will also investigate the factors of habitability which affect crew morale and effectiveness with the goal of making future Space Stations increasingly productive.

The Skylab Program is a first step in manned utilization of space, but further steps must be taken to realize the full potential of this capability. Operating costs must be reduced and workers with varying skills and normal physical constitutions must be accommodated to facilitate the nation's uses of space. In the nearby regions of Earth orbit, a new, semi-permanent space facility supplied by a new, low cost, surface to orbit and return transportation vehicle is needed. These same systems will be building blocks in the system to be employed in future space activities of continuing the exploration of the moon and the planets. The Space Station module design may be used as living quarters in various Earth orbits, in lunar orbit or on a planetary mission. The very long lifetime of the Space Station permits major reductions in utilization costs.

This booklet describes the Space Station and some of its future returns. In a non-technical manner, it seeks to convey information that has been presented at technical conferences and meetings.

# Background

2

## Accomplishments

Our nation's goal in the first decade of space flight was to reach a necessary level of capability. The focus of this effort was to work to place men on the surface of the moon, conduct scientific investigations, and return them safely to Earth. The elements needed to achieve this goal were hundreds of thousands of skilled people in industry, the universities and government, manufacturing and testing facilities, spacecraft, launch vehicles, launch facilities, tracking, data acquisition, and mission control facilities and experience in conduct of space operations. Crews have been trained and flight and ground operations have been carried out with unexcelled precision and safety. The nation now has the opportunity to employ these capabilities to achieve new goals in space and to put space to work in an even more practical sense.

## Space Utilization

To exploit space for direct practical benefits, the scientific, technological and operational capability which our country has achieved in the last decade should now be focused on mature, routine, productive and cost-effective utilization of space. A necessary step in the evolution of this approach will be the establishment of advanced space stations allowing the direct involvement of the most talented scientists, technologists and specialists of all kinds without regard to their piloting skills, physical stamina or nationality.

Centralized permanent space stations can support many diverse activities, can be modified and expanded as required, and can be operated at much lower unit costs because of the economy inherent in large-scale operations. These space stations would be national research, development and operations centers in space, comparable to major Earth-bound government, university and industrial laboratories. They would provide pilot plants for the introduction of commercial activities in space in line with the precedents set in the 1960s in the area of communications satellites, thus returning further direct dividends from the space investment. The program would bring together and make the best use of our skills in designing both manned spacecraft and automated satellites. New modes of support and control of space activities would be investigated. Finally, the Space Station will be a vital link in a space transportation system extending outward to permit the exploration of the moon and the planets.

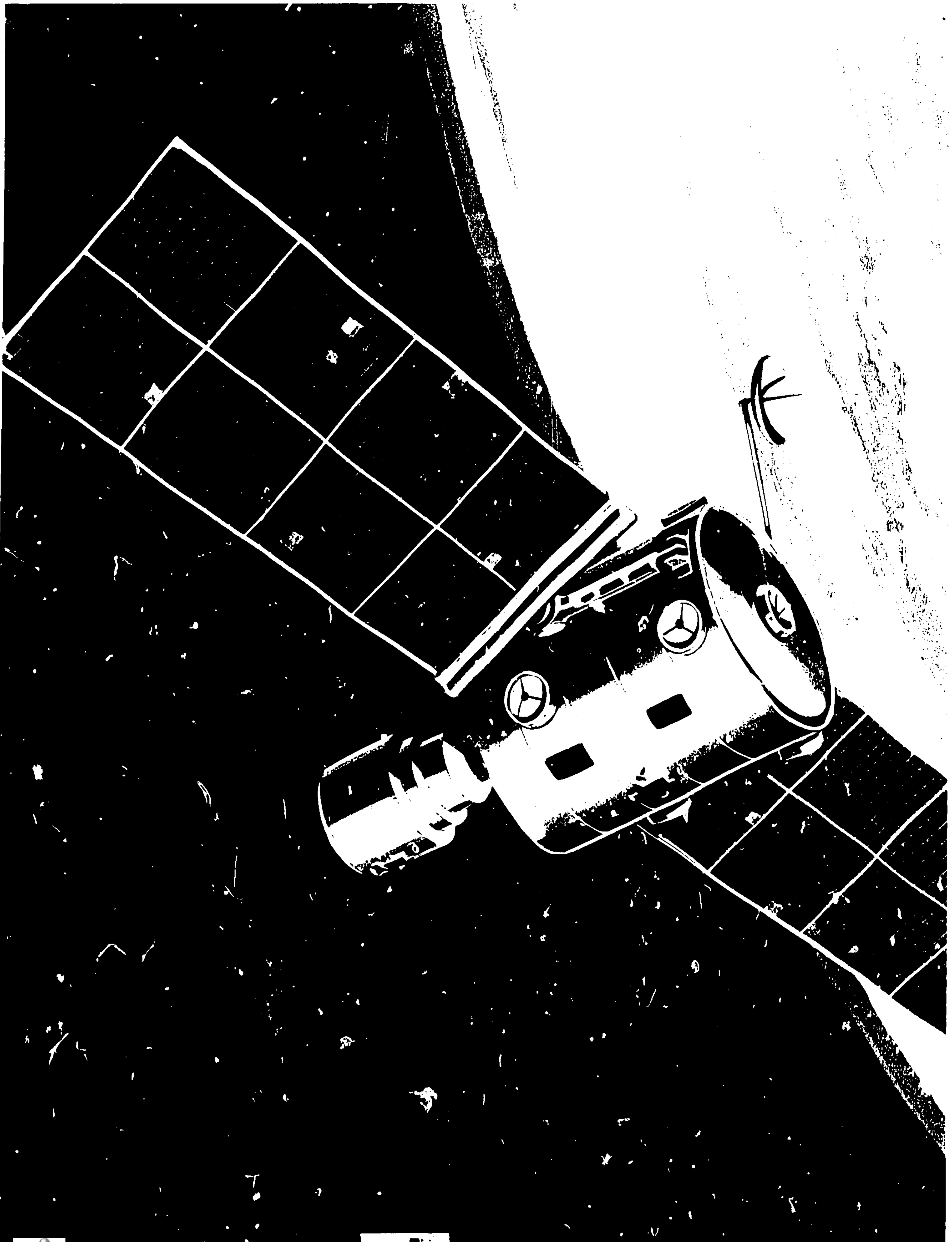
The desired system characteristics for the Space Station are routine productive operations, minimum operating costs, program flexibility and crew efficiency and safety.

Productive space utilization will require a sufficiently large staff of disciplinary and technological specialists working in a general purpose laboratory which can easily accommodate many different research tasks and applications. Frequent resupply from Earth will conveniently provide the materials and apparatus required for productive operations. Relatively large margins on resources such as electrical power and communications with the ground, coupled with the ability to modify, repair, adjust and calibrate equipment onboard will contribute to the station's broad utility.

The Space Station will achieve major cost reduction through its long useful life, its reduced dependence on ground operational support and its reusable ground to orbit transportation system. Flexibility in operation will result from a design that permits modular replacement of systems and components. This in turn allows growth to meet changing demands. The station will be constructed gradually over a period of years by placing in orbit and docking together an increasing number of structural modules of standard design. Specialized modules will be developed by installing different kinds of equipment in the standard structure.

The Space Station staff will work and live in comfortable, safe and convenient accommodations. These conditions will be achieved by using good architecture, appetizing foods and adequate personal hygiene facilities. A normal atmosphere and artificial gravity (where appropriate) will be provided. Automation will be used to reduce the amount of housekeeping required and enhance safety by failure warning and fault isolation. Damage control and temporary refuge will be provided for emergency conditions and onboard medical help will be available.

*This figure shows the external configuration of the twelve man Space Station. Large wing-like solar cell arrays are shown deployed on double articulate arms. An experiment module, in this case an astronomy module, is shown docked to the far end of the station for servicing or modification.*



## Science and Applications

The Space Station will be a scientific laboratory and a site for applying the new environment of space to the direct benefit of man.

From the outset, the thrust of the U.S. space program has been one of exploration to determine what benefits can accrue from space. Starting with the first Explorer satellite in 1958, we have been building on previous knowledge, expanding our horizons. As this expansion of new knowledge continues, we find increasing application of the new knowledge to the benefits of man. Satellites now serve us in the areas of meteorology, communications, navigation and mapping. There are a number of other areas where the exploration and research point to early direct benefits. The planned adaptability of the Space Station and the versatility of its transportation system should readily assist in the development of these applications. Of the number of promising areas of exploitation, two broad ones are discussed in this section: Earth Applications and Materials Processing.

## Earth Applications



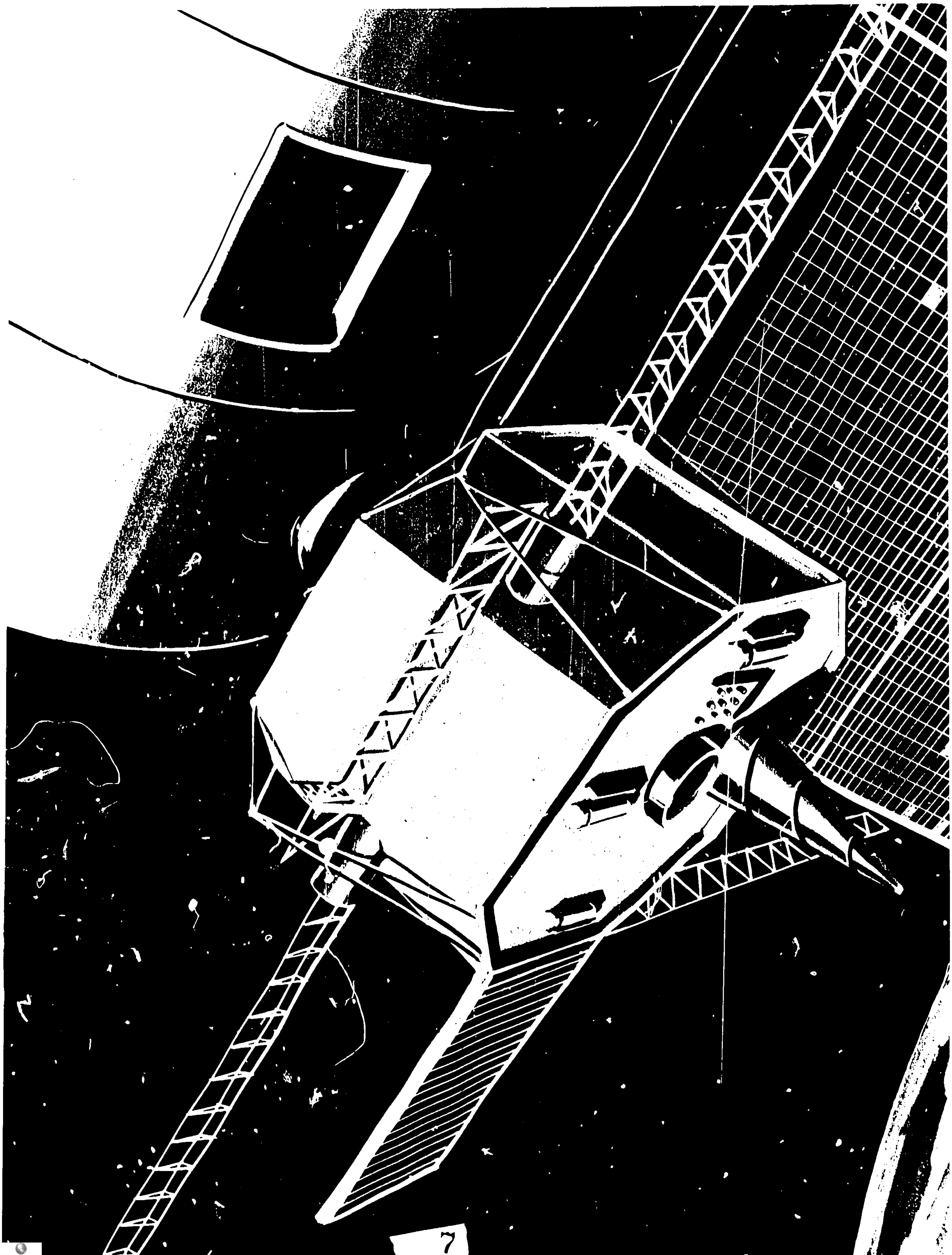
Direct economic returns can be foreseen in the exploitation of the potential of Earth orbiting space platforms. The broad areas of the Earth that can be observed from orbital altitudes cannot be observed simultaneously even by the most advanced aerial and ground techniques. Trends in large-scale dynamic Earth phenomena, such as changes in snow pack, crop condition, air and water pollution and relationships between the sea and the atmosphere can be detected as they occur. Instruments in space will observe occurrences in areas where surface observations are infrequent, such as the broad expanses of ocean and the Arctic and Antarctic masses.

### Man's Contribution

The Space Station will allow man to directly participate in the definitive determination of what useful phenomena can be observed from space and what systems and techniques are best suited to the tasks. Man should be sent into space and maintained there only to perform tasks best handled in this way. One such task will be in the development and testing of systems to be employed in the exploitation of space. As the techniques become established and the operations repetitious, automated equipment can be introduced, freeing humans for maintenance, redirection and supervision of the machines. Humans who are informed in the area being studied can also interpret and analyze the raw information obtained in flight, selecting which is to be transmitted to Earth, thereby reducing the great burden on the communication system. Here man's role is recognizing patterns—a task that can be very difficult to program into a computer.

The cost of transportation and Space Station operation can be expected to decline as usage increases, just as has been the case in aviation, communications and other applications of advanced technology. When these reductions proceed far enough, it will be more economical to repair satellites than to abandon them.

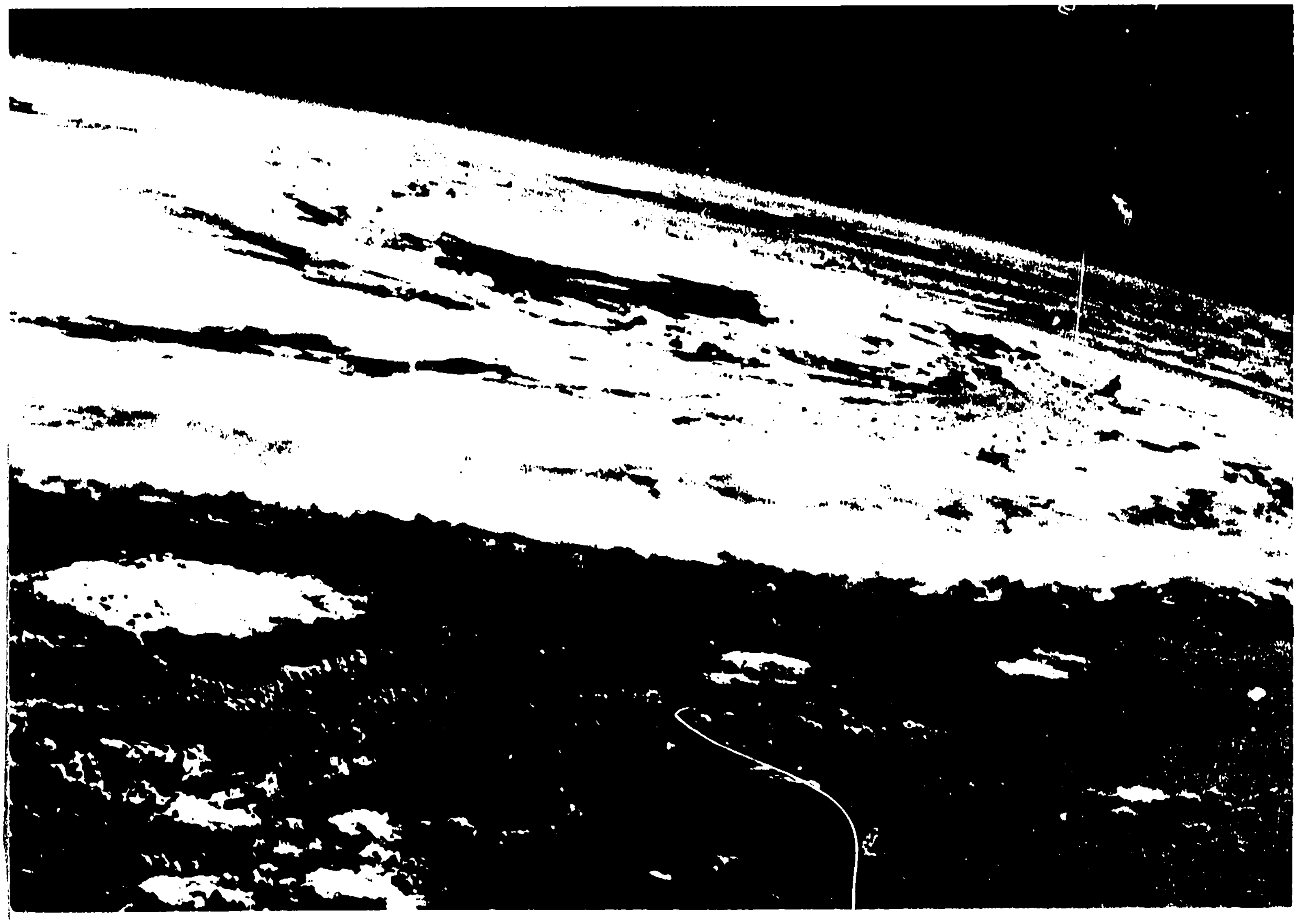
*The Earth Resources Sensor Module, attached to the side of the Space Station, could be used to study the geology of the earth's surface.*



# Meteorology 6

Meteorology is one of the better known areas where space application has already benefitted the world. Very successful observations have been made since 1960 by automated satellites. Information on Hurricane Carla permitted 500,000 persons to evacuate the areas of Galveston and parts of Louisiana in the path of the storm, reducing loss of life and property. The accompanying photograph taken during a recent manned flight shows an entire weather disturbance. Equipment tended by men on the space facility would supplement the observations of the automated satellites. In addition, maintenance and repair of these very complex automated satellites would be possible, resulting in significantly extended useful lifetimes.

*Cyclonic Storm Photographed From Apollo 9*



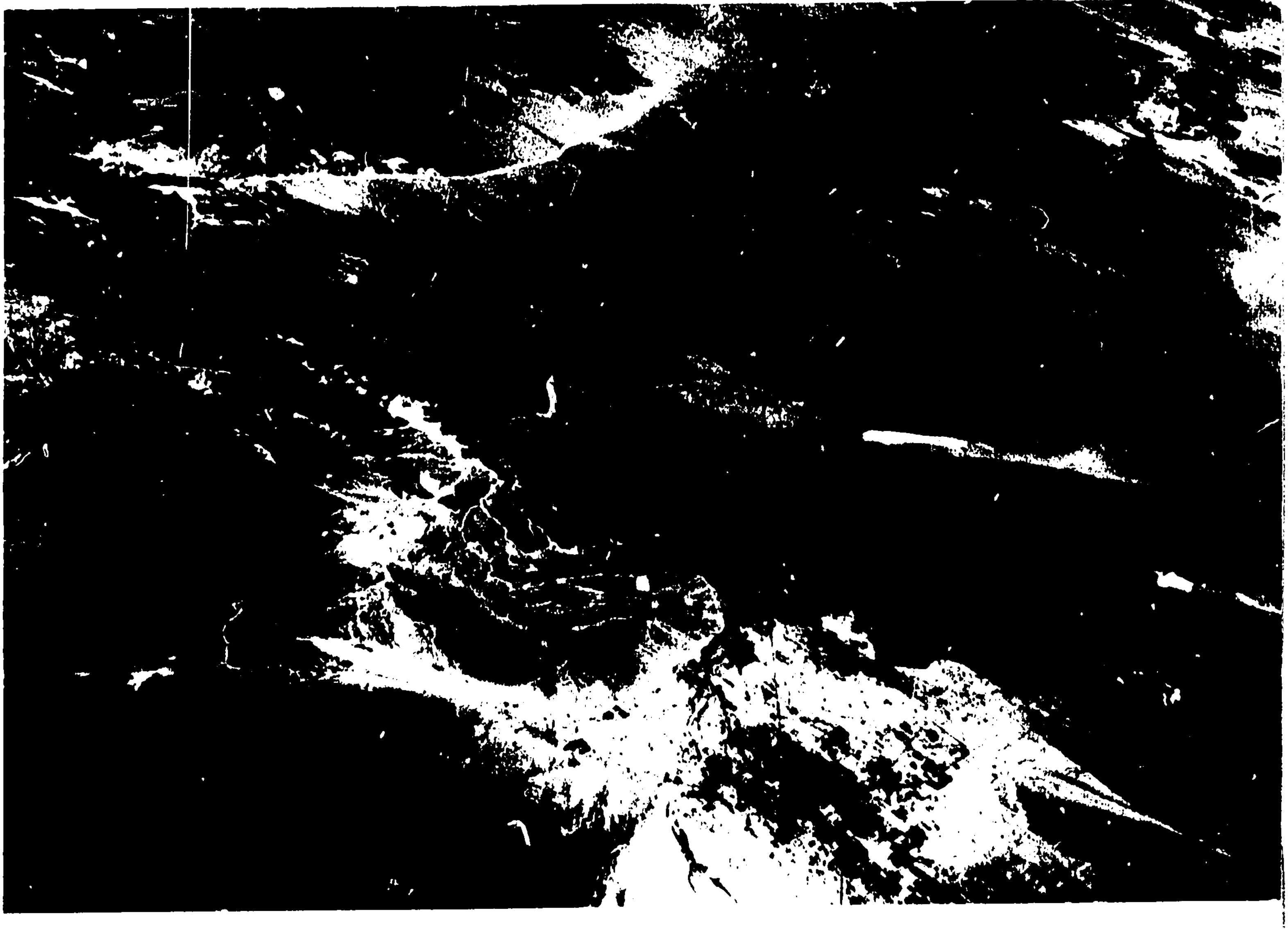
# Earth Resources



**Mineral Prospecting**

Another area of great potential return is prospecting for mineral resources. Every chemical element or compound has a characteristic "signature" like a human fingerprint. It radiates and reflects not only visible light but also radiations of wavelengths not visible to the naked eye—such as ultraviolet, infrared, microwave, radio, etc. Simultaneous photography with film sensitive to radiations in different parts of the spectrum give promise of revealing much information henceforth unavailable. The accompanying photograph of the Colorado River, Lake Mead and Las Vegas in the foreground, is an example of the high level of topographical detail available through infrared photography.

*Earth Surface Infrared Photograph*

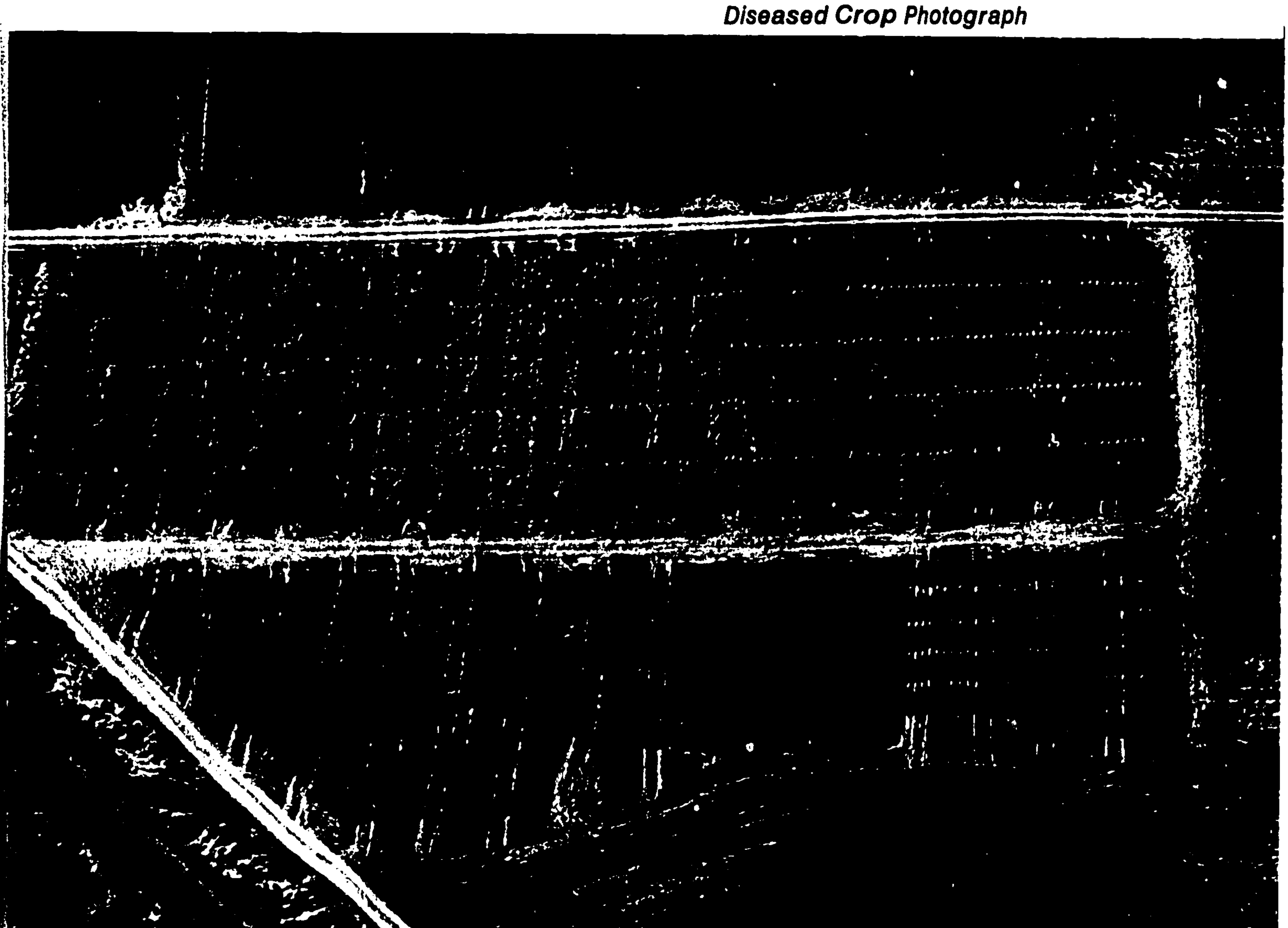


## Crop Conditions

8

To investigate a different use, an experiment was carried out by introducing a blight into certain portions of a potato planting. The field was then repeatedly photographed with infrared sensitive film. The dark portions of the accompanying photograph, which are far more vividly seen on the color print, are the diseased areas. They were discernible in infrared photographs several days before any changes were noted on the ground. While these photos were taken from an aircraft, comparable results over much larger areas can be achieved from spacecraft. In fact, crop condition identification would be possible on a world wide basis.

*Diseased Crop Photograph*



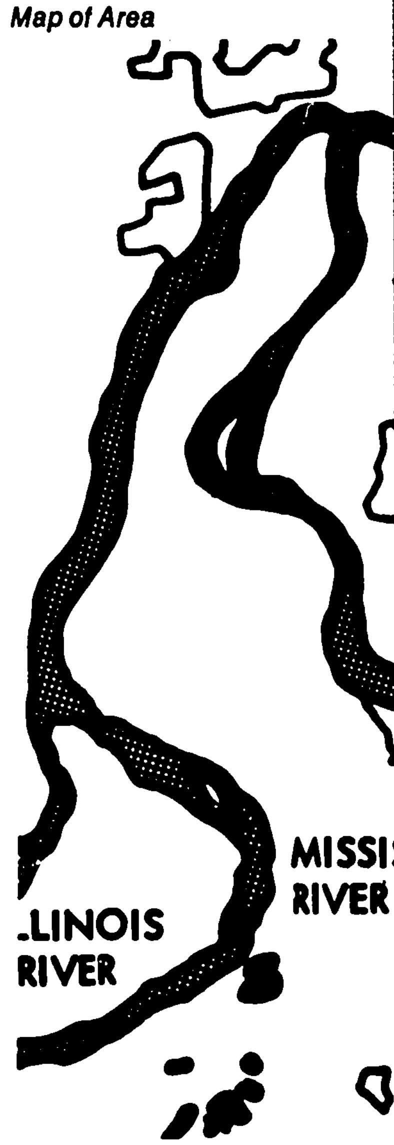
**Hydrology**

The use of microwave imagery offers a unique opportunity to understand the distribution of water both on the Earth's surface and in the ground near the Earth's surface. The illustration below demonstrates how the water can be sensed even though completely obscured to the human eye. The frame at the left shows a complete cloud coverage over the area to be hydrologically mapped. The center frame, taken with a microwave system shows the water distribution sensed through the clouds and may be compared to the same section taken from a map. A close examination of the center frame indicates darkened areas around the streams representing the water-saturated stream banks. In some locations, such as shown in the right upper center side of the center frame, areas of subterranean seepage are detected far inland from the streams. This seepage is not discernible in visible light either from high altitude or from the surface.

*Cloud Cover*

*Microwave Image*

*Map of Area*



# Materials Processing

### Advantages of Space

The weightless environment in an orbiting spacecraft opens new possibilities for utilization of space to develop new industrial processing and materials science and technology. The absence of strong gravitational fields and the presence of high vacuum in space may make it possible to produce new and greatly improved materials, to manufacture products more precisely, and to process materials in new and different ways. Early space experiments will investigate basic factors affecting the processing of materials of direct commercial importance which cannot be produced elsewhere.

### Materials Processing Module

A module for the conduct of materials processing experiments would be attached to the Space Station. However, for some experiments it might be desirable to detach it from the station. Such a free flying mode would permit operations absolutely free of the vibrations and contaminants associated with the Space Station or would assure safety in the handling of hazardous materials.

The module would provide a workroom with a number of processing chambers, tools and equipment as well as storage space for raw materials and gases. A large airlock would afford access to the space environment or could be opened to space to provide a large, sheltered vacuum chamber.

*Astronauts, trained in metallurgy and crystallography, are shown experimenting with new material processes in the weightless environment.*

# Metal Foam

Space offers the promise of producing stable foams from a wide variety of liquefied materials and gases. It should be possible to produce a foamed steel with the weight of balsa wood but with many of the properties of solid steel. Such materials cannot be produced on Earth because the weight of the liquid metal causes the gas foam bubbles to float to the surface before cooling can occur. However, in space, gases would remain entrapped, producing a porous spongelike material.

The illustration shows the significant part of a conceptual experimental setup. A charge of powdered metal and foaming agent mixture is placed in the left end of the feed mechanism and pushed through by a piston. As the mixture passes through the heating zone it melts and the foaming agent causes bubbles to be formed within the metal. It then is cooled into a solidified foam.

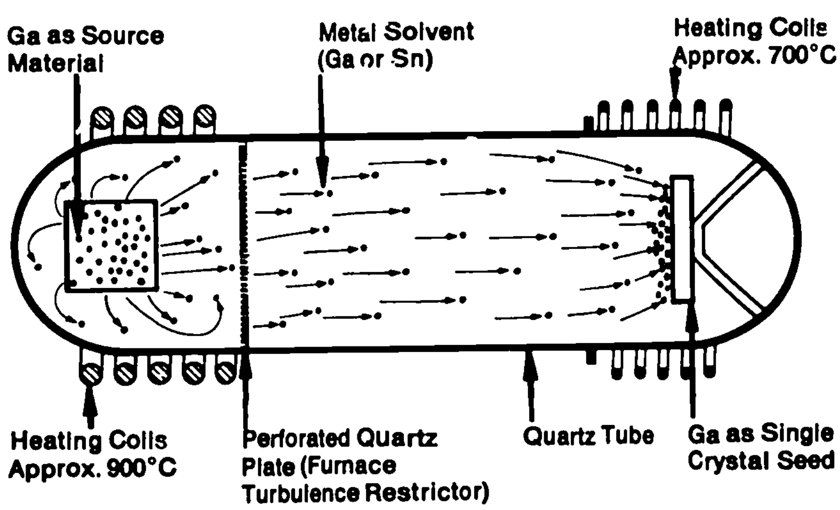
Similar techniques can be used to mix other materials of vastly different densities and properties; steel and glass for example. Such composite and foamed materials should result in lighter and stronger material for basic study, probable industrial applications, and the construction of future spacecraft.

# Crystal Growth

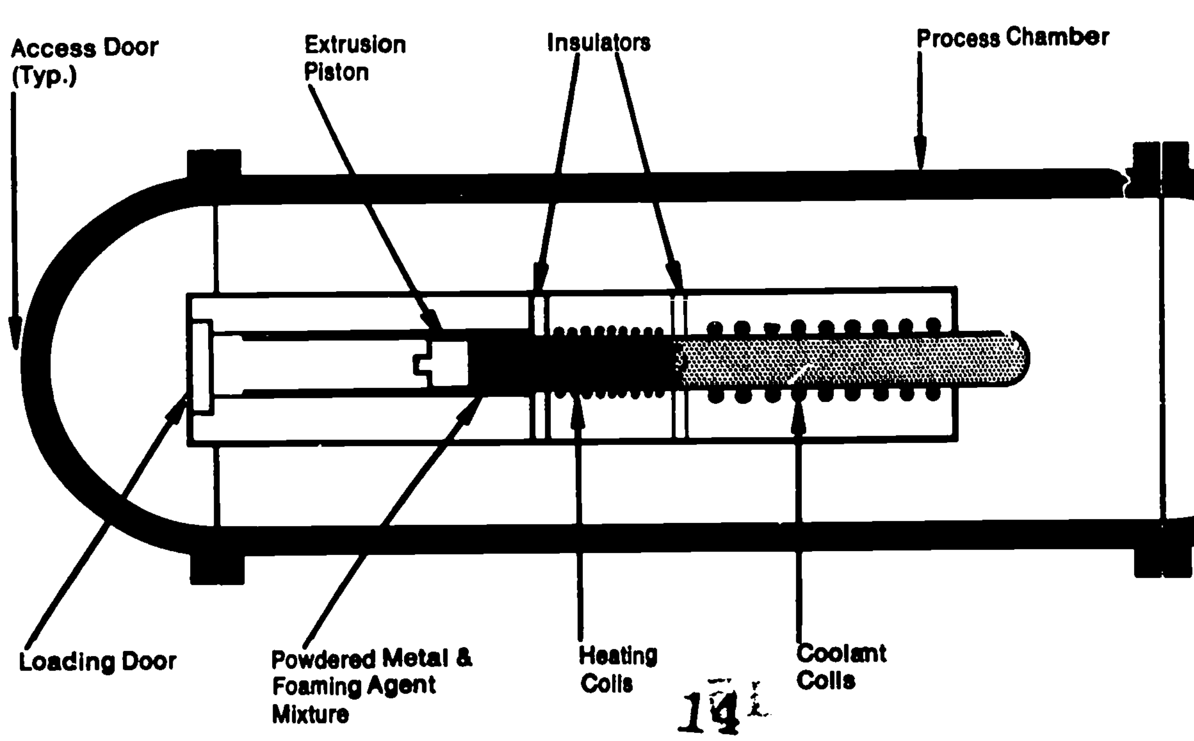
The size of single crystals grown on Earth is limited by disturbing outside forces or introduction of contaminants.

In a very clean, zero gravity environment of space, there are no such limits to the growth and, therefore, very large single crystals may be grown. These crystals, if grown of the right material and with the proper controlled impurities, might be used as very large power transistors, or if of pure quartz, as optical blanks for lenses of near perfect quality. Thus, prime candidates for commercial space manufacturing, even at today's cost of space transportation, are the very large dislocation free crystals we expect to be able to produce.

*Galium Arsenate Crystal Growth*




*Structural Metal Foam Concept*



# Levitation Melting

Suspending a specimen of material (levitation) is important because it offers the possibility of melting materials without the contamination from a crucible or any type of mechanical restraint. Metallic materials and structures may be shaped by manipulating surrounding electromagnetic fields with resulting perfect shapes. The virtual absence of gravitational forces makes this a natural process to investigate in space.

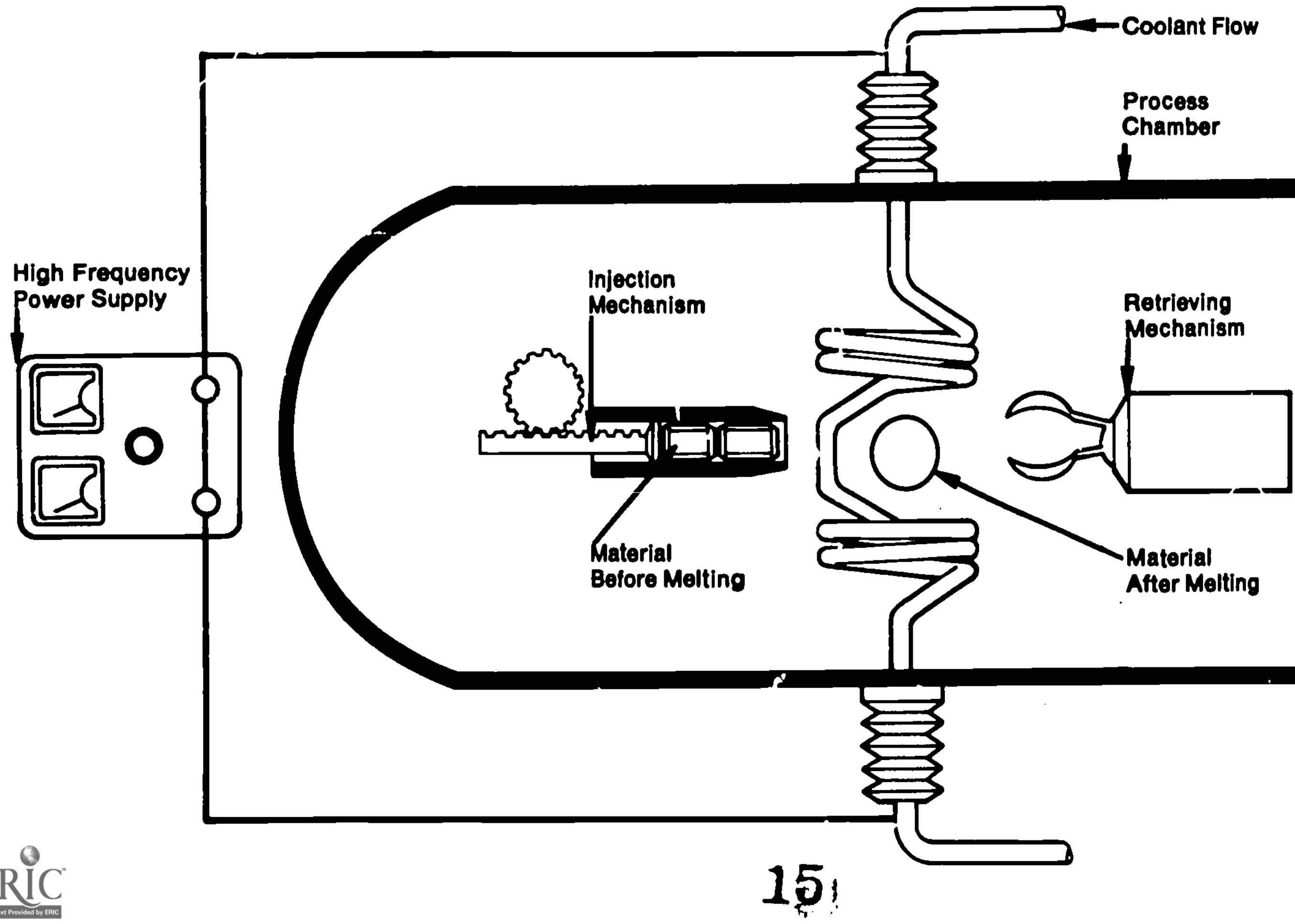
**Suspension Techniques**

Levitation melting can be accomplished on Earth using a scheme similar to that in this illustration. Electricity passing through the coils creates a magnetic field of such a nature that a metallic specimen placed in the center will remain there as in a bottle. The high frequency current also heats. Unfortunately, under the gravity conditions on Earth, it takes more current to levitate the material than it does to melt it. It cannot be cooled without coming to rest on something. In weightless space, however, the metallic material is easily levitated and maintained in place and the current can be raised to cause softening or melting. By manipulating the magnetic fields in a system of such coils, the specimen can be moved about without touching anything. Thus, it can be both melted and resolidified without becoming contaminated or deformed. By such a method, perfect spheres could be produced for use as ball bearings. Alloys could be produced with uniformity resulting from maximum intermixing of constituents. Refinement of metals to high levels of purity should also be possible.

**Other Processes**

The foregoing are but three processes that have been considered as among the first candidates for investigation aboard the Space Station. Other processes difficult to perform in the atmosphere or in Earth's gravity, are also being studied for conduct in space.

*Levitation Melting Concept*



# Science

Another initial and continuing use of a permanent space research facility is to conduct scientific investigations to extend man's knowledge of the nature of the universe. Man's curiosity has caused him to explore the entire surface of the Earth and now to go beneath the seas. It has led him to the moon and will in time lead him to the planets. Science offers answers to man's natural curiosity and the promise of the unforeseen rewards of new knowledge.

To the sciences of astronomy and certain branches of physics, the universe is both a vast arena for observation and a laboratory for the conduct of experiments difficult or impossible on Earth. Astronomers, physicists, biologists and physicians have all found the environment of space to offer exciting opportunities for research. They seek understanding of the basic laws of physics, the nature and origin of the universe, the solar system and the Earth, life not of Earth origin and how living organisms respond to the absence of gravity and night/day rhythms.

# Astronomy

### Instruments in Space

Astronomy and related sciences have proved invaluable in man's exploration and understanding of Earth—in marine navigation, in aerial navigation, in communications, meteorology and other sciences. All draw upon man's ability to study the skies and make deductions about the Earth (helium, for example, was first discovered on the sun). But astronomical observations have always been limited by the atmosphere; for man, like a fish, peers up through a semi-transparent fluid.

Astronomers have long wished to get their instruments into space, where they will be above atmospheric interference, free from atmospheric turbulence, light-ray scattering, sky brightness, cloud cover and pollution. In space, there will be virtually no resolution limitation imposed by the medium and astronomers will be able to fully use the inherent capabilities of the instruments.

Just as when Earth was first studied from space, so astronomical observations from space have revealed new, previously unknown phenomena. This is especially true in ultraviolet and infrared astronomy. The atmosphere effectively blocks from the Earth's surface much radiation in these important spectral bands.

Automated astronomical instruments have been orbited to overcome these handicaps. The most notable of these has been the Orbiting Astronomical Observatory. Instruments of larger size and greater capability are needed. But the cost of these instruments mounts rapidly with size and complexity. Manned attendance for modification adjustment, maintenance repair, film recovery, and replenishment could greatly extend useful life of the observatory and reduce costs.

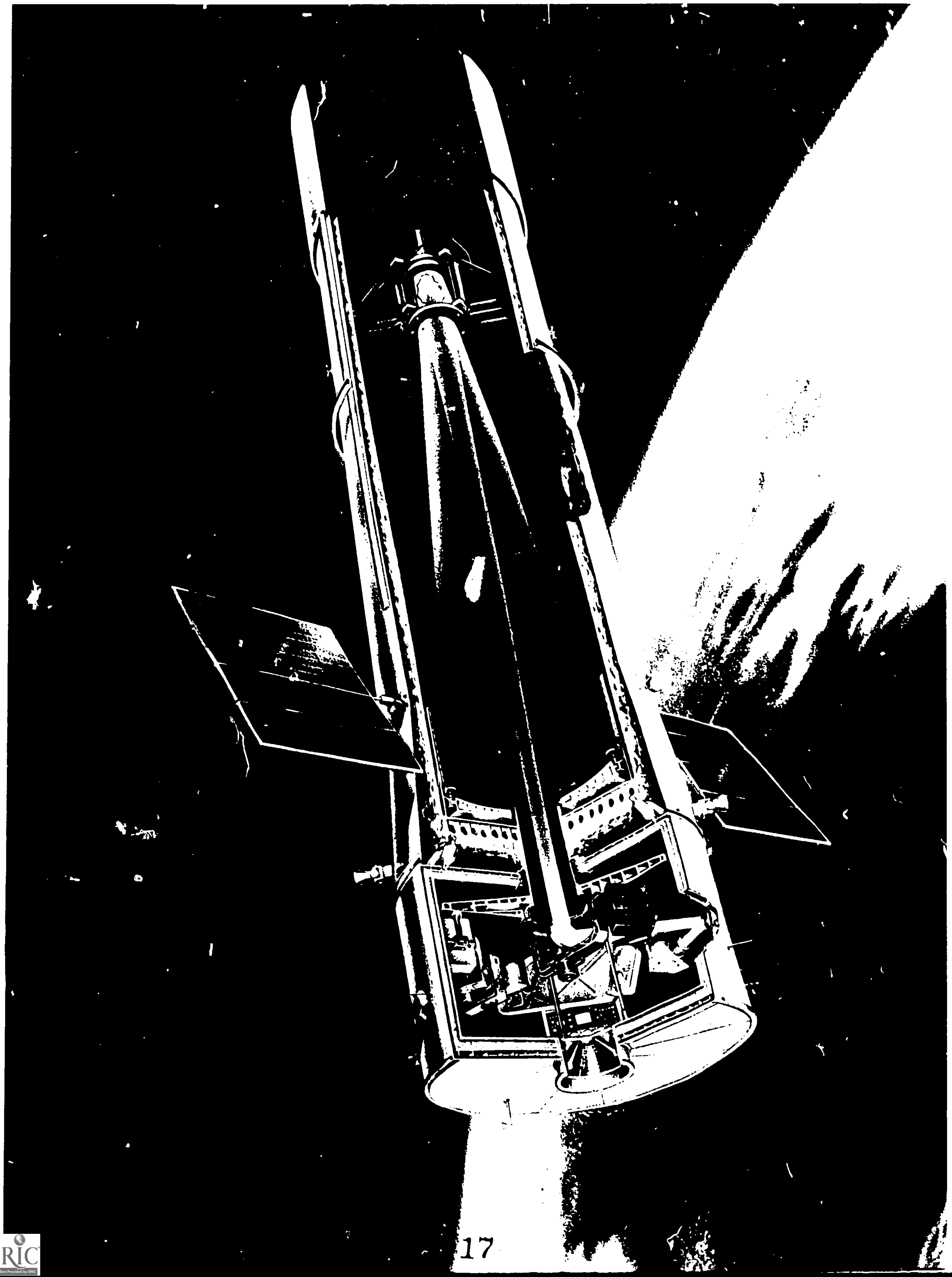


### Multiple Use of Instruments

These illustrations show a large telescope module operating in conjunction with a Space Station. The concept depicted is designed for observing ultraviolet and infrared as well as visible radiation from stars and planets. Similar modules equipped with different instruments could be used for solar observations or study of X-rays from celestial objects. In the design shown, the telescope compartment and instrument area can be pressurized to accommodate a man. The module would operate at a distance from the Space Station to remove it from disturbances caused by the crew moving about or from contamination by waste products from the Space Station. The large shade shown around the telescope aperture screens off unwanted sunlight.

Since man's motion in the telescope module may upset measurements even when the module is free of the station, it should have the capability for completely automated operation. This would give two approaches to flexible observatory operation. Instead of orbiting an unretrievable, unmanned observatory, a retrievable one would be controlled from the Space Station. In one option, the automated module could be sent out for operation and brought back, repeatedly, for maintenance, repair, and replenishment. In the second option, a man could be put aboard to conduct observations and experiments and to make on-the-spot repairs. When operating properly and long term observations were desired, it could be sent out unmanned and brought back at the conclusion of an observation. Multiple reuse of the same laboratory would reduce costs and increase the knowledge gained.

***The large aperture telescope shown orbited above the atmosphere would allow clear and sharp seeing of individual stars in distant galaxies ten times smaller than can be seen from same size telescope on the Earth.***



# Life Sciences

### Specimens in Space

The Space Station offers life scientists the opportunity to study life processes under conditions that cannot be duplicated on Earth. These conditions include removal from the gravity and from the periodicities associated with the Earth's rotation—and perhaps removal from other phenomena not yet recognized.

There is a pervasive, complex relationship between biological functions and environment. When the environment is altered, living organisms show a great capacity to adapt themselves. They do this by maintaining a uniform internal environment. Or they adapt genetically, to improve the probability that the species will survive. Researchers have come to understand a great deal about biological functions by applying the technique of altering environmental factors and studying adaptive processes as they come into play.

But the closest biologists can come to weightlessness in their laboratories is by use of a device known as a clinostat. This device rotates living samples so the force of gravity alternates. The effect is to have no net effect of gravity about any single axis. Use of the clinostat has been productive in research on plants, but the difficulties with higher animals or through several generations of plants are obvious.

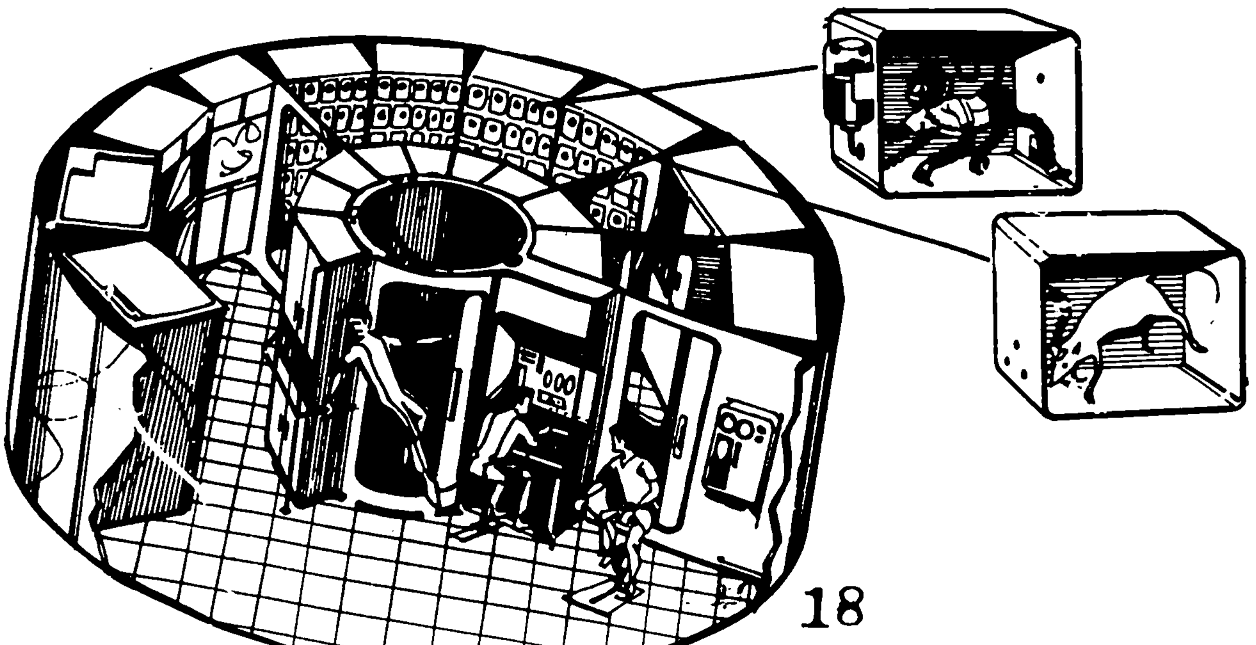
### Advances in Life Sciences

Significant advances in life sciences should come about through prolonged study of all kinds of plants and animals, including man, in space. This work has already been started, using automated biosatellites and through monitoring man's reactions in space travel; but, a manned biological laboratory is expected to yield vastly more information. Man's presence is highly desirable for most of the experiments; however, there are times when this is a deterrent. Biological organisms and their life processes are inherently variable and complex, requiring interpretation, extraction of information from incomplete data, and rearrangement of experiments. Equipment that can manipulate soft tissue and handle lively animals defies automation.

The biological laboratory concept illustrated is designed for experiments with plants and animals, and for human physiological and medical evaluation. Special compartments will house specimens for study and will have separate environmental control systems. A radioisotope facility will occupy two wedge-shaped segments, along with equipment for measuring and data-handling.

The human physiological assessment laboratory uses an integrated monitoring and data-management system, filling about a third of the available space. An astronaut is pictured undergoing cardiovascular and metabolic assessment on a bicycle ergometer. A crew member monitors his responses while measurements are fed to a computer for storage and comparison to past performance. The development of this capability has two important facets. First, it enables a continuing evaluation of the astronaut's physical condition as the mission progresses. In earlier space programs these tests could be performed only after the flight was completed. Second, the equipment and techniques developed, which allow a small staff to perform a comprehensive physical analysis, may find wide application to civil medical practice.

*Astronaut/Biologists and medical doctors are shown observing the physical condition of a fellow astronaut riding the exercise bicycle. Small animals would be kept aboard for several generations to observe the adaptations to space.*



# Physics

### Cosmic Rays and the Nature of Matter

Some of the basic questions about the nature of matter can best be illuminated by the study of cosmic rays, which are charged particles such as protons and electrons that originate outside the solar system and travel at very high speeds. Much of the rapid progress in physical science in recent years has resulted from the study of secondary effects of cosmic rays after they strike the upper reaches of the Earth's atmosphere or by employing powerful magnetic fields to accelerate such particles to high speeds in earthbound machines.

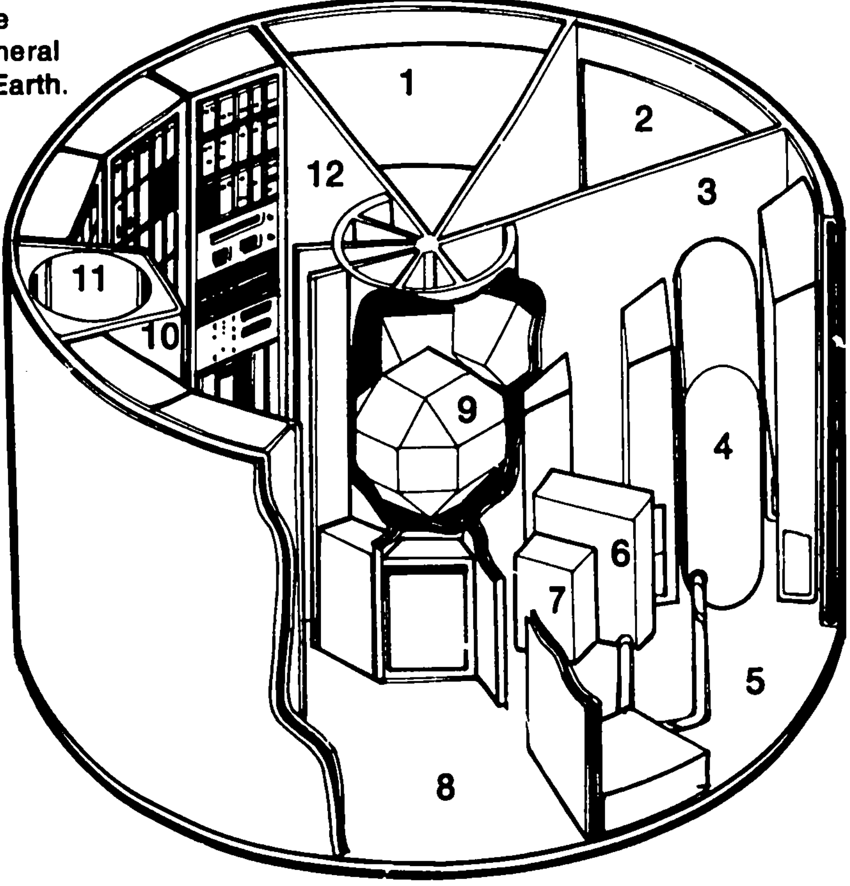
Since 1958, automated satellites have carried instruments to detect and measure cosmic rays in their original form in space. From these observations came Dr. James A. Van Allen's discovery of the trapped radiation belts about the Earth. Now physicists would like to take the next step of placing in orbit machinery to generate powerful magnetic fields that might detect cosmic rays of much higher energies and possibly prove that "anti-matter" occurs naturally in the universe. The equipment for such experiments would be so large and complex that it would best be operated in conjunction with the Space Station.

Other experiments that might be conducted in a physics laboratory in space would test those aspects of Albert Einstein's Special and General Laws of Relativity that cannot be tested on Earth.

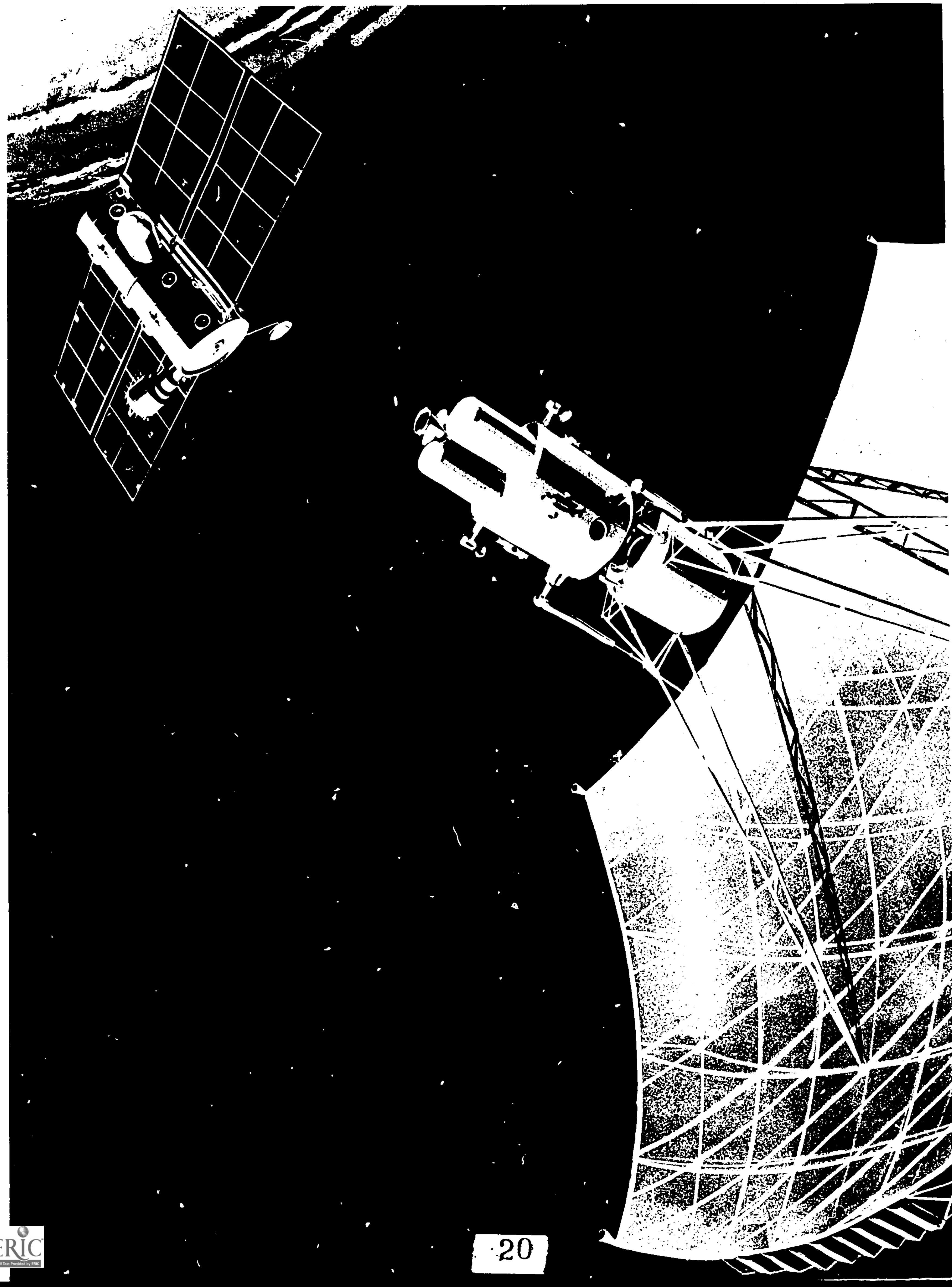
### High Energy Physics Laboratory

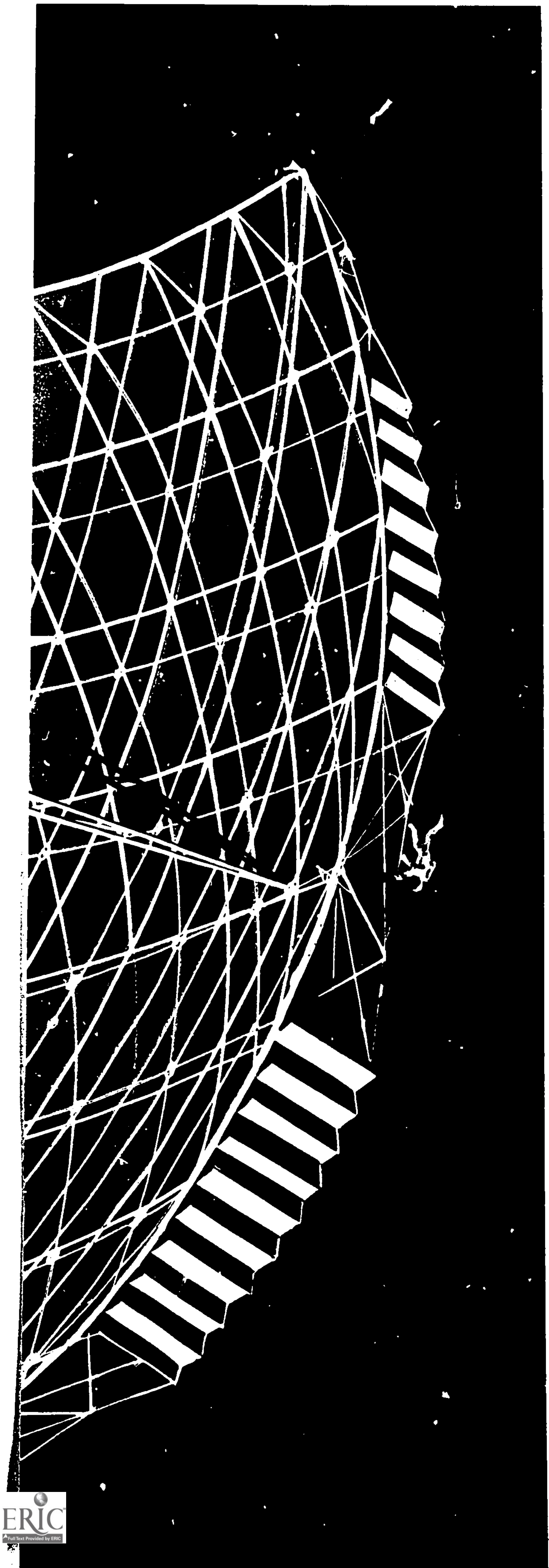
This illustration shows a laboratory concept for high-energy physics and cosmic ray studies. The laboratory could be one deck of the Space Station or could be a separate module to operate in conjunction with the station.

The heart of the facility is a superconducting magnet two meters in diameter. It is surrounded by two concentric octagonal chambers for tracking incoming high-energy particles. One octagonal face is shadowed by a target of liquid hydrogen and a second set of track chambers. Particles passing through the target react with the hydrogen. The reaction products are the primary object of study. They can be analyzed immediately or they can be transmitted to the ground for analysis. The laboratory arrangement allows simultaneous scanning of large areas of the sky. As experimental knowledge develops, the configuration can be changed to meet new requirements.




1. Experiment Bay 3
2. Experiment Bay 2 & 4
3. Experiment Bay 1
4. Liquid Hydrogen Target
5. Cryogenics Laboratory
6. Super Conducting Magnet
7. Emulsion Storage
8. Cryogenics Control Room
9. Ionization Spectography
10. Emulsion Laboratory
11. Intra-Deck Tunnel
12. Ionization Spectography Cont. Room





# Large Structures in Space

Much communications work can most economically be conducted from space. These uses will require large antennas. An antenna like the one shown in this illustration is too large to be launched fully extended. It might be sent up from Earth folded or in several pieces. Men might contribute to the work in space to assemble, deploy, calibrate, service, and repair such a large structure. Because of its size and the precise manipulation required, full automation of a large antenna deployment seems to have too high a risk of failure.

The large antenna deployment problem might be regarded as a technology development area, with the Space Station the base of operations. Modified parts and tools could be developed in the station or sent up from Earth as needed. An antenna in good working order in space would be the end item of the development program and the experience gained would make setup of another, better, antenna far more routine.

The antenna shown is a rigid, lightweight type that could be used for direct television and voice broadcasting, traffic control radar, or for deep space communications. As shown here, it is fully operational and is being readied for removal from the vicinity of the Space Station to a more suitable location (for communications) by a space tug. Grappling arms on the tug are latched to the antenna. The tug could return the antenna to the station or carry a man to the antenna for adjustment or repair.

A communications antenna is only one of many large structures that might be built in space. Others include launch platforms for deep space probes and space factories for making new products.

*A Space Station crewman is making final adjustments on a large communication antenna prior to towing to a higher operational altitude.*

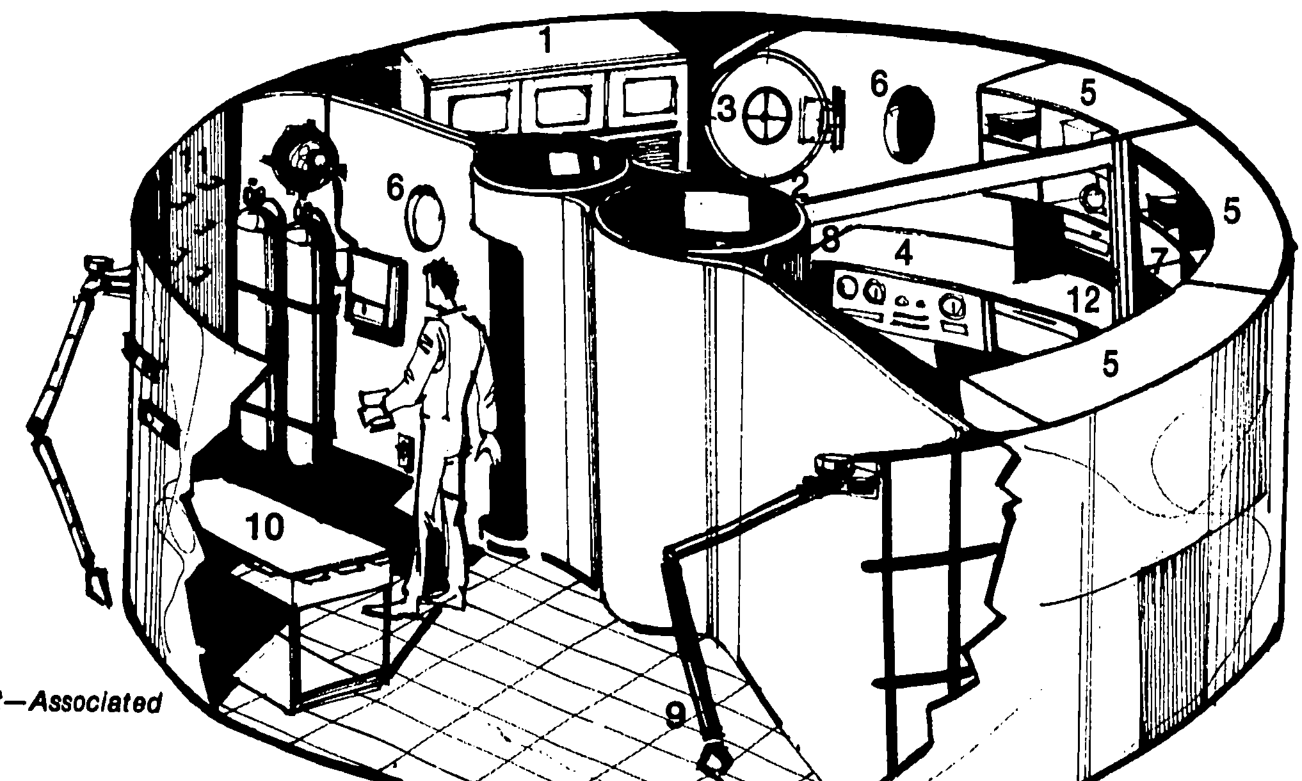
*Hybrid Space Suit*

# Advanced Technology

At the Space Station, efforts will be made to reduce operating and maintenance costs, to improve the station's efficiency and to extend its life. This effort will result in technology and knowledge of direct value in extending the life of devices used in every day life on Earth. Research and engineering will also be conducted to develop better longer life systems, components, and materials. These advances assist the Nation in world industrial competition and enhance its security.

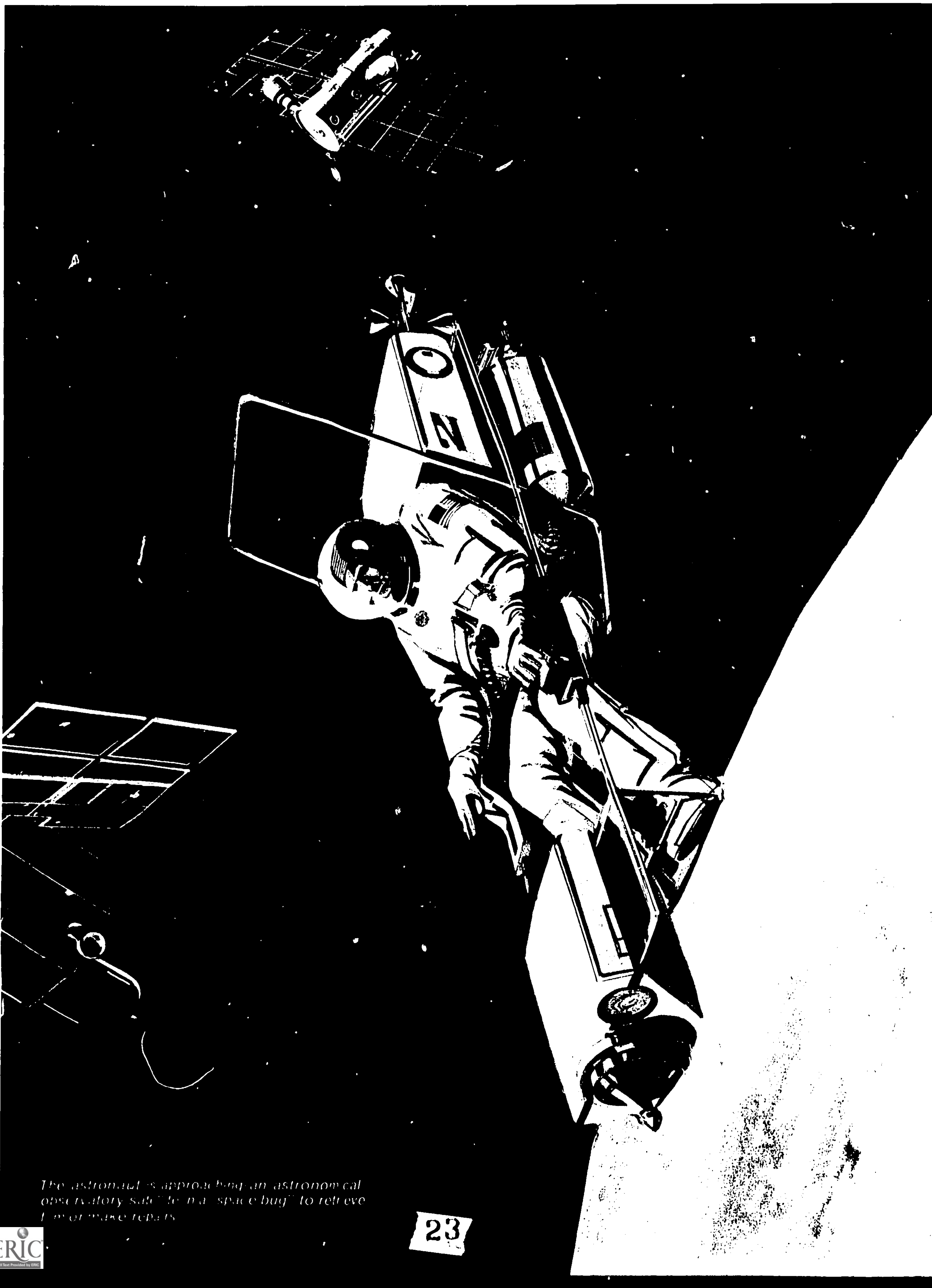
Much of this work will be conducted as at present on the ground. But there will be areas in which the Space Station and its environment will be needed to validate or qualify ideas and equipment.

A concept of an advanced technology laboratory in a Space Station is illustrated. Space suits, environmental control systems, personal maneuvering units, liquid storage and transfer equipment, electrical power systems, reaction controls, and structural repairing could be tested and developed safely in the laboratory or the surrounding space.




*R&D Advanced Technology Laboratory*

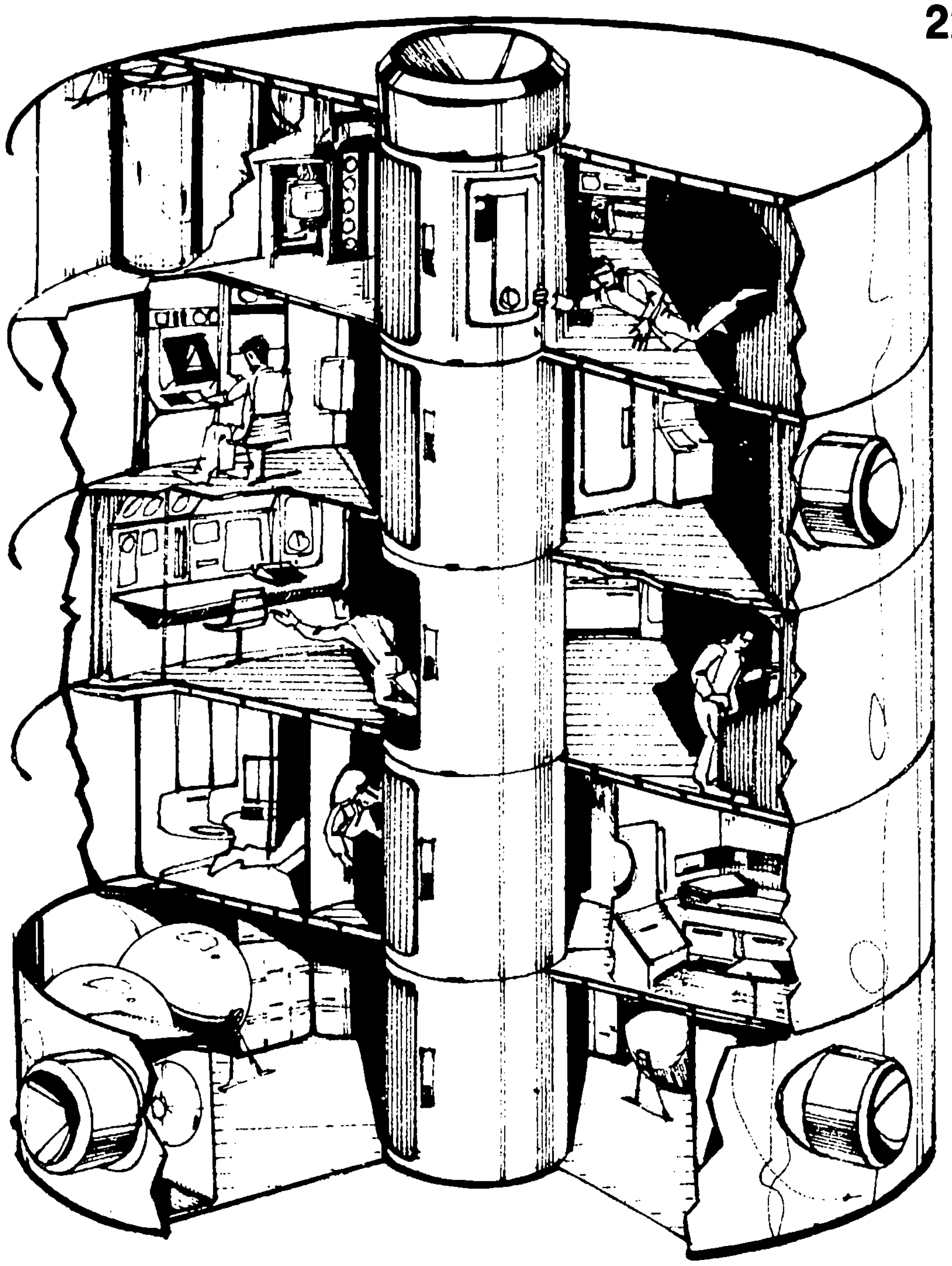
1. *Display Equipment—Associated Electronics*
2. *Equipment Airlock*
3. *Logistics Module Docking Adapter*
4. *Mass Spectrometer*
5. *General Parts & Equipment Storage*
6. *Viewing Port*
7. *Fluid Handling Enclosure*
8. *Experimenter Racks (Removable)*
9. *Manipulator Arm*
10. *Test Fixture*
11. *Experiment Mounting Brackets*
12. *Work Bench Area*



*The astronaut is approaching an astronomical observatory satellite in a "space bug" to retrieve film or make repairs*

*Space Station Core Module*

22




*The Station has five decks, each with a particular function. The men would spend most of their time in the upper four decks, the fifth serving primarily for storage. The artist has attempted to convey zero gravity by showing the crew free floating about the Station. Our Apollo experiences lead us to believe the crew will find zero "g" environment pleasant and conducive to functioning effectively.*

**The Space Station**

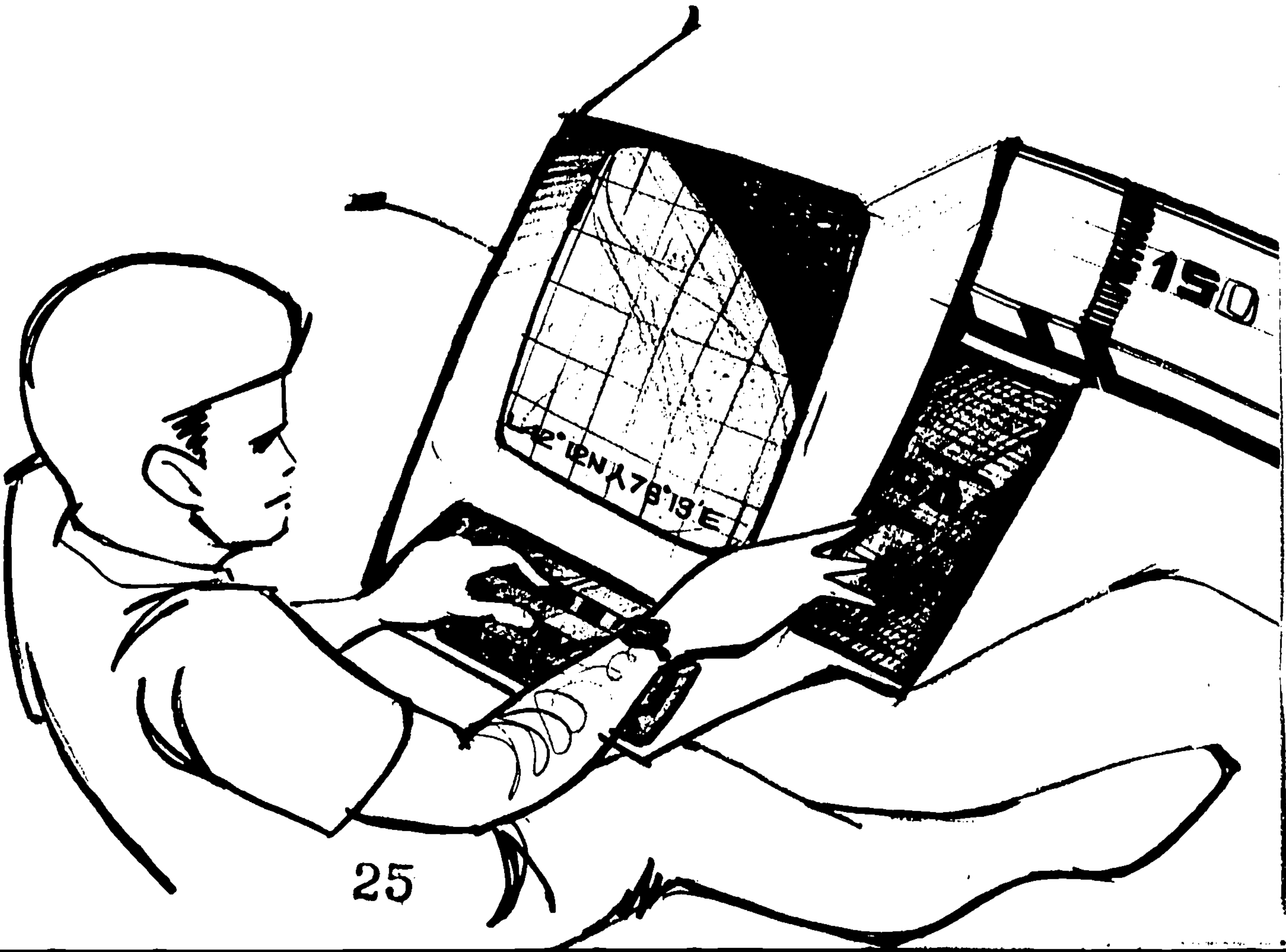
The Space Station will be a semi-permanent facility in orbit with an operational life of ten or more years. It will be a site of research, Earth-oriented practical applications and support of space flight operations. For such an installation to be useful for so long a period, it must be capable of evolutionary change to meet new requirements. This need for flexibility is found in any laboratory, space or terrestrial. As one type of activity is completed, it is replaced by another with new support requirements. New apparatus will be installed, old systems will be modified and the training and makeup of the crew will change.

Core stations may weigh up to 100,000 pounds. They will have as many as five decks. Two will be devoted to living, eating, sleeping, and controlling the Space Station. One will be used to receive and house supplies. One will contain such subsystems as environmental control to maintain a pure, breathable atmosphere and water management to reclaim waste water for reuse. The fifth deck would be a laboratory equipped to conduct a wide variety of experiment activities. This deck would be supplemented with other modules containing specialized experiments or developments. Electric power would be supplied by large solar cell arrays or by a nuclear power system.

**Crew Provisions**

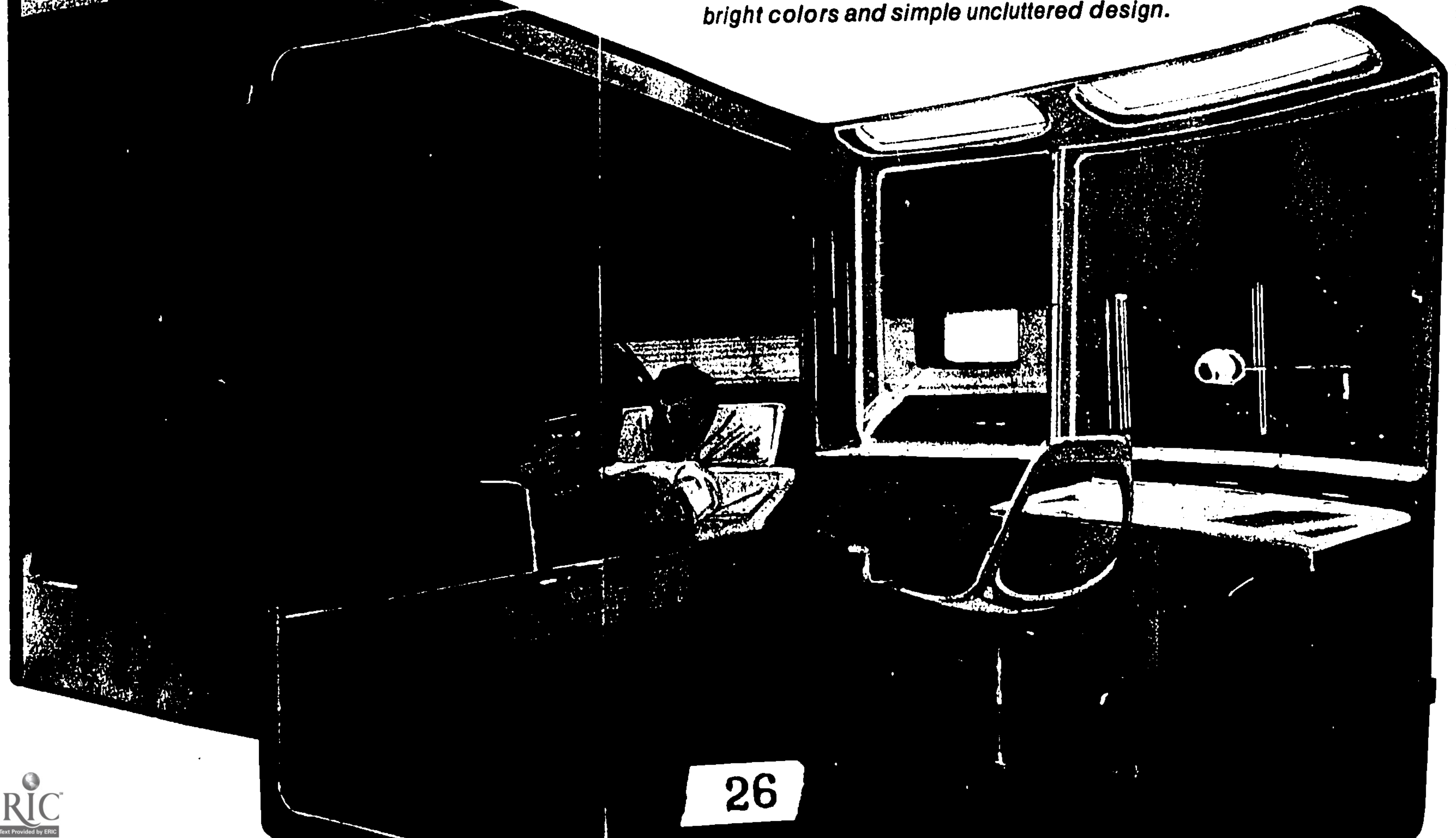
The station will provide living accommodations for a crew of 12, some responsible for the maintenance and operation of the Space Station others for the conduct of experiments or to make observations. A crewman may be aboard the station for up to six months. To keep the crew morale high and to stimulate creative and effective research operations, a great deal of care will be taken to selection of the every day living facilities. Food served will be as near as possible to that served on Earth. Some fresh frozen meats and vegetables will be included. Quiet, private areas will be provided in which the crewmen can work, read or write. Adequate personal hygiene facilities will be provided to allow the crew to keep themselves clean and well groomed. A wardroom area will serve both for dining and to hold meetings to coordinate the station's activities.

*Shown below is a crew member operating a multi-purpose control and monitoring station. By the crew men selecting different modes of operations, the single display screen can be used to show data on performance of a spacecraft system or to monitor the operation of a remote experiment. In this case, the operator has selected a TV view of the Earth. Latitude and Longitude are also displayed on the screen.*




*This sketch illustrates the type operations which might be carried on, on the subsystems deck. Crew members are shown checking equipment performance prior to making a repair. This type of routine repair activity will become a normal mode of operation as the Space Stations life is extended to ten years.*

*An artist's concept of a compartment designed to house one crewman. The design is intended to make a very small room (about 6' x 8') seem larger and more comfortable through the use of bright colors and simple uncluttered design.*

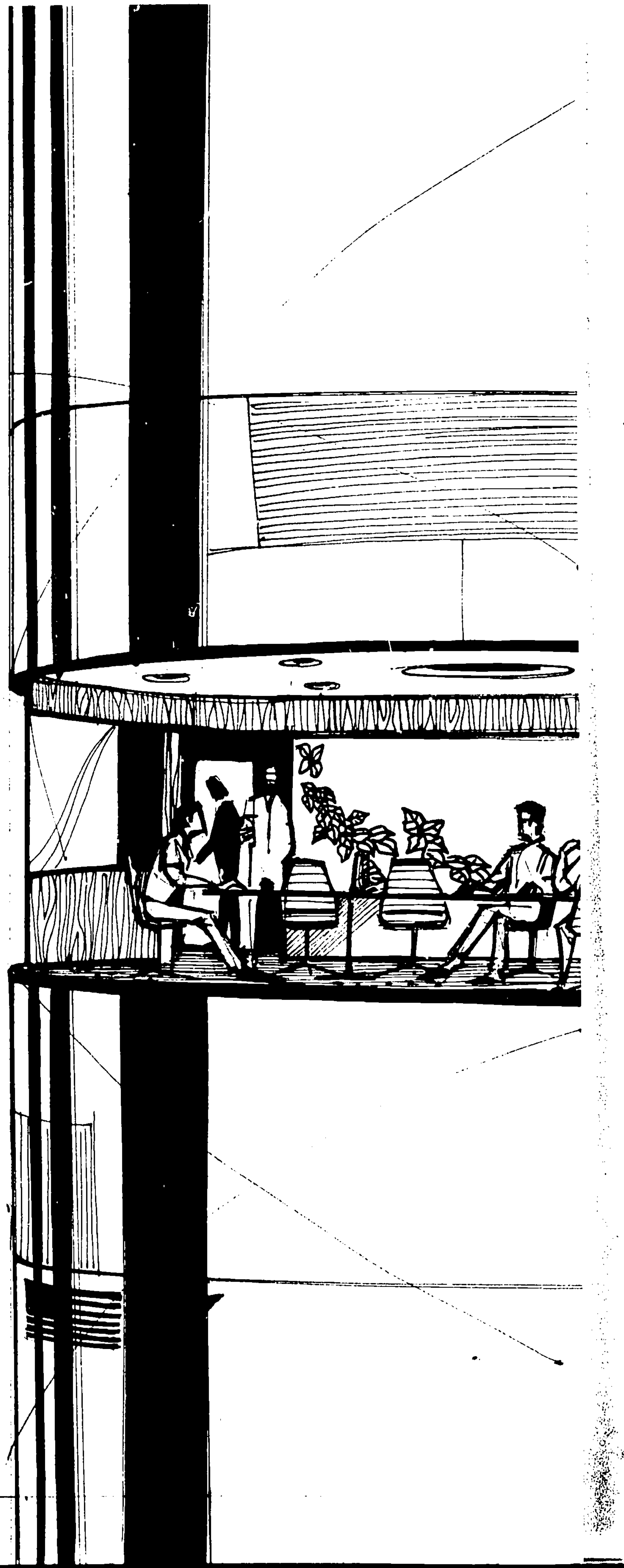


**Environment**

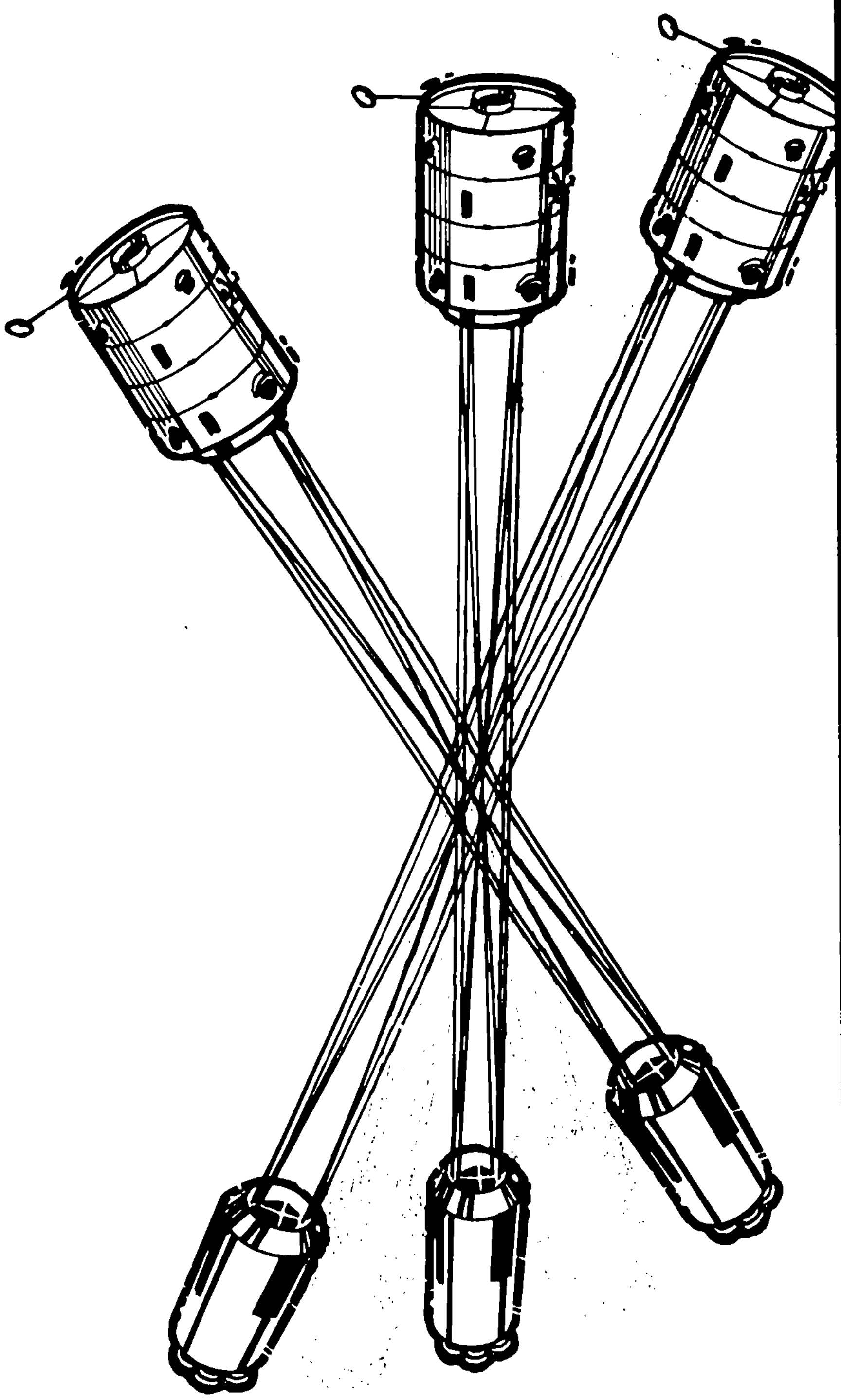
The crew will live in an Earth-like environment. The atmosphere will have the same constituents and pressure as air at sea level. Artificial gravity, obtained by swinging the Space Station counter-balanced by a spent booster stage, will be evaluated early in the station's mission and should it prove advantageous to conduct of operations or contribute to crew comfort, a future growth version of the station would have volumes of both zero and artificial gravity.

**The Future**

The history of scientific and technological progress would indicate that many uses will be made of space beyond those now envisioned. Thus, it is important to take steps that assure that what is built today will continue to serve in the future. Design is proceeding with the goal in mind of eventually having a national research facility in Earth orbit called Space Base. The Space Station would serve as the first part of this facility to be retained and used as the Space Base grows, just as today it is common for colleges to retain and use their initial buildings. Space Stations will grow by addition of Space Station modules, experiment modules, utility modules and storage units for liquid fuels, oxidizers and other consumable supplies. The Space Base will provide both artificial gravity volumes, used in those operations enhanced by the presence of gravity, and zero gravity volumes in which to conduct experiments. It would also serve as a supply depot, launch site and mission control facility for deep space spacecraft.

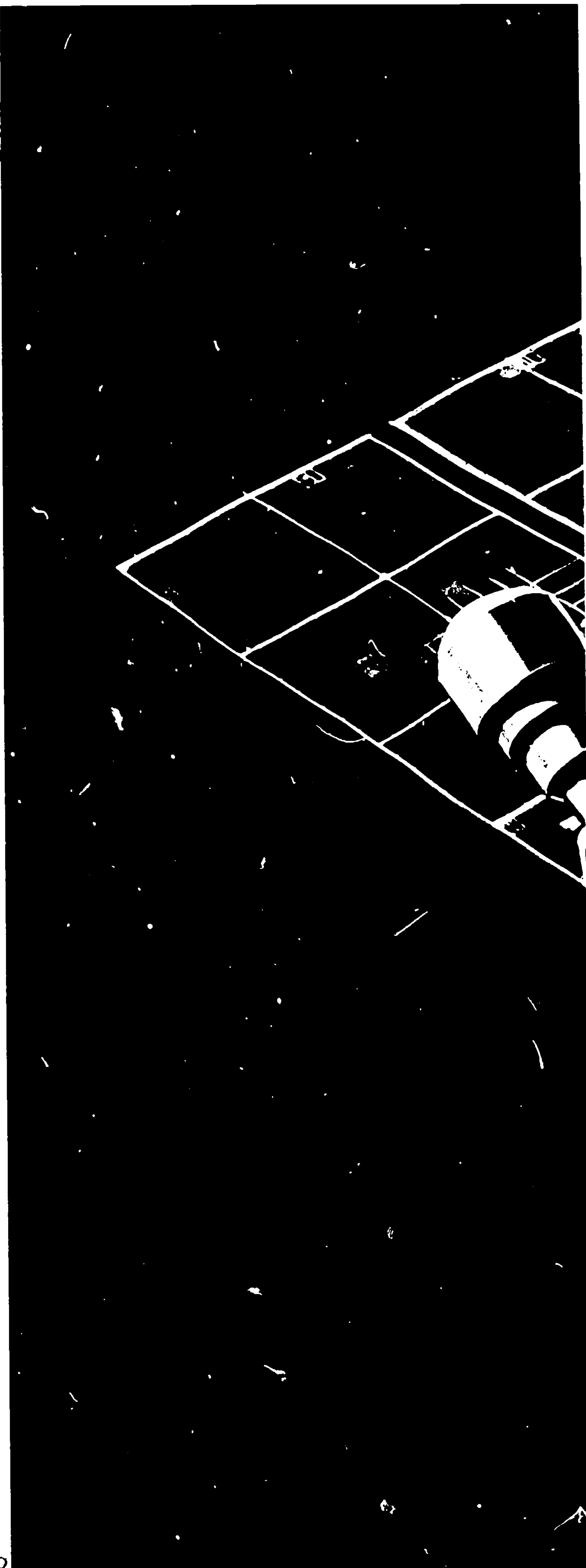


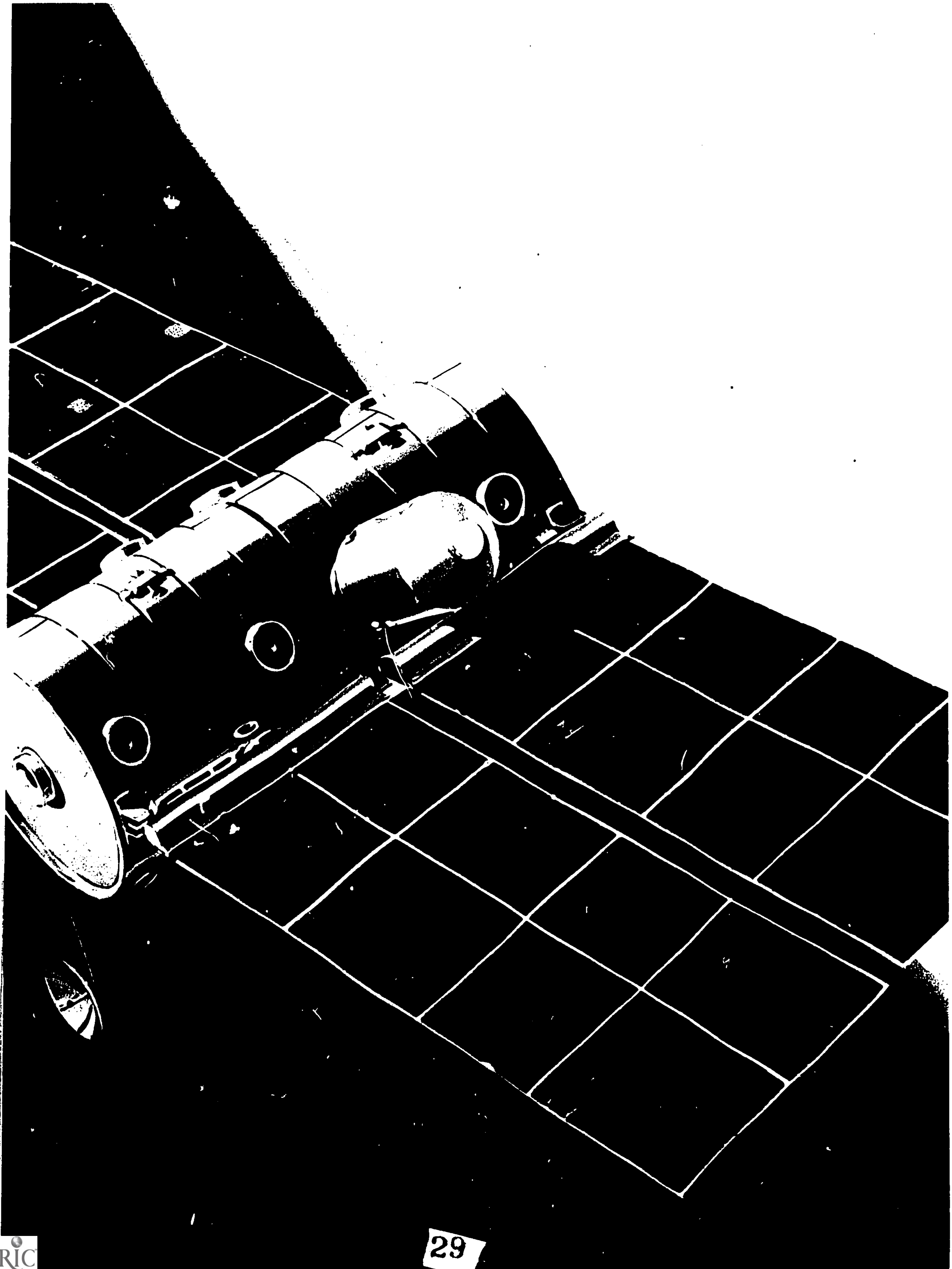
*Shown in this cut-away is a portion of a deck used as a ward room. In this area, the crew will dine and hold discussions to plan the Station's activities.*

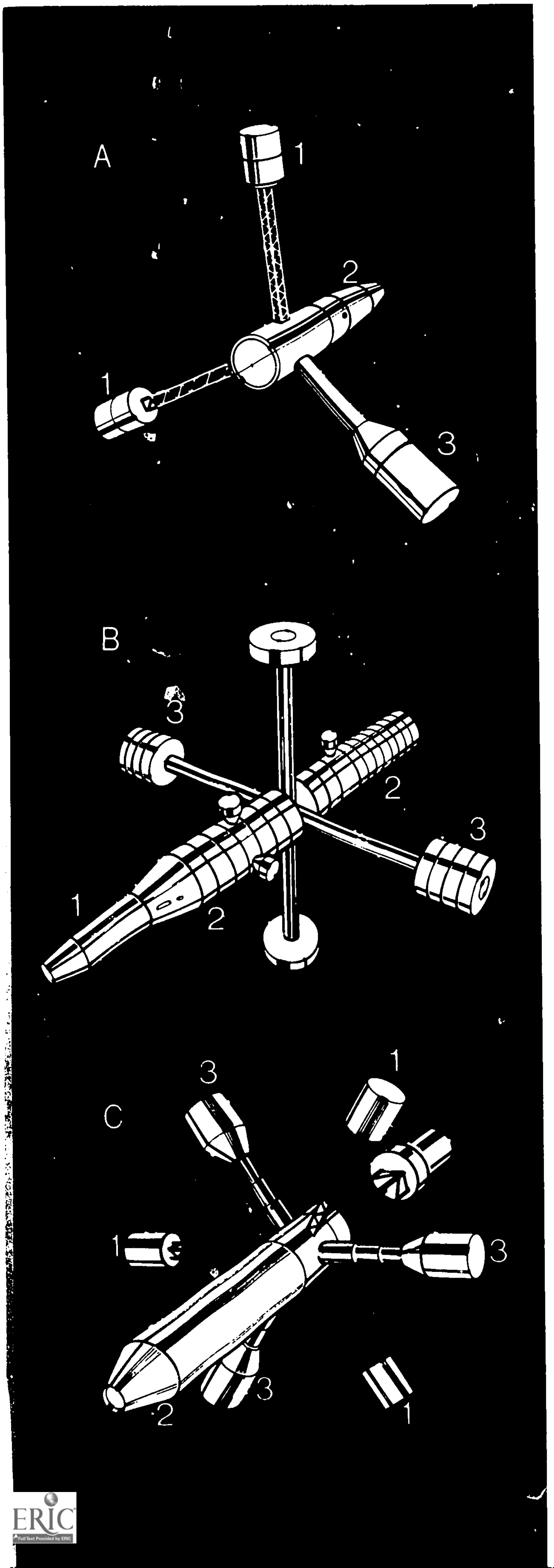


One of the initial evaluations to be made in the Space Station Program is the usefulness of artificial gravity. In this concept, the Space Station (upper module) is connected to the spent S-II booster stage (lower module) by long cables. The two are then spun, one counter-balancing the other to provide artificial gravity. The solar cell arrays are shown retracted to protect them from possible damage during the test.

As the activities in the Space Station increase, it will be necessary to add additional living and working space. Shown here are two identical space stations docked together to provide housing and laboratories for a crew of 24 men.



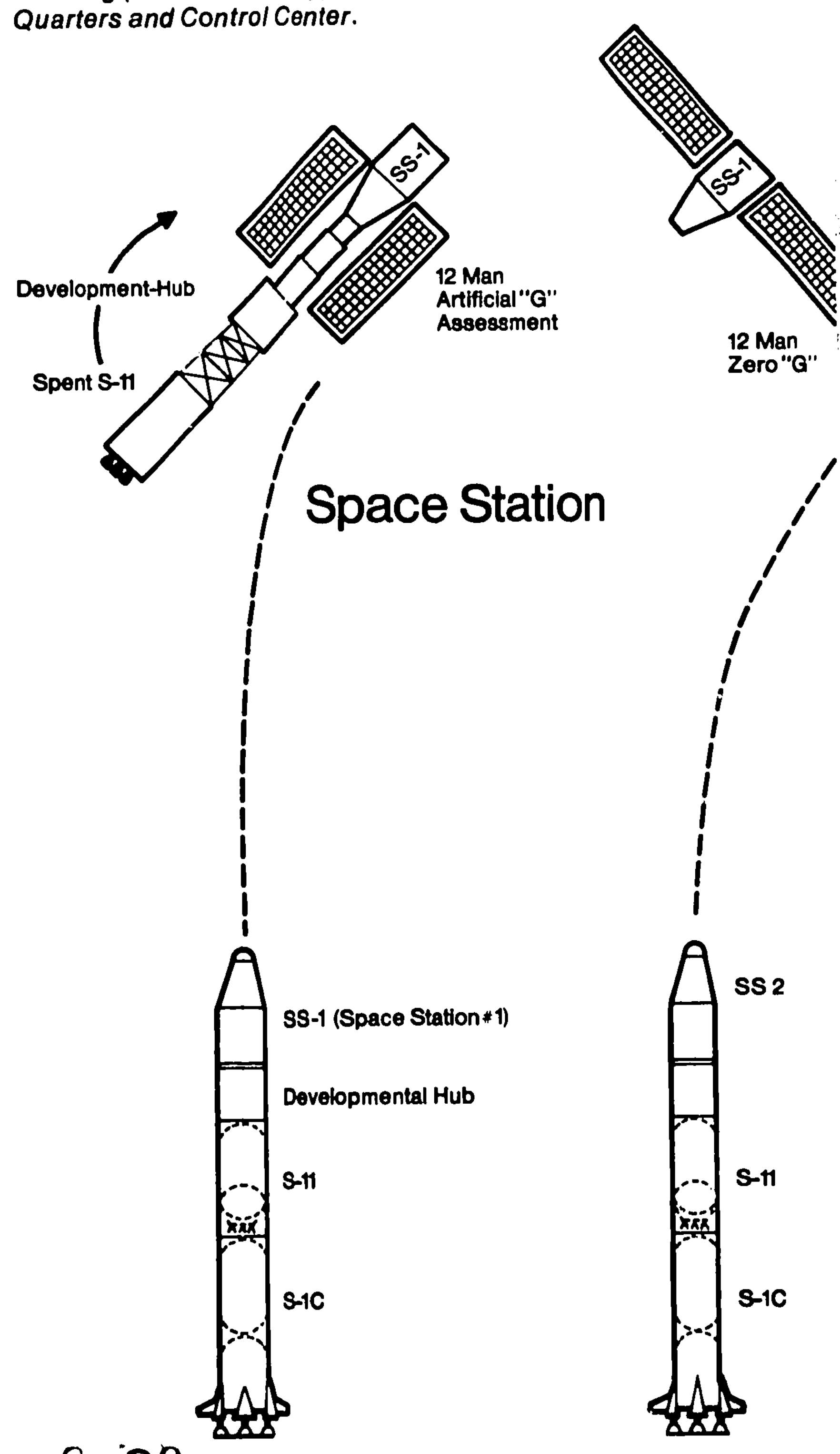





**28**

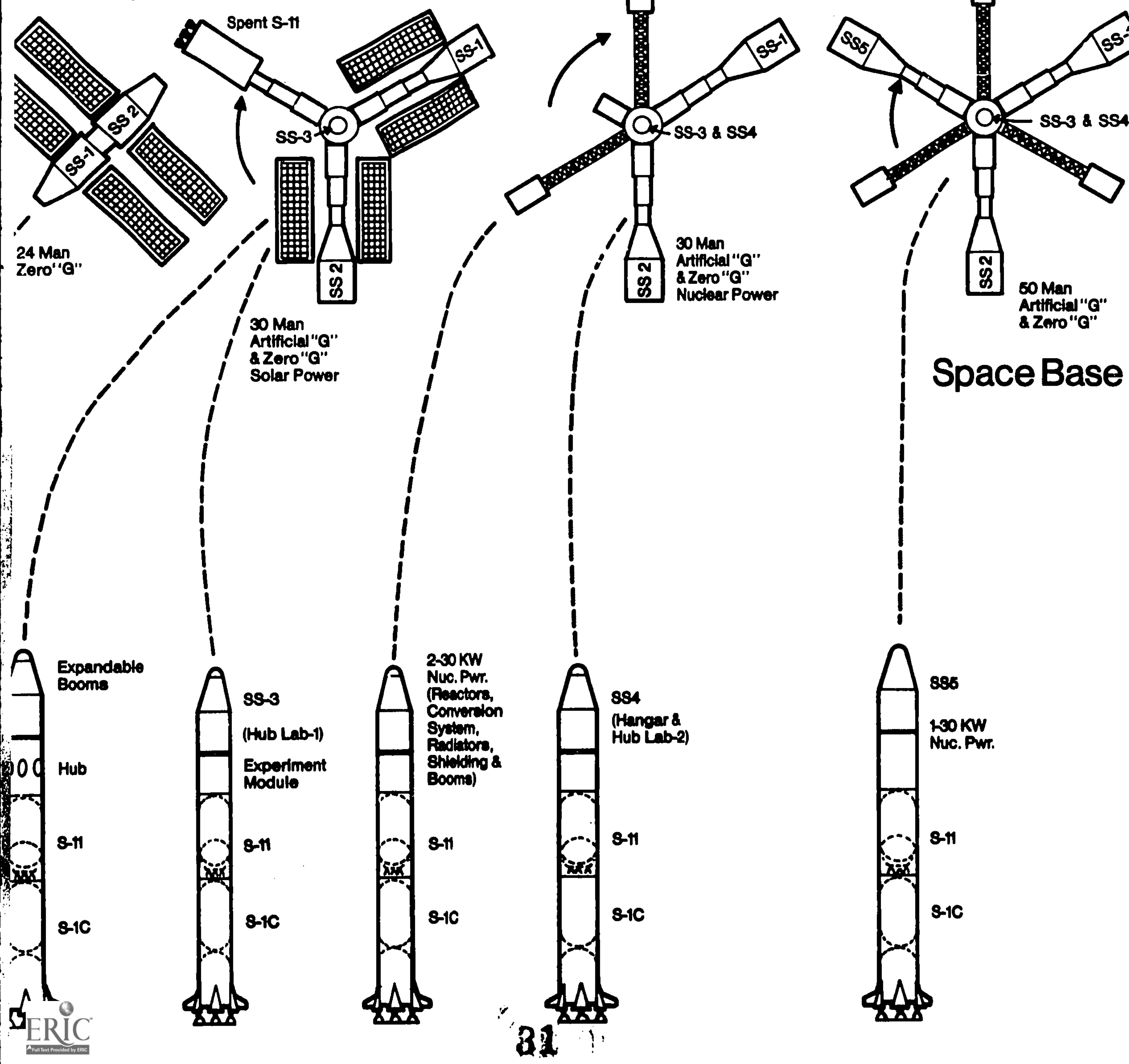
*This figure illustrates some other configurations which may prove desirable for a large Space Base. Concept C is the result of the build-up shown in the previous figure. Concept A is for a Y station having a large amount of electric power available from four nuclear reactors. Concept C offers larger habitable volume. Concept B maximizes the amount of zero "g" volume available for experiments or manufacturing activities.*

1. *Nuclear Reactor Power Plant (Total 100 Kw)*
2. *Non-rotating (Zero Gravity) Hub for Docking, Hanger and Laboratories.*
3. *Rotating (Artificial Gravity) Module for Living Quarters and Control Center.*



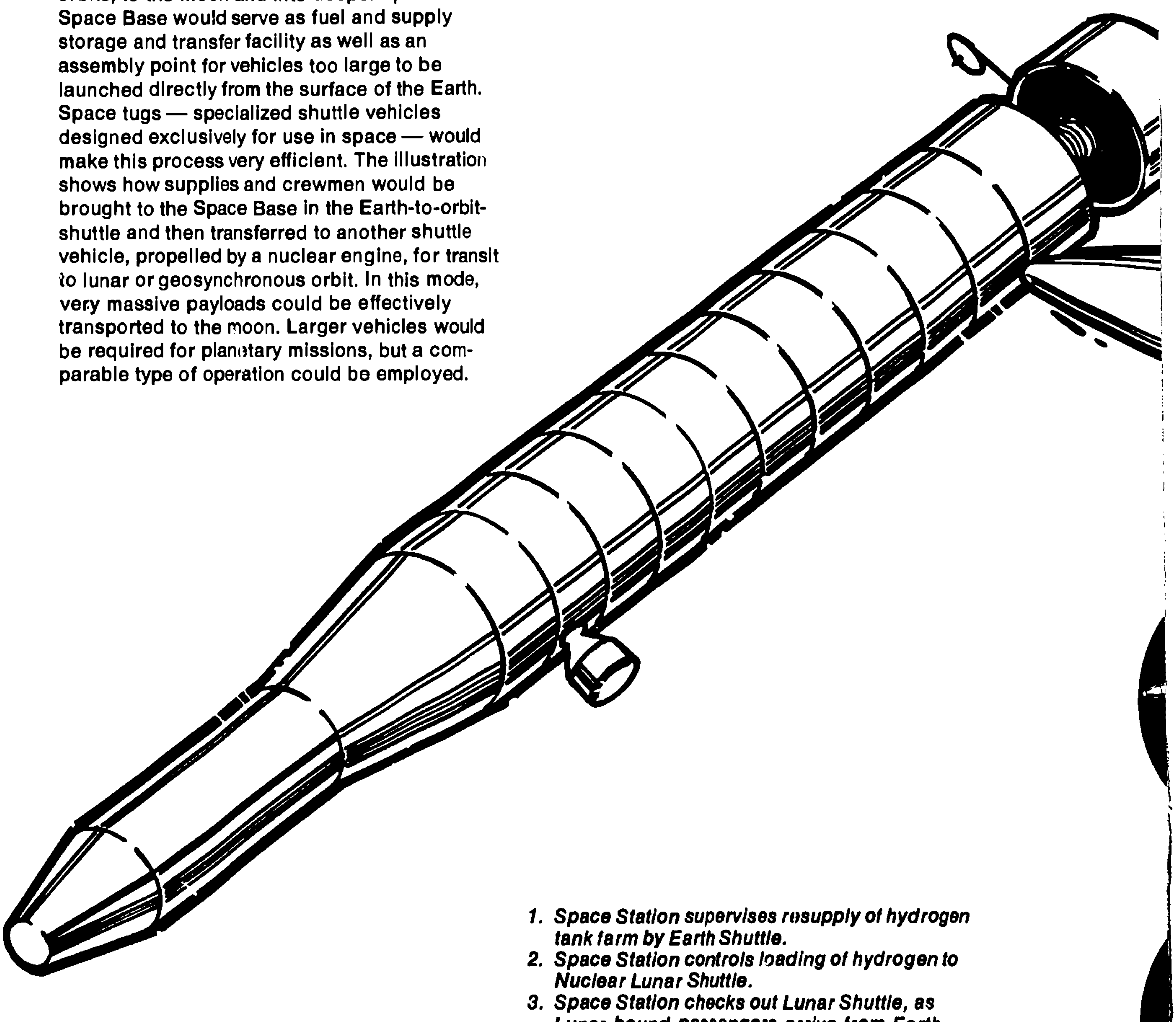
# Typical Expansion Sequence

The concept of growth by addition of modules is new to space, but commonly done in schools and laboratories. This schematic shows how the initial 12-man Space Station could grow to a 50-man Space Base over several years of operation. For such a large station it will be more economical to change from solar electric power to nuclear electric power, particularly if high power consumption activities such as materials processing proves profitable.

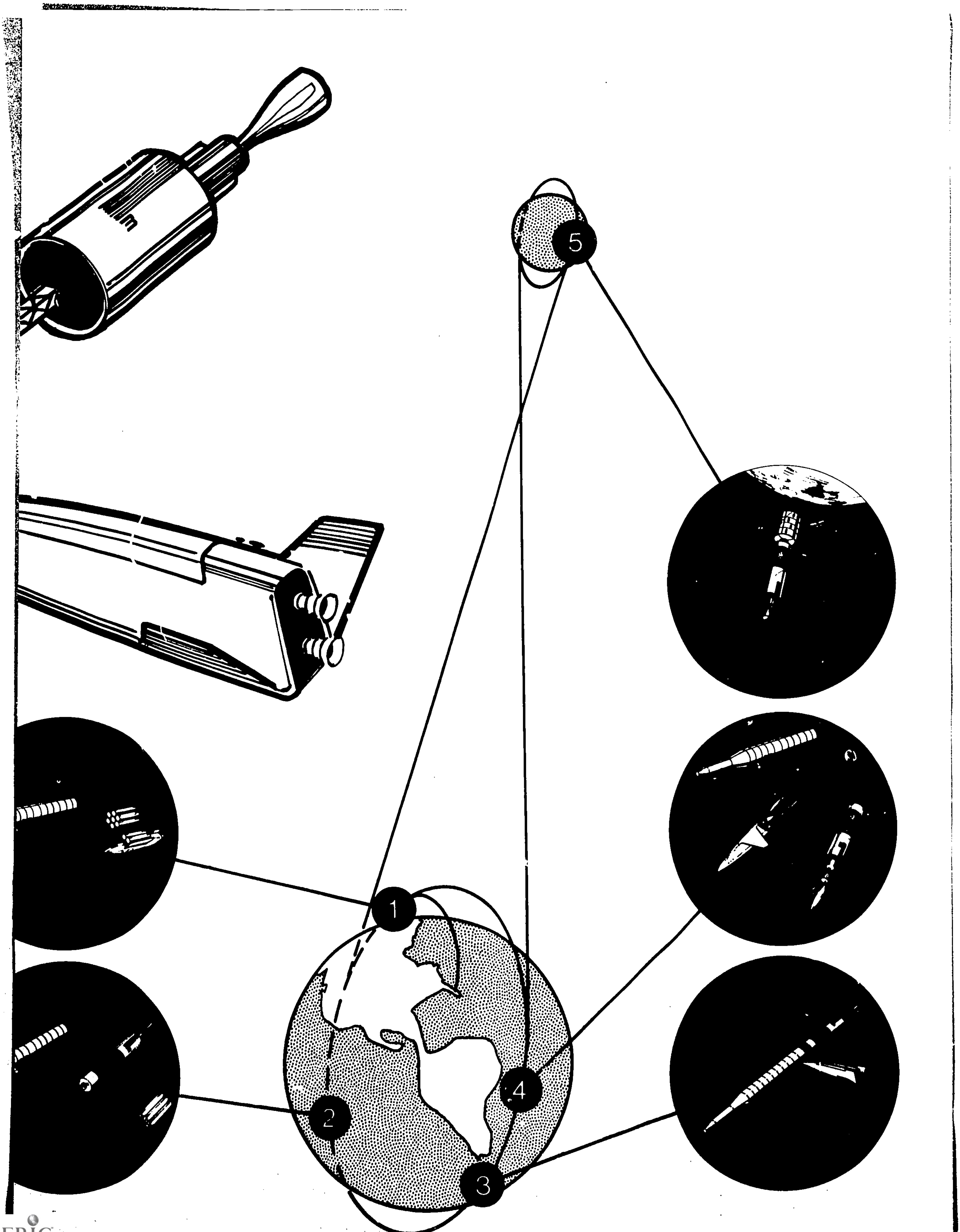


# Space Station as Transfer Point

Planners have been intrigued for years with the possibility of using a low Earth orbit Space Base as a base for launching missions to higher orbits, to the moon and into deeper space. The Space Base would serve as fuel and supply storage and transfer facility as well as an assembly point for vehicles too large to be launched directly from the surface of the Earth. Space tugs — specialized shuttle vehicles designed exclusively for use in space — would make this process very efficient. The illustration shows how supplies and crewmen would be brought to the Space Base in the Earth-to-orbit-shuttle and then transferred to another shuttle vehicle, propelled by a nuclear engine, for transit to lunar or geosynchronous orbit. In this mode, very massive payloads could be effectively transported to the moon. Larger vehicles would be required for planetary missions, but a comparable type of operation could be employed.



1. *Space Station supervises resupply of hydrogen tank farm by Earth Shuttle.*
2. *Space Station controls loading of hydrogen to Nuclear Lunar Shuttle.*
3. *Space Station checks out Lunar Shuttle, as Lunar bound passengers arrive from Earth.*
4. *Lunar Shuttle goes to Moon, Space Station remains in Earth orbit, shuttle returns to Earth.*
5. *Lunar Shuttle docks with Lunar Space Station, transfers payload, then returns to close proximity of Earth-orbital Space Station.*


1
2
3
4
5

# Transportation System

A round-trip transportation system between Earth and Earth orbit is essential to the continuous operation of large manned Earth orbital facilities. This system is used to rotate personnel, to resupply expendable items, to return cargo from orbit to Earth, and to deliver experiments and equipment. Transportation is potentially a fruitful area of major operating cost reductions. Studies show that logistics costs based upon vehicles and spacecraft in current use could account for 40% of the costs of the Space Station program through development and the first year of operation, then jump to nearly 70% of the annual costs thereafter.

### Cost of Transportation

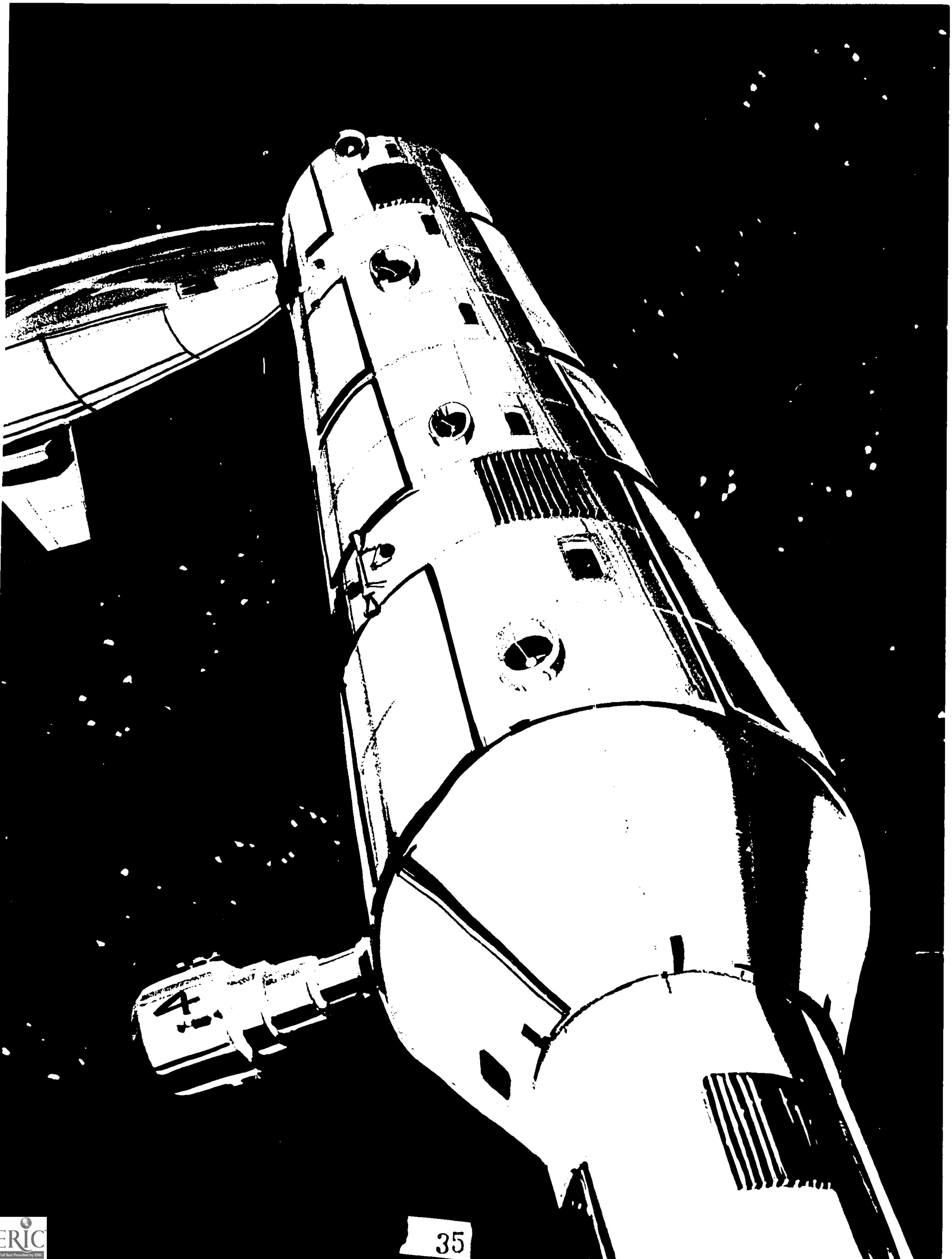
The cost of transportation into space has been dramatically reduced since the inception of the space program. The costs of launching our first satellites were on the order of $1 million per pound placed into Earth orbit. Economies of scale have been achieved over the past dozen years. With the Saturn V, this has been reduced to less than $1,000 per pound of payload. This is very real progress but it is only a beginning. Within the next decade, the cost of transportation can be reduced by one or more orders of magnitude. When such an economical space shuttle becomes available, it will be possible to carry thousands of tons of material to and from space.

### Reusability

The surest way to achieve cost reduction is by developing maximum reusability of the vehicle, rather than discarding it after each flight as is done at present. The secret of the success of modern aviation is the long lifetime of the aircraft. They become very economical to operate even though they are large, complex and costly to produce. By building space vehicles for repeated usage, comparable reductions in costs can be achieved.

### Airplane Type Operations

Repeated usage is only one of the essentials for the transportation system. Other directions in which to look for cost effectiveness include aircraft development testing procedures, aircraft manufacturing techniques, long life components for maximum reuse, flexibility for multiple uses, complete onboard checkout and airline maintenance and handling procedures, such as minimum refurbishment and requalification testing between flights.


4

# Space Shuttle Objectives

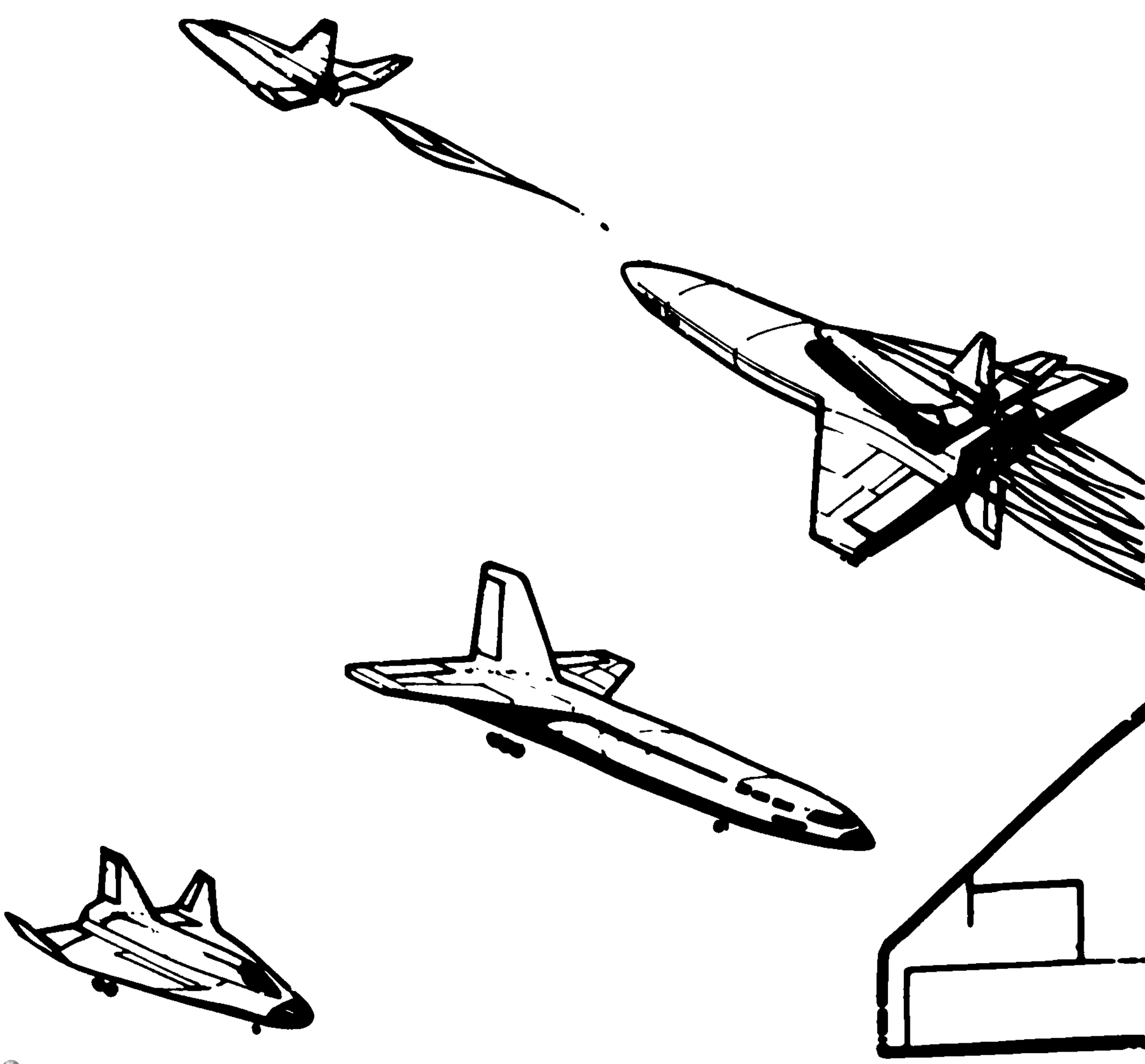
The goals of the space shuttle program are to bring into operation a fully reusable vehicle capable of carrying up to 50,000 pounds of payload (passengers, cargo or a mixture of the two) on both legs of the round trip between Earth and Earth orbit. The cargo compartment would be at least 15 feet in diameter and 60 feet long.

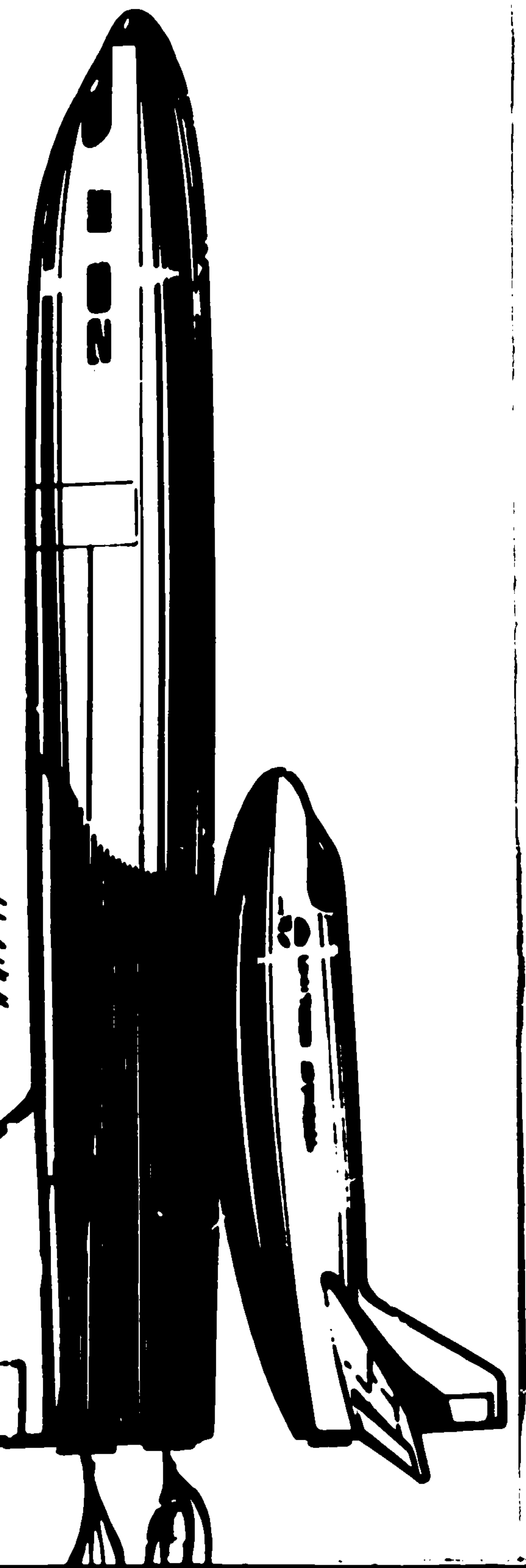
The vehicle will take off from and land on land. Flights would be up to a week in duration. Turn-around time would be no more than a few weeks. The vehicle will be designed for a lifetime of at least 100 flights. If longer lifetimes can be achieved in actual operation, unit costs will decline below the presently projected targets.

Under present thinking, the vehicle would weigh up to 3½ million pounds at launch. Its engines, generating thrust of 400,000 pounds each, would burn liquid hydrogen and liquid oxygen. Two types of fully reusable space shuttles are illustrated.

**Tandem Concept**

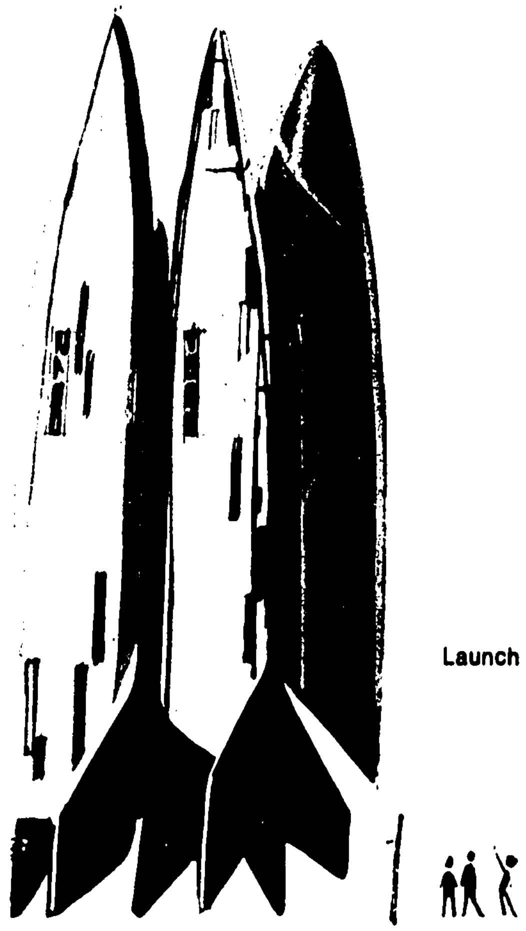
Shown below is a fully reusable Tandem concept resembling a modern high performance airplane. The large vehicle, with a smaller orbital vehicle attached, is launched vertically. After the fuel is exhausted in the large vehicle, it stages free of the smaller vehicle and returns to Earth, landing in a fashion similar to an airplane. The smaller vehicle uses its own engine to gain orbital velocity and later to return to Earth.



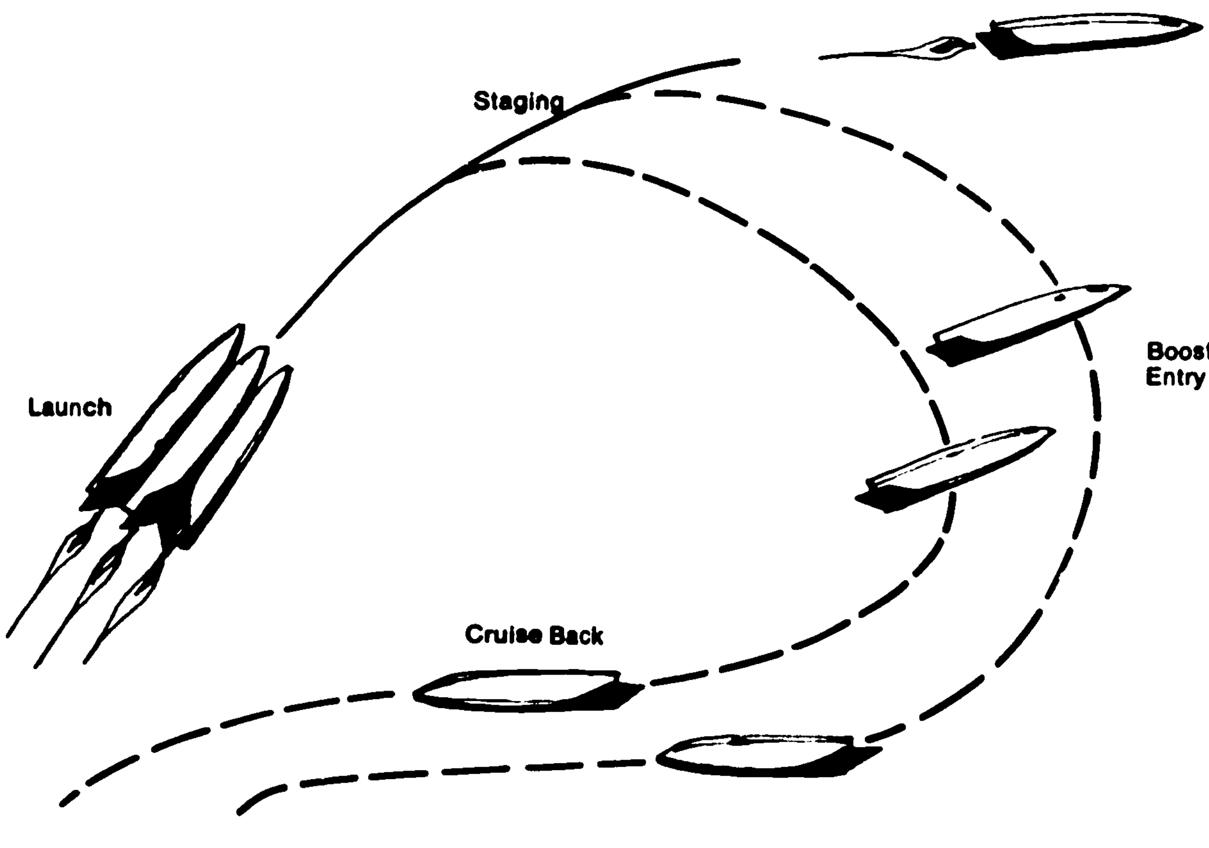


**Triamese Concept**

Another space shuttle concept is the Triamese. In the Triamese two boost elements and one orbital element are joined together in parallel at launch. The three elements are aerodynamically similar with identical basic structures and propulsion systems. As shown in the illustration, the vehicle takes off vertically with the engines from all three elements operating. The hydrogen/oxygen engines in the orbital element draws propellant from the booster sections up to staging velocity, approximately 8,000 ft./sec., when the propellant exhausted booster sections are staged off and the orbital section continues to accelerate to orbital velocity. The two boosters return to Earth and perform a lifting body type entry. Next, their wings and turbo-fan engines are extended providing for subsonic flight up range and landing at the launch site. The orbital element, when its mission is complete, deorbits, enters and returns to the launch site in essentially the same manner.



Launch Configuration



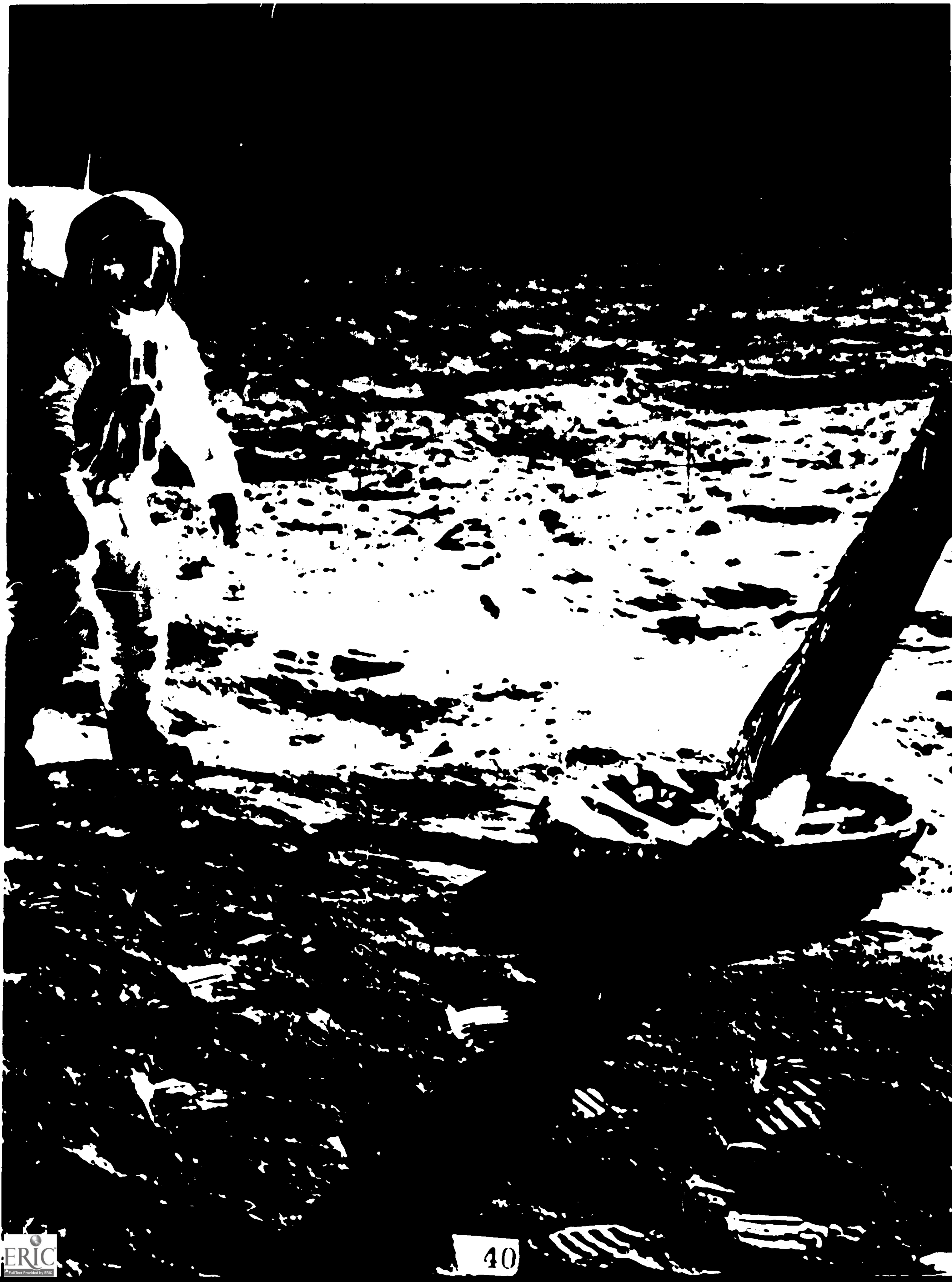
# Space Shuttle Operations

The shuttle will be able to operate in a mode similar in many ways to that of large commercial air transports and be compatible with the environment of major airports. Ground crews to service the craft for launch would be almost as small as those required for intercontinental jet aircraft. The space shuttle, upon its return from orbit, would reenter the atmosphere and fly to a runway landing. Noise will occur only on takeoff and at reentry. The landing could be completely automated with prime dependence upon the spacecraft guidance system, but with ground control backup and pilot emergency takeover. The operating crew would consist of a pilot and a co-pilot.

## Ground Operations

The space shuttle will employ a large land facility such as Cape Kennedy for landings and takeoffs while under development. At the outset, the ground equipment for the space shuttle will be unique. However, the cargo handling, tractors, air conditioning and other airport servicing equipment will eventually become as standard as the conventional equipment at major airports. Thus, it can be anticipated that other airports will ultimately be employed. Equipment and processes for refurbishment, maintenance, and repair will be planned and designed to minimize down time. Preventive maintenance as presently practiced by all major airlines will further minimize the turn-around time of the shuttle.

*Staging of a Tandem Space Shuttle*



# Critical Roles of Man

Man has the demonstrated capability to observe, to correlate information, and to learn from unusual phenomena; to respond and adjust to new or changing situations; and, to overcome difficulties through innovation and improvisation. The value of man in the conduct of scientific investigations has been proven by the thousands of years of experimentation he has conducted on earth. The Space Station program will have a primary goal of making space accessible for the conduct of research or to be applied earth problems. Crewmen will be called upon to operate complex and sophisticated experimental apparatus. They will view the results of these activities, communicate them to earth, and in concert with colleagues on the ground draw conclusions and redirect the experiment. Thus, by using man's most valuable attributes; his natural curiosity and courage, his ability to observe, to learn and to take new directions when results indicate a new course is desired, the increases in knowledge and returns obtained by the use of space will be enhanced and their achievement accelerated.

When the Space Station and the reusable logistic system begin operation, it will no longer be necessary to limit space flight to persons trained extensively as test pilots. It will be possible to transfer others to the station to maintain and repair space equipment. It will also be feasible to return space equipment to Earth for maintenance and repair. The possibility of maintenance and repair will extend the lifetime of such equipment indefinitely, thus greatly increasing the value provided for each dollar of cost. It will also make it possible to greatly reduce the cost of space equipment.

Man's ability to observe and select situations of opportunity opens possibilities for gathering information on a wide variety of phenomena without tying up instruments, data processing and communication facilities unnecessarily.

*"That's one small step for a man, one giant leap for mankind."*

A large space facility containing precision, complex equipment will place a premium on the manipulative skills of man. Large structures will be launched in stored condition and will be deployed and aligned in orbit. As trends toward greater size, complexity, and precision continue, the need will increase for human beings to be present to assure that the machines operate properly.

Since many types of experiment and application equipment have common basic instruments such as telescopes and cameras, it is expected that a trend toward larger instruments will be accompanied by increasing demand for multiple usage. With these complex arrays of filters, data recording media, and other ancillary equipment, it will be necessary to have man present to control and understand their functions and results.

# The Prospect— Immediate and Ultimate



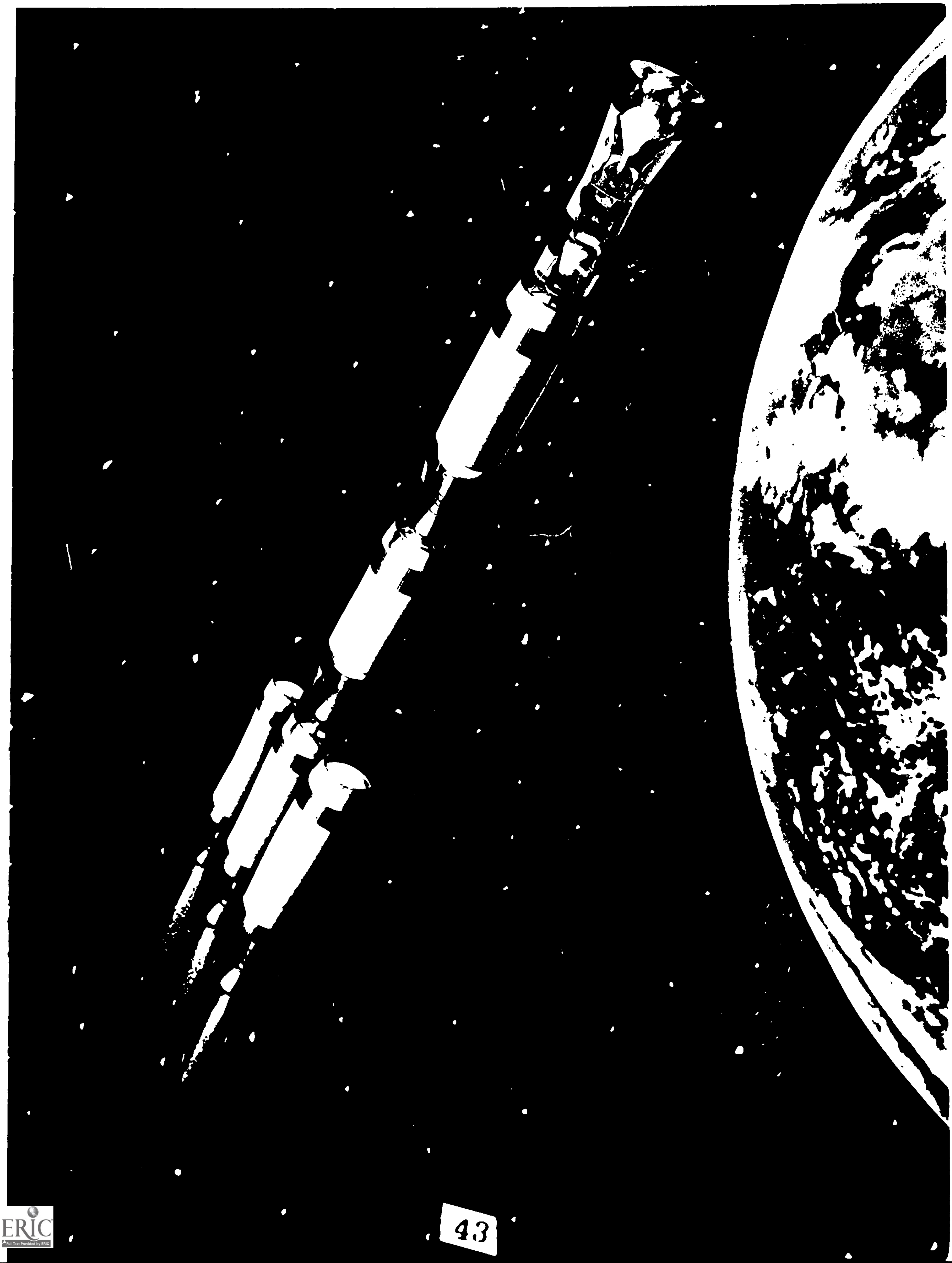
We are now harvesting our national investment in the programs of the first decade of the Space Age. Today, we use communications satellites to transmit color television and messages around the world. The dependability of the INTELSAT communications satellites is so high they were used to replace transatlantic cable transmissions recently while the cable was being repaired. More communications satellites are planned. No one can now predict the extent of the applications of Earth Resources satellites. Mineral-producing industries are using Earth photographs taken from Gemini and Apollo to guide the search for ore deposits. High-altitude cameras and films have revolutionized mapping. Other benefits include new products, new manufacturing processes and testing techniques, new materials, new treatment of familiar materials, and a host of medical, health and safety devices, techniques and procedures.

Space-related developments permeate the economy. The resulting new products, new jobs and high productivity stimulate national growth. In the long run, this new wealth created in our economy, will pay the cost of the program and will provide solutions to many problems not evidently related to space.

Americans who have recently traveled abroad can appreciate the impact our space program makes on other nations around the world. People in all parts of the world are impressed by ambitious objectives stated openly in advance, by missions conducted openly, and by results that are made available to all.

NASA is now conducting technical definition studies of a Space Station, a Space Shuttle and the activities to be conducted in orbit. A target date to have this national facility in use has been established for the late 1970s.

*In the future man will venture to the planets. Shown is a planetary exploration mission departing from Earth on a year and half expedition to land on Mars and return.*



National
Aeronautics
And Space
Administration