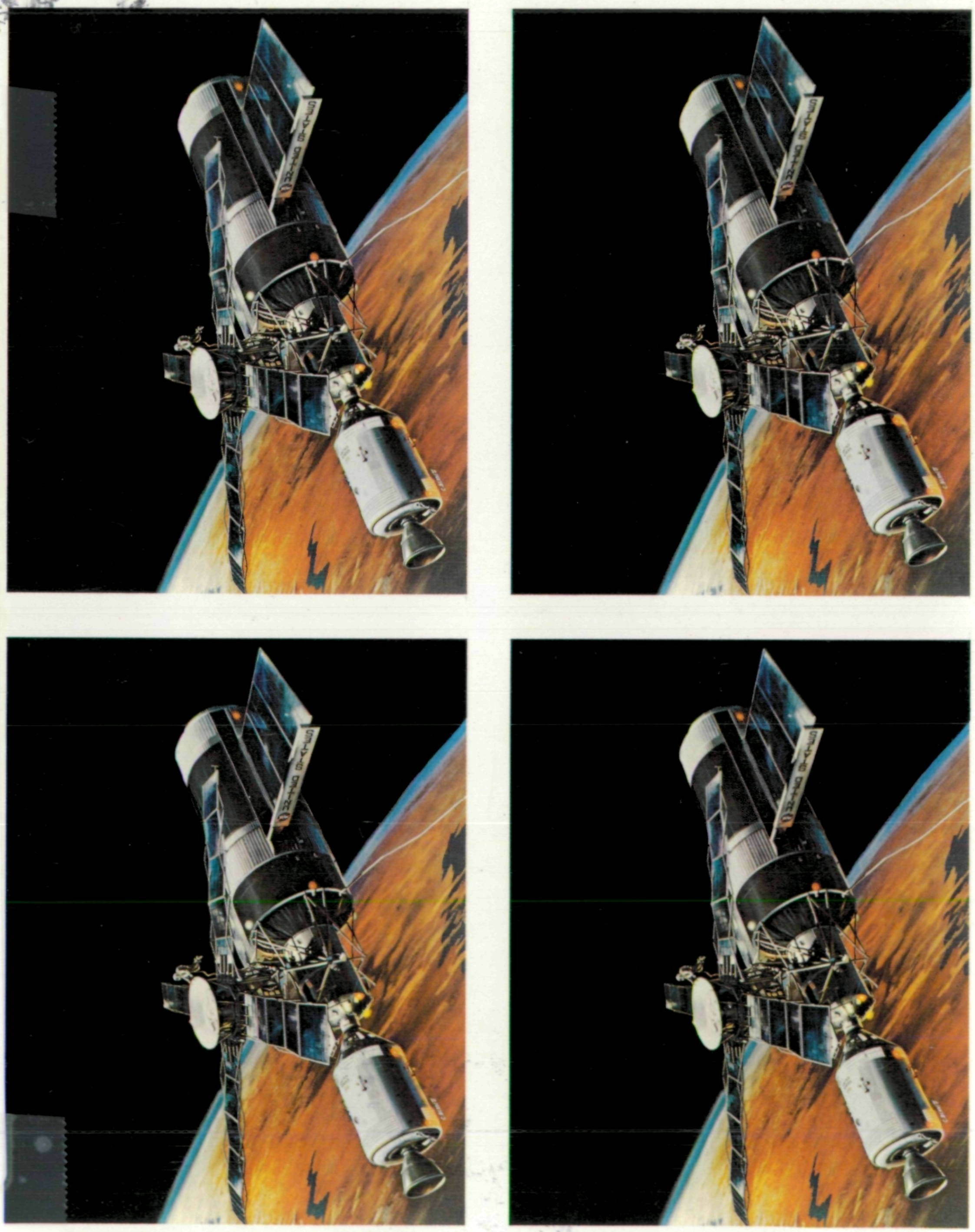
MAN IN SPACE

Space In The Seventies



National Aeronautics and Space Administration

SPACE IN THE SEVENTIES

Man has walked on the Moon, made scientific observations there, and brought back to Earth samples of the lunar surface.

Unmanned scientific spacecraft have probed for facts about matter, radiation and magnetism in space, and have collected data relating to the Moon, Venus, Mars, the Sun and some of the stars, and reported their findings to ground stations on Earth.

Spacecraft have been put into orbit around the Earth as weather observation stations, as communications relay stations for a world-wide telephone and television network, and as aids to navigation.

In addition, the space program has accelerated the advance of technology for science and industry, contributing many new ideas, processes and materials.

All this took place in the decade of the Sixties.

What next? What may be expected of space exploration in the Seventies?

NASA has prepared a series of publications and motion pictures to provide a look forward to SPACE IN THE SEVENTIES. The topics covered in this series include: Earth orbital science; planetary exploration; practical applications of satellites; technology utilization; man in space; and aeronautics. SPACE IN THE SEVENTIES presents the planned programs of NASA for the coming decade.

January, 1971

COVER:

The components of Skylab—workshop, airlock, multiple docking adapter and the Apollo Telescope Mount (ATM)—are being checked out by the crew of a docked Apollo Command/Service module.

MAN IN SPACE

By Walter Froehlich

National Aeronautics and Space Administration, Washington, D.C. 20546

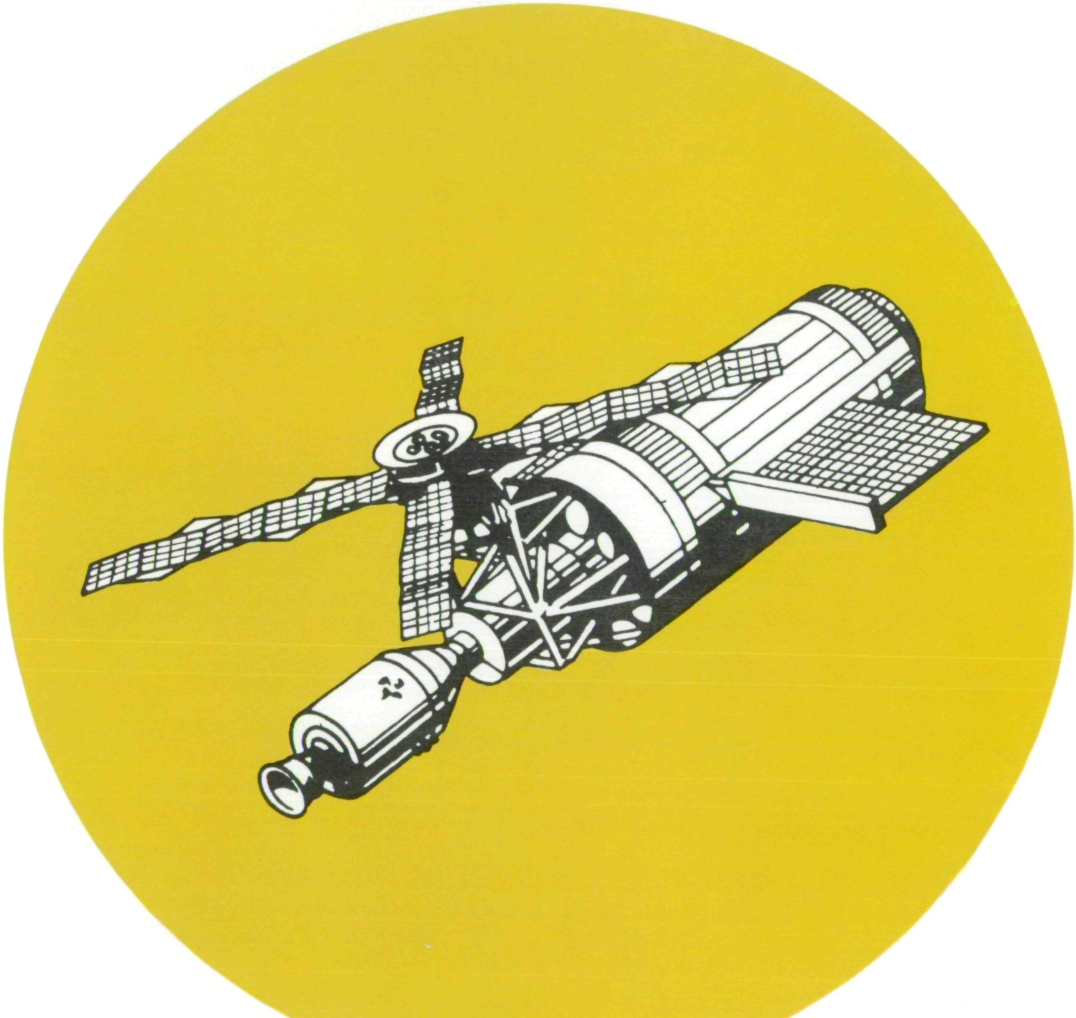


TABLE OF CONTENTS

NOTE:

Illustrations of Skylab, Lunar Rover, Space Station, Space Shuttle, Lunar Surface Base, Space Tug, Lunar Colony, and Planetary Base (Mars) are artist's interpretations of planned and proposed programs.

INTRODUCTION

The endless frontier now lies open. Outer space is accessible to Man in the 1970's. He gained entrance to it in the 1960's. These first travels beyond the immediate vicinity of the Earth fulfilled an old dream. They culminated a primordial human aspiration, and started a movement that will never stop.

Daring and ingenious as were these first space voyages, they were only a beginning. In time, they will seem puny and primitive; ventures into the solar system will become increasingly sophisticated in the 1970's. Colossal as was the impact of the recent missions on Man's image of himself and of his Earth, even more profound implications are inherent in the space ventures now in the making.

"Man on the Moon" became the theme of the 1960's. Building the capability for landing astronauts there and bringing them back was the prime objective of America's manned space exploration program in that decade.

No such single overriding focus exists for the 1970's. In this new decade, U.S. space planners have set multiple objectives. Perhaps the most promising among the new goals is development of facilities that would permit non-astronauts to fly into space and perform research work there.

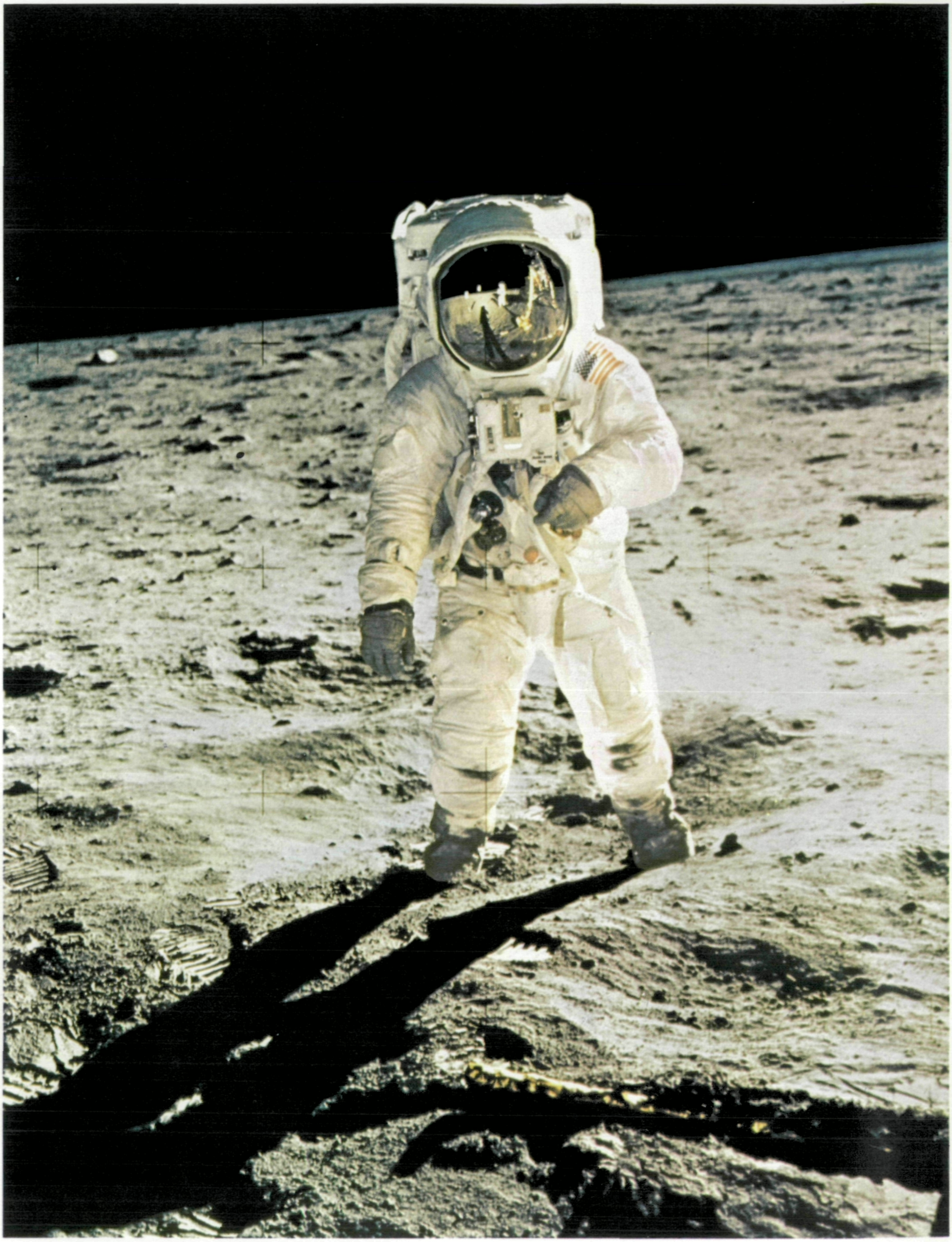
These new concepts and approaches are generating new expectations and new opportunities. Hopefully, these visions will turn into new triumphs. Hopefully too, from these will blossom new knowledge, inspiration, technological advances and economic and social benefits even greater than those which emanated from the U.S. Moon exploration program in the 1960's.

These aims are not vain ambitions. Research and development for the U.S. space program of the 1970's is already far advanced. Many of the teams of scientists, engineers, astronauts and administrators who blue-printed the projects to send astronauts to the Moon in the 1960's are planning the U.S. space thrust for the 1970's.

President Nixon has announced these projects as part of his comprehensive space program for the next 10 years.

The Congress has approved and funded the initial steps for that program.

This publication is a guided tour through the outlines for Man in Space in the 1970's.



Apollo 11 astronaut Edwin E. Aldrin, Jr. is photographed on the Moon by Neil Armstrong on July 20, 1969.

"We choose to go to the Moon in this decade and to do other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills."

President John F. Kennedy as he proposed the U.S. Man-to-the-Moon program in May 1961.

"Through You, We Touched the Moon"

Inscription on hand-lettered sign held by a youngster watching Apollo 11 astronauts in a New York motorcade, August 1969.

THE 1960's IN RETROSPECT:

Man's Great Plunge into Space

After eons of longingly gazing up at it, men finally looked down on the Moon during the 1960's. Thwarted since time began by distance and the intractability of Earth's gravity, men solved the problems by 1969. They went to the Moon, picked up pieces of it, and carried them back to Earth for scientific examination.

Investigation so far suggests that no life existed on the Moon until the astronauts arrived.

When the 1960's began, no human had ever flown above the atmosphere. At the decade's end, U.S. astronauts had orbited the Earth 959 times and the Moon 116 times. In 22 flights they spent 5,834 man-hours in space, the equal of one man living in space for eight months. In one flight, two men remained in Earth orbit for nearly two weeks. Four astronauts lived on the Moon for a total of 106 man-hours and spent more than 20 man-hours outside their landing craft.

The 1960's were years of almost incredible achievement. Inspired by the manned Moon landings, newspapers ran headlines: "The Future Has Commenced" and "Farewell, Science Fiction." Terms like "countdown," "launch" and "orbit" became household words. A formerly obscure point in the universe was named "Tranquility Base," to be known by that designation for all generations to come as the first landing site of men in a place other than Earth.

That first manned landing on the Moon took place at 4:17 p.m., (EDT), Sunday, July 20, 1969, on a lunar plain known to astronomers as Mare Tranquillitatis, the Sea of Tranquility. A little over six hours later at 10:56 p.m., (0256 GMT, July 21) came one of history's monumental moments. A 38-year-old American, Apollo 11 Commander Neil A. Armstrong, lowered his left foot from the landing pad of the landing craft. As the sole of his boot made contact with the surface below, he became the first human to stand upon another celestial body.

A few minutes later, he was joined in his "Moon walk" by Astronaut Edwin E. Aldrin, Jr. Alone, as these two men were, nearly 250,000 miles from Earth, they were simultaneously the most widely observed human beings in history. More than 500 million persons in almost every country watched the astronauts on television or listened by radio to their conversations. The two astronauts spoke with Mission Control in Houston, Texas, and with their colleague, astronaut

Michael Collins, who was piloting the Command/Service Module in Moon orbit awaiting the landing craft's return.

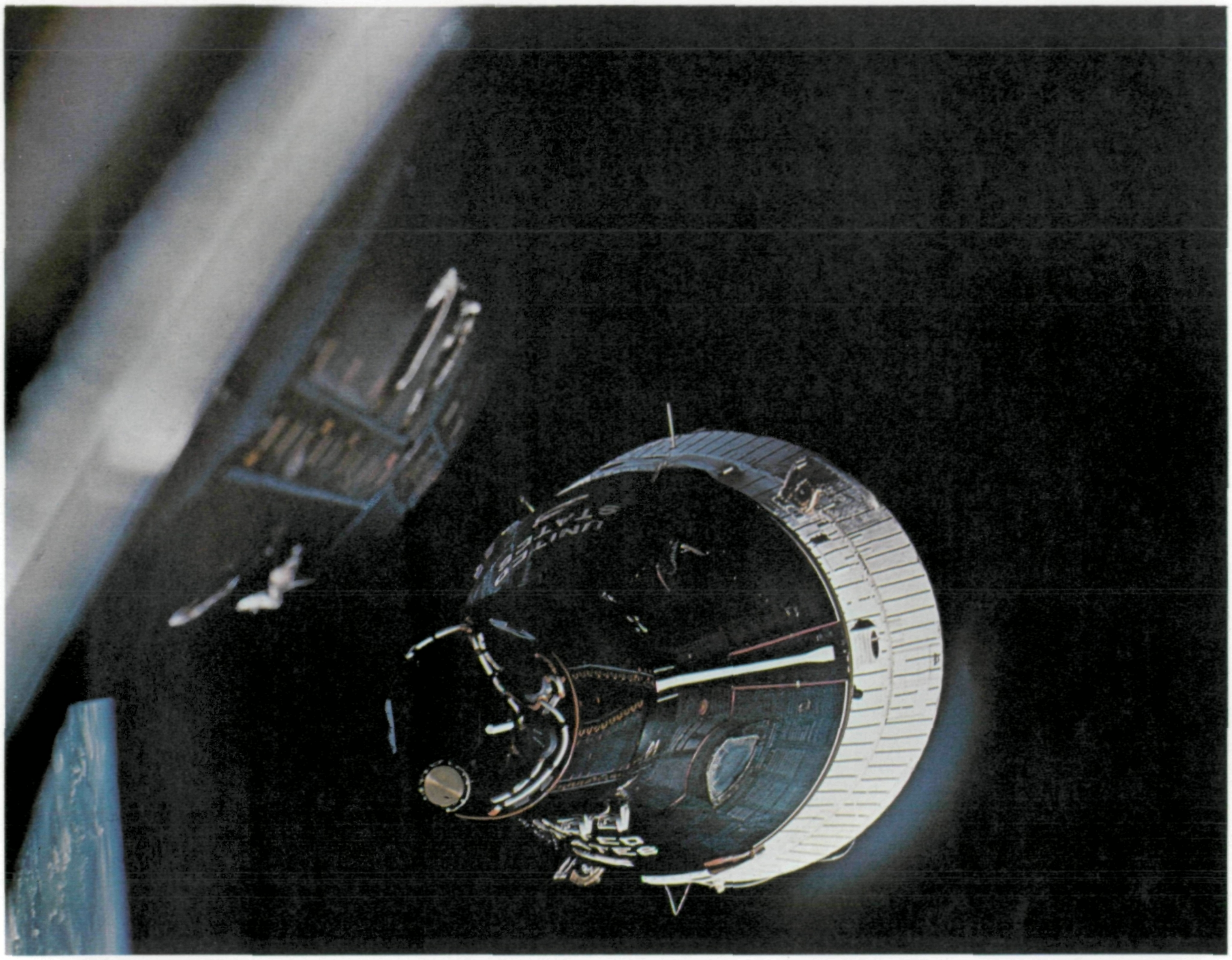
A similar Moon landing was successfully carried out in November 1969 by Apollo 12 astronauts Charles Conrad, Jr., and Alan L. Bean in the lunar Ocean of Storms. They became the third and fourth humans to live and walk on the Moon while astronaut Richard F. Gordon, Jr., tended to the Command Module in Moon orbit.

In 1961, President Kennedy had proposed that the United States initiate a national project to place man on the Moon "before this decade is out." Subsequently, about 500,000 persons were employed in the U.S. manned space effort. They designed, built and tested the world's mightiest rocket, the 28-story-tall Saturn V, and they conceived and built the eight-story-tall Apollo spacecraft with its three million components. They constructed a myriad of associated equipment, helped train the astronauts, and prepared the vehicles for launch. They erected and manned the ground tracking and communications stations, and they managed what came to be the most massive science and engineering project of all time.

Six flights in the one-man Mercury capsule between 1961 and 1963 proved men could survive in space. Ten Earth-orbital flights in the two-man Gemini craft in 1965 and 1966 demonstrated that men could steer their craft in space and link up with other orbiting objects. In the Apollo 7 and 9 flights of 1968 and 1969, astronauts tested the new three-man spacecraft in Earth orbit. In the Apollo 8 and 10 missions in those same years, other astronauts tried out the craft in Moon orbit in preparation for the Moon landing flights.

There were setbacks too. Mishaps and malfunctions in several flights provided tense moments of drama and danger. Three astronauts died in a spacecraft fire during a mission rehearsal on

Faith 7 astronaut L. Gordon Cooper being assisted from the Mercury spacecraft after recovery on May 16, 1963.



First rendezvous of two manned spacecraft in Earth orbit is achieved by Gemini VII and Gemini VI on December 15, 1965.

the launch pad at Cape Kennedy in January 1967.

From these accumulated experiences in success and adversity emerged techniques and tools useful also for non-space endeavors. Such "spin-offs" contributed to progress and stimulated innovation in almost every field of human activity. Machines and processes derived from the demands of the space program were borrowed or adapted for use in medicine, aviation, industry, transportation, communication, education and large-project management.

Perhaps the most significant by-product of space exploration was the "psychological fall-out"—the influence on men's minds. Having attained what had seemed impossible, men became instilled with a belief that other apparently unyielding problems could also be overcome through similarly single-minded, dedicated effort. Men gained confidence in their own ability to cope with such traditionally obstinate predicaments as war, poverty, excessive population growth and environmental pollution.

As men looked for the first time at the Moon at close range, they also saw the Earth and themselves in a new perspective. As viewed from the vicinity of the Moon, the Earth appears as a small, bluish sphere suspended against the velvety black backdrop of the vast universe. Through such pictures of the Earth brought back by astronauts, men began to see each other, in the words of poet Archibald MacLeish, as "riders on the Earth together."

As most other happenings of the 1960's become submerged in the continuing flow of history, these first travels by men into space will be unforgettable occurrences. No matter how deeply men penetrate space in the decades and centuries ahead, or how much they perfect the methods and machines for space travel, the 1960's will be remembered forever as the time when it all began.

An Apollo 12 astronaut unfurls the American flag on the surface of the Moon November 19, 1969.

"The journey of the astronauts is more than a technical achievement. It is the reaching out of the human spirit."
President Richard Nixon, June 4, 1969

APOLLO:

Man on the Moon in the 1970's

The Moon—a mere three-day journey from Earth—lends itself more readily to exploration than did the continents when they were weeks or even months apart by the best means of transportation then at hand. Scientific investigations are the main objectives of manned Moon exploration in the 1970's.

The wealth which men are likely to carry from the Moon in this new decade is not of a material kind. The matchless treasure to be retrieved from the Moon in the 1970's is knowledge. The Moon reveals solid clues to the history of the solar system. Nature may have hidden coded messages into Moon rocks about the evolution of that neighborhood of the universe of which the Earth is a part. From rocks on the Moon, man may be assisted in learning about his origin and his destiny. He may discover clues for answers to his questions, "Where did I come from?" and "Why am I here?"

In the 1970's, men will stay on the Moon longer, dig deeper below its surface, move farther from their landing craft, and explore more extensively and intensively than they could in the 1960's. Astronauts will gather and bring to Earth larger quantities of Moon rocks, and they will set up networks of automated scientific instruments on the lunar surface. To the rapidly increasing number of human bootprints on the Moon will be added tire tracks.

Astronauts will transport equipment and rock samples across the Moon on vehicles rather than carry these items as they had to do during their two Moon landing expeditions in 1969. With vehicles, astronauts will be able to use more and heavier equipment and cover larger areas on the Moon.

Apollo 13, the first planned Moon landing flight of the 1970's failed to reach its destination. An oxygen tank ruptured, blew a panel out of the Service Module and deprived Apollo 13 of its main power supply. The Lunar Module had to be pressed into service as a "life boat." In a dramatic, suspenseful, highly complex series of improvised maneuvers, Mission Control on the ground and the astronauts in Apollo were able to return the stricken craft to Earth after looping once around the Moon without attempting a landing.

Apollo 14, delayed until early in 1971, was re-programmed to carry out Apollo 13's assignment. The flight plan called for exploration in the scientifically promising Fra Mauro region, a hilly upland area believed to be covered with rocks far more ancient than men have ever seen. To make their rock gathering and other explorations easier, Apollo 14 would take with it a 21-pound cart. Named by engineers "Modular Equipment Transporter" (MET), the two-wheeled, hand-pulled conveyance is more familiarly known to astronauts as a "rickshaw." It can hold hand-tools, cameras, spare film magazines, scientific instruments, and Moon rock containers. It can also double as a mobile workbench.

Beginning with Apollo 15, astronauts will ride on the Moon in a Rover, a four-wheel, battery-driven Moon car. The 440-pound, jeep-like vehicle will be carried in the Moon landing craft and can very easily be extracted after the landing. Rover's top speed is ten miles an hour and its range about 65 miles. Astronauts will drive it in a wide circle around their base camp remaining within walking distance of the landing craft if Rover should become disabled.

A prototype of the Modular Equipment Transporter (MET) that increases mobility of Apollo 14 astronauts on the lunar surface. MET, called "rickshaw" by its astronaut pullers, is a hand-drawn vehicle that serves as a portable workbench, a camera mount, and as a platform for the Lunar Portable Magnetometer experiment.

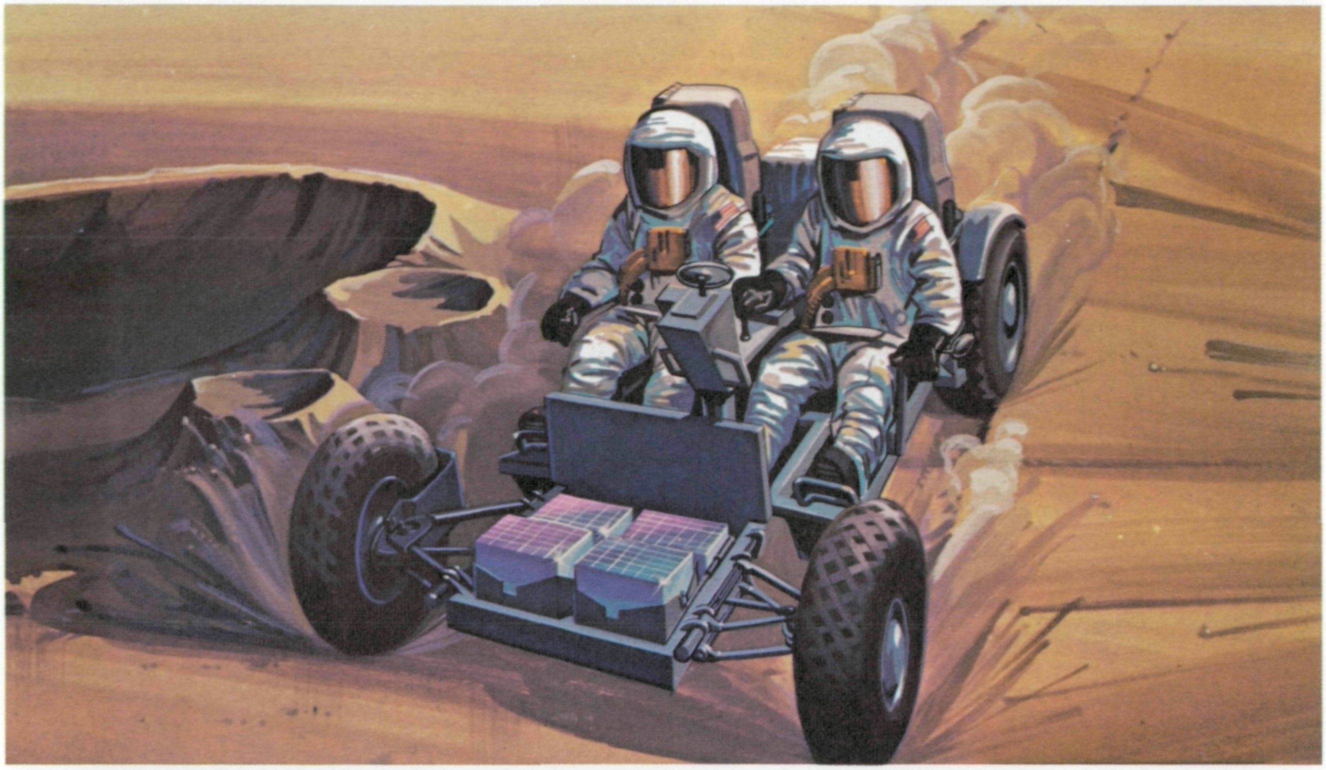
Also beginning with Apollo 15, a modified Moon landing craft will be used that offers increased storage capacity for food, oxygen, and atmosphere-purifying lithium hydroxide. These additional provisions will allow the astronauts to extend their stay on the Moon to more than 66 hours, double the maximum 33 hours permissible with the present craft. Astronauts can then extend their excursions on the Moon outside the landing craft to 40 man-hours, more than double the present limit. The men will tour the Moon on three separate excursions of about 6 hours each outside the landing vehicle.

Design improvements in the main spacecraft—the Command and Service Modules—will allow crews to increase the present standard 10-day round-trip to 16 days. The men will spend most of that extra time in lunar orbit, conducting scientific experiments there. Increased weight-carrying capacity will allow installation of research equipment in the Service Module. The astronauts will be able to release a small satellite into Moon orbit. This satellite, which can measure the Moon's magnetic properties, can remain in orbit and continue to report measurements long after the astronauts have returned to Earth.

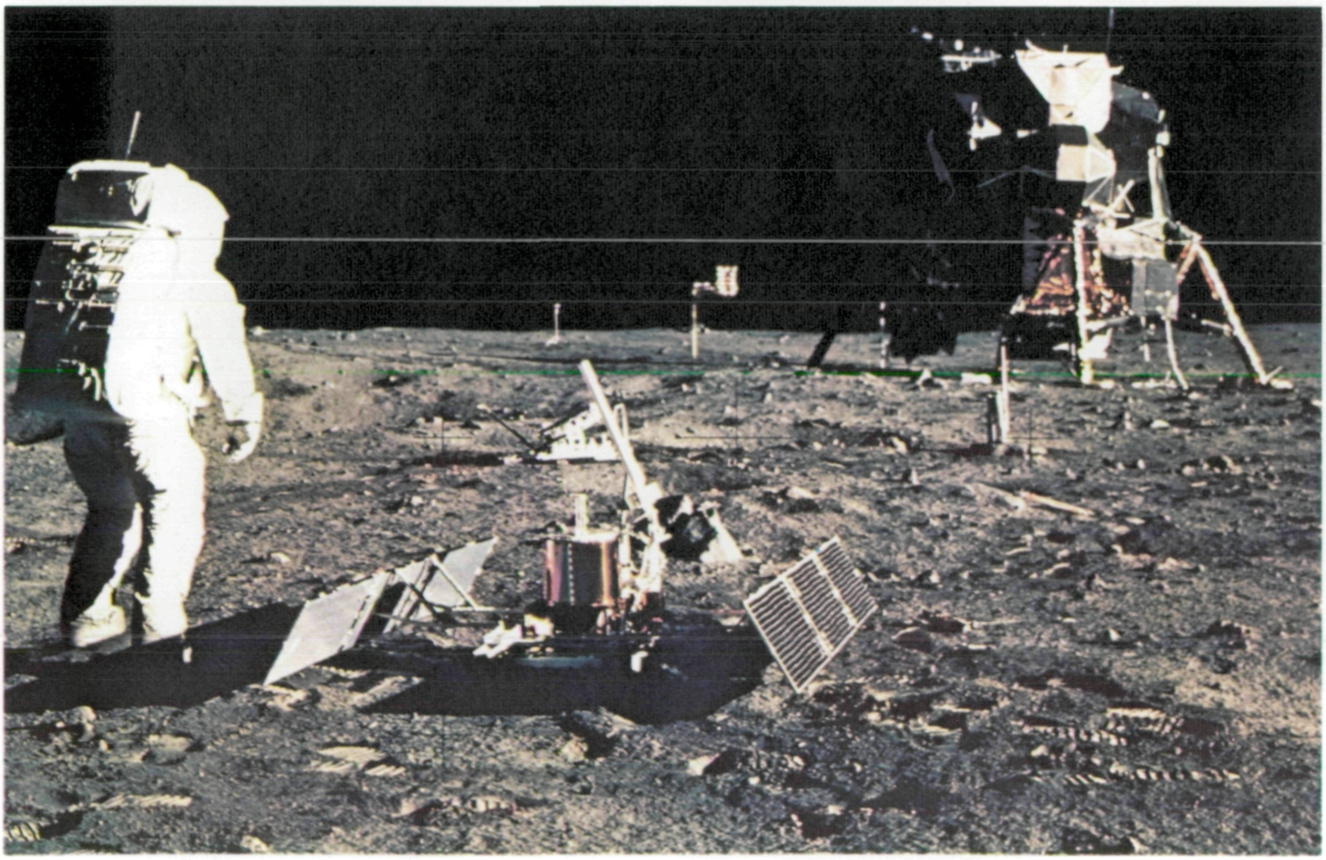
Other research devices in the equipment bay of the Service Module will permit precise measurements so that exact heights of lunar mountains and depths of craters can be determined. Cameras from the bay will record the Moon in the invisible and visible radiation spectrums. Astronauts will "walk" through space outside the orbiting craft to retrieve exposed film from the Service Module for return to Earth.

Some flights will be targeted to difficult-to-reach landing sites at considerable distances north and south of the Moon's equator. At the new outposts, the astronauts will install moonquake recorders, radiation sensors, atomic particle counters and various other devices from ALSEP—the Apollo Lunar Surface Experiments Package. The nuclear-powered instruments automatically relay their findings by radio to Earth.

In the 1970's, the Moon is destined to become a space island of the Earth, a sister world that is almost the Earth's eighth continent.



A two-man, electrically powered Lunar Rover Vehicle will extend the area of exploration for astronauts on the later Apollo missions.



Deployment of the Passive Seismic Experiment by an Apollo 11 astronaut on the surface of the Moon July 20, 1969.

A cutaway view of Skylab in Earth orbit.

"The peaceful conquest of space is the only form of conquest in which modern man can proudly and profitably engage. In this struggle all men are allies, and the only enemy is a hostile environment."

President Lyndon B. Johnson, 1965.

SKYLAB:

A House in Orbit

A cylindrical aluminum container as big as a five-room house is to be launched into Earth orbit late in 1972 to become America's first experimental space station. Inside the 28-ton structure—far larger than any spacecraft launched so far—are a small bedroom, a kitchen, a bathroom, and a medium-sized combination laboratory-workshop.

About one day after the station is launched and has stabilized in its orbital path, three astronauts will arrive near it in an Apollo craft. That is the same type of craft which carries astronauts to the Moon and back. But this Apollo will be minus the Lunar Module, which is not needed in Earth orbital operation. The astronauts will steer the craft for rendezvous with the station and dock with it.

Then, the astronauts will crawl through a connecting tunnel (a multiple docking adapter) into an airlock and from there into the station. They will live and work in it for several weeks. Finally, the crew will crawl back into the Apollo spacecraft and return to Earth, leaving the station in orbit for similar use by subsequent crews.

This is Skylab, the next major advance in Earth orbital operations in the U.S. manned space exploration program. It is a project for carrying out the most elaborate scientific investigations yet attempted in Earth orbit. Skylab will allow astronauts to remain in space longer, live there more comfortably, and employ more intricate research equipment than they have been able to do in space until now.

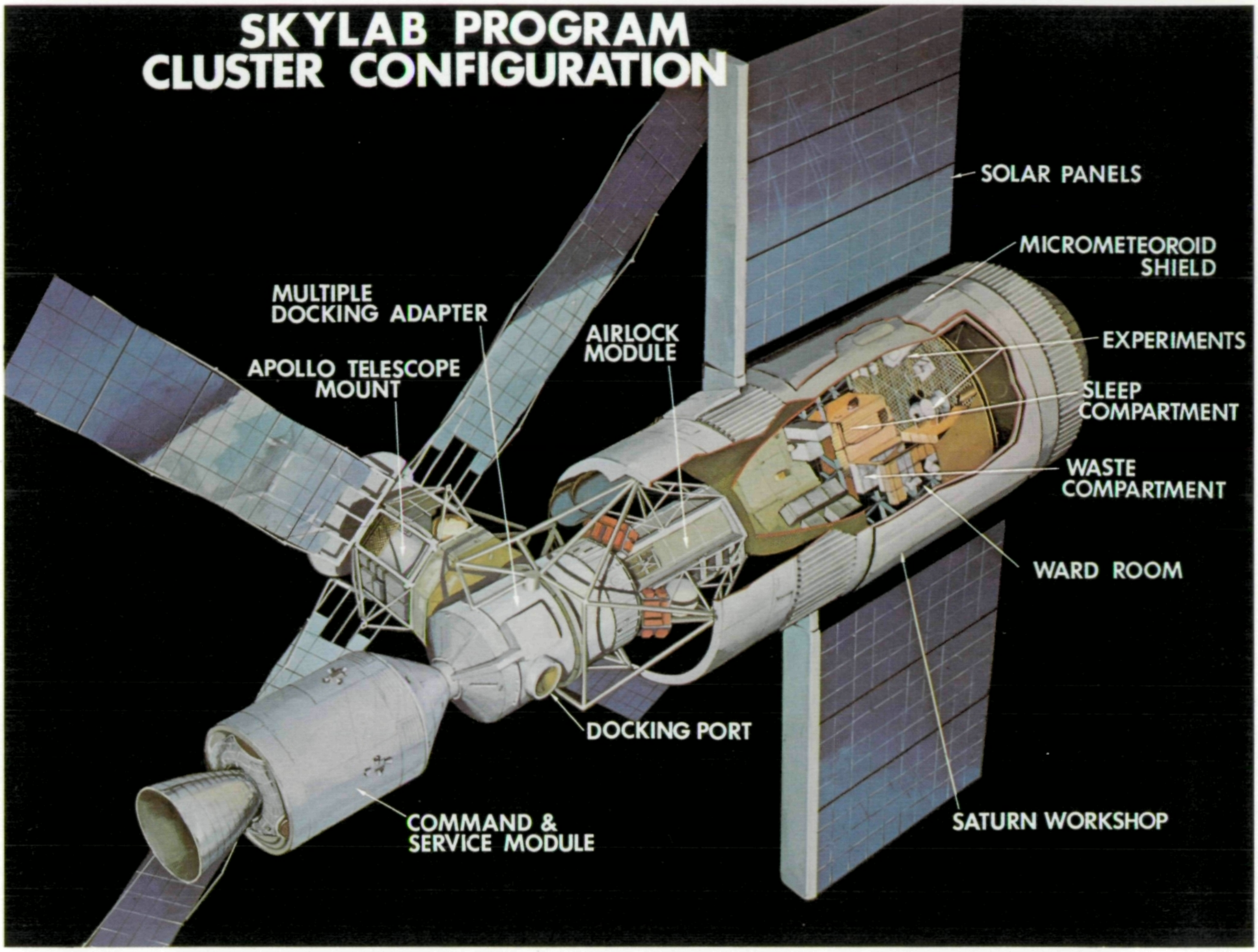
The first three-man crew to enter Skylab is expected to live and work in it for 28 days, more time than anyone has remained continuously in space. After that crew has left Skylab, a second crew is to arrive in an Apollo craft, probably early in 1973. After docking, these three astronauts will also enter Skylab and remain in it for 56 days—twice as long as the first crew.

After the departure of the second crew, a third crew will take over and operate for eight weeks, in about mid-1973.

Skylab resembles a large vacuum bottle. The airlock, a cylinder-shaped protrusion, represents the bottle's neck. The main workshop cylinder is 48 feet long and has a diameter of 21.6 feet. Once Skylab is in orbit, panels extend from its sides. These panels are covered with solar cells which convert sunlight into electricity for Skylab's operation. Also moving into place, attached to and at a right angle to the airlock, will be a large section resembling a windmill. It is the Apollo Telescope Mount (ATM), an astronomical observatory for use by the crew. The "windmill's" main section houses the telescopes and related instruments. Its paddles consist of solar cell arrays to power these instruments. These are designed for studies of the Sun from this vantage point, free from atmospheric absorption of the Sun's radiations. Periodically, one of the astronauts will leave Skylab through the airlock and "walk" through space to the outside of the telescope mount to exchange film cartridges and carry out other work.

Scientists hope that from this work will emerge a better understanding of the Sun and, especially, its profound influence as the Earth's major energy supplier.

Inside Skylab, the crew will perform a variety of industrial experiments. On Earth, the heavier components of fluid mixtures settle during cooling and solidification. In orbital zero gravity, the distribution remains consistent. The astronauts will test and assess possible manufacturing processes which could eventually lead to space factories creating entirely new materials. In space, it may be possible to produce lenses, bearings, electronic devices and possibly



Another view of Skylab with the Apollo Telescope Mount (ATM) locked in place

vaccines of now unattainable quality.

From their lofty perch in the sky, the astronauts will test Earth observation techniques that could lead to vastly improved mapping, surveying and prospecting; inspection of agricultural and forest growth; air and water pollution detection; and the charting of fish distribution, snow runoff, and glacier and iceberg movements.

But the most important research objects are the astronauts themselves. A key objective of Skylab is medical and biological research.

Scientists want to know the effects on body functions of prolonged exposure to weightlessness. Other scientists are eager to learn about the psychological impact, if any, resulting from the absence of normal day-night cycles. This knowledge would assist designers of lengthy space missions in the future, and would add to the understanding of the human system in health and illness and, perhaps, lead to better treatments of certain disease conditions.

Skylab will be boosted into a 235-nautical mile circular orbit by a Saturn V, the same type of launch vehicle that sends U.S. astronauts to the Moon. But for Skylab, only the lower two stages are to be fueled. The third, or uppermost stage, the S–IVB rocket, remains free of fuel. It is this rocket stage that gives Moon-bound astronauts a final push for insertion into Earth orbit and, later, shoves them out of orbit and into a trajectory toward the Moon. But for Skylab the empty S–IVB is outfitted before launch as the astronauts' living and working quarters—the basic Skylab cylinder.

Its more than 10,000-cubic-foot interior accommodates the astronauts' sleeping compartments, food preparation section, sanitary and waste disposal units, and the orbital workshop and scientific research installations.

Skylab is a forerunner of the larger space stations to be established later in the 1970's, and the still more massive and spectacular space bases envisioned for the 1980's.

"We stand at the start of a new era which will see space flight become as safe, as reliable and as economical as aircraft flight through the atmosphere is today."

Dr. Thomas O. Paine, Administrator, National Aeronautics and Space Administration, November 1969

THE SHUTTLE:

Spaceliner of Tomorrow

As far as anyone can foresee now, the single most significant contribution to the advancement of space travel in the 1970's will be a revolutionary vehicle known as the Space Shuttle.

When it makes its first flight, in 1977 or shortly thereafter, the shuttle will expedite the transformation of spaceflight from the spectacular of today to the routine that air travel became long ago.

Besides a cockpit for its astronaut crew, the shuttle will have seats for about 12 passengers plus cargo space. While the astronauts pilot the craft, the passengers will relax in comfort comparable to flight in today's jetliners.

Passengers need not wear space-suits or other special garments. They will need no special training or physical conditioning as astronauts do today. The cabin will maintain a "shirtsleeve environment." Eventually shuttles may fly into space on timetables like those of buses, trains, ships and airliners.

But what makes the shuttle even more of a significant and economical innovation is that, like all common conveyances, it can be used for numerous trips. This is the main reason why the shuttle is expected to drastically reduce the cost of a space journey in comparison with today's missions.

These advantages are expected to make spaceflight desirable and feasible for selected non-astronauts. Seats will remain too scarce to admit the general public. But scientists, physicians, engineers, technicians, photographers and other specialists whose work can benefit through research in space may get an opportunity to go there. Scientific and technological experiments will benefit from the fact that the shuttle is steerable. It can be maneuvered into any desired near-Earth orbit, and can remain in space continuously for as long as 7 days.

The shuttle can insert unmanned satellites into orbit simply by releasing them in flight. These satellites will then remain in orbit after the shuttle leaves. It can catch up with satellites which need maintenance or repair and can resupply them with film, batteries or other needed equipment. If desired, the shuttle can retrieve an orbiting satellite and bring it back to Earth.

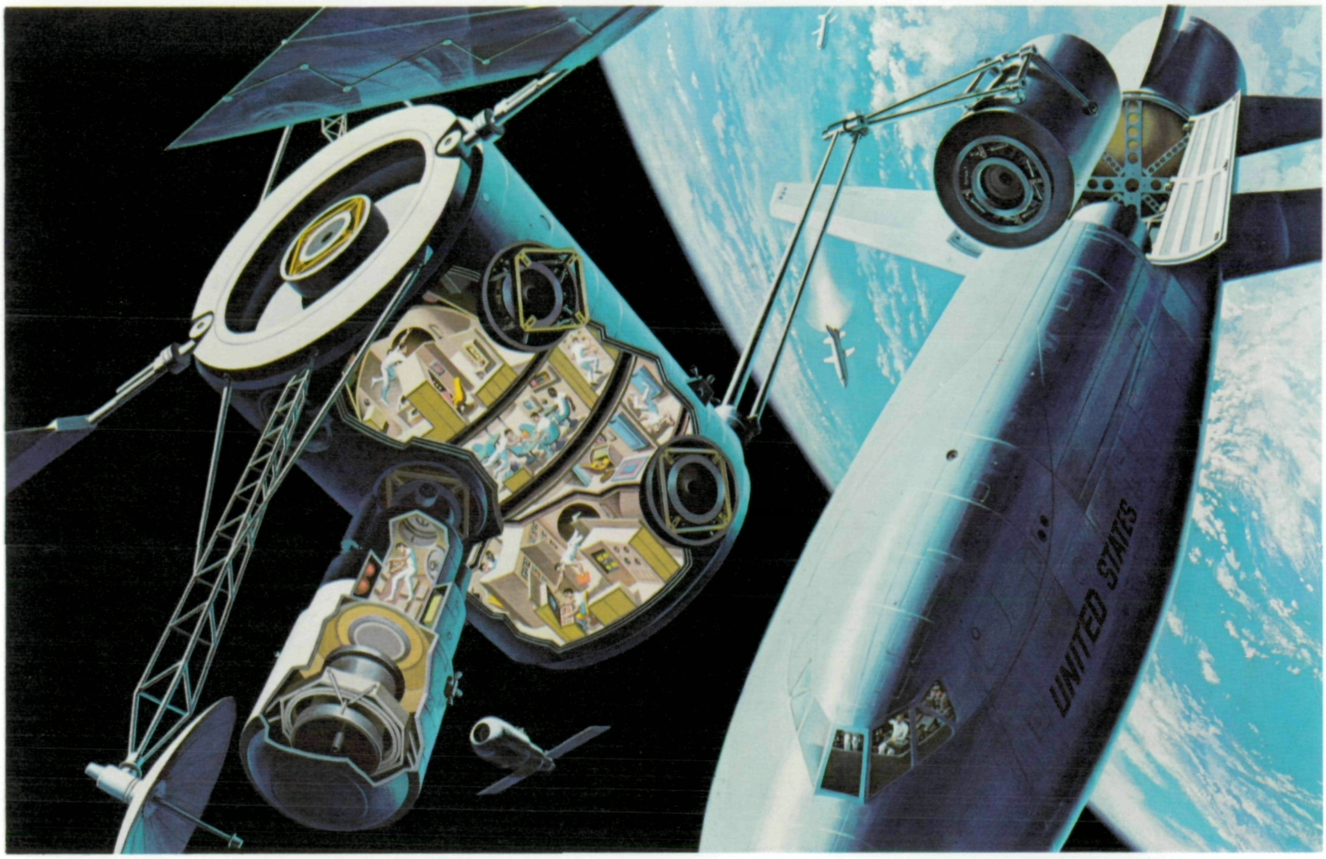
One of the shuttle's major tasks will be to commute between Earth and space stations to exchange personnel, resupply the stations, and pick up and return to Earth the instruments and records of completed experiments. As the number of space stations increases, the demand for shuttle commuter service is bound to grow accordingly. For passengers, a shuttle trip to or from space stations may be similar to a business trip by air to a distant city.

The shuttle's reusability, for perhaps 100 missions or more, will become possible through shielding materials which are quickly replaceable or can withstand atmospheric friction during reentry into the Earth's air envelope. Studies and research for such materials and for the shuttle's best body design have been underway for several years.

Research is also continuing on the shuttle's rocket propulsion system, whose engines must be able to vary their thrust and start and stop as many times as the pilots desire.

As now envisioned, the shuttle would weigh about 1,700 tons at launch and combine the functions and appearance of rockets, airplanes and spacecraft. It would fly at speeds ranging from subsonic (slower than the speed of sound) through sonic and supersonic to hypersonic (many times the speed of sound). It would have to be able to withstand the stresses of launch, engage in maneuverable orbital flight and be suitable for high-altitude gliding and low-altitude powered descent.

Tentative designs picture the shuttle as consisting of two distinct sections—a booster and an orbiter—each piloted by two astronauts. Driven



A space shuttle unloads a supply module at an orbiting space station, 280 miles above the Earth's surface.

by the booster's engines, the combination craft would lift itself off its launch pad vertically like a rocket. After reaching the speed of about 6,500 miles an hour and an altitude of about 40 miles, the booster would detach itself. The booster's pilots would return with it to Earth, landing it horizontally like an airplane on a conventional airport runway. After refueling, the booster would be ready to lift another orbiter into the sky.

Meanwhile, the pilots of the orbiter section, with passengers and cargo aboard would have started their section's own engines to provide acceleration to orbital speed and altitude. After completing its space mission, the orbiter would be landed by its crew horizontally on an airport runway (similar to the booster section). After refueling and routine maintenance (which might include rebuilding burned sections of the reentry heat shield—a process which could take up to two weeks), the orbiter would be ready for another space mission. Ground personnel for the shuttle would be comparable to a maintenance group for airliners. The shuttle would require no elaborate launch preparations and no recovery forces as do today's rockets and spacecraft. Monitoring devices in the cockpit allow the crew to conduct its own countdown.

These qualities allow the shuttle to be launched on short notice—perhaps within hours—if the need should arise. Present rockets require weeks of preparation and several days of final countdown before launch. This fast availability would qualify the shuttle as a space rescue vehicle to fetch marooned or injured astronauts from space or bring relief supplies to a stricken craft.

Parts or all of the shuttle's passenger compartment can be converted for cargo whenever desired. Passenger and cargo compartments have a combined diameter of 15 feet and a combined length of 60 feet. Together they offer more cubic feet of usable space than an average railroad freight car.

The shuttle principle may later lend itself to transporting passengers and cargo from one point on Earth to another in very short travel times. Orbiters could reenter the atmosphere and land before completing their first orbit. Thus, they could carry passengers and cargo between such places as New York and Sydney or Tokyo and Paris in less than one hour. In that way, the shuttle, the harbinger of a new kind of space travel, could also inaugurate a new epoch in Earth transportation.

"Exploration really is the essence of the human spirit, and to pause, to falter, to turn back on the quest for knowledge, is to perish."

Astronaut Frank Borman in address to Congress January 9, 1969, 13 days after returning to Earth from man's first flight to vicinity of the Moon.

SPACE STATION/SPACE BASE:

A City in Orbit

A bustling space city, suspended high in the sky, may well come within the realm of possibilities through research in the 1970's. The trend of developments points to eventual construction of a space base, the ultimate in orbital installations. It would presumably be a combination hotel and research center. In it, 100 or more scientists, physicians, research experts, technicians, statisticians, photographers, writers, and other occupational specialists would simultaneously be conducting wide varieties of projects encompassing almost every scientific discipline and technological specialty.

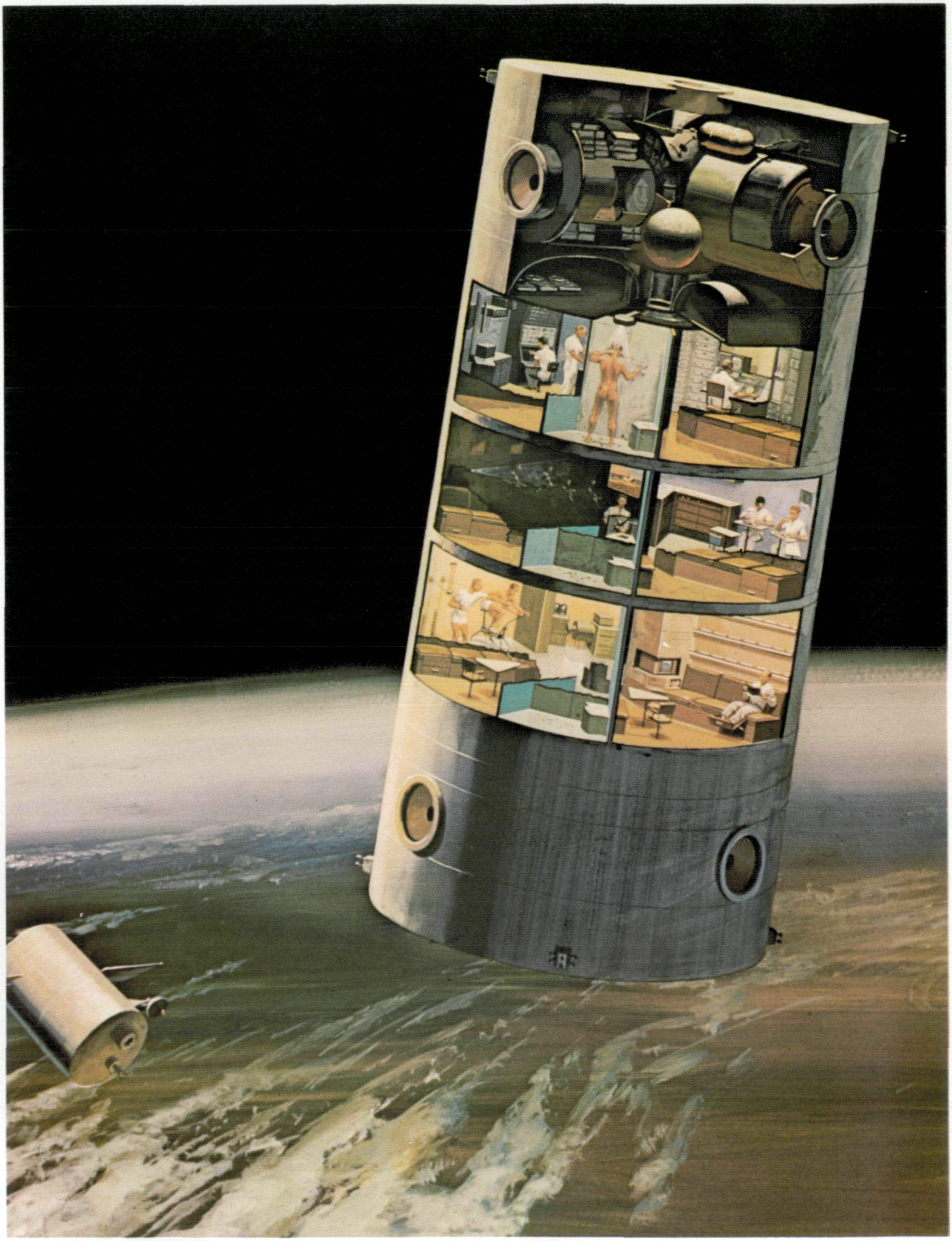
Some of these men and women would come to the space base for stays of a few hours or days or weeks, depending on their particular assignments. Others might be semi-permanent residents. They would return to Earth only on their weekends and vacations and for occasional conferences or shopping trips. Supplementing these professional space base staffs would be cooks, waiters, telephone and radio operators, computer operators, clerks, maintenance and repair men and other auxiliary personnel to operate the restaurant and dormitory and the numerous other on-board service facilities. Laboratories of many kinds might be available. These would be staffed by expert technicians trained to run tests and experiments in the vacuum and zero-to-low gravity space environment.

Such a space base would be the logical outgrowth of Project Skylab. How soon such a space base would come about, and what its specific design will be, depends largely on the experiences of the first American experimental space stations. Project Skylab, in 1972 and 1973, is to be followed in the 1970's by larger space stations accommodating crews of 6, 12, and later, up to 50 men.

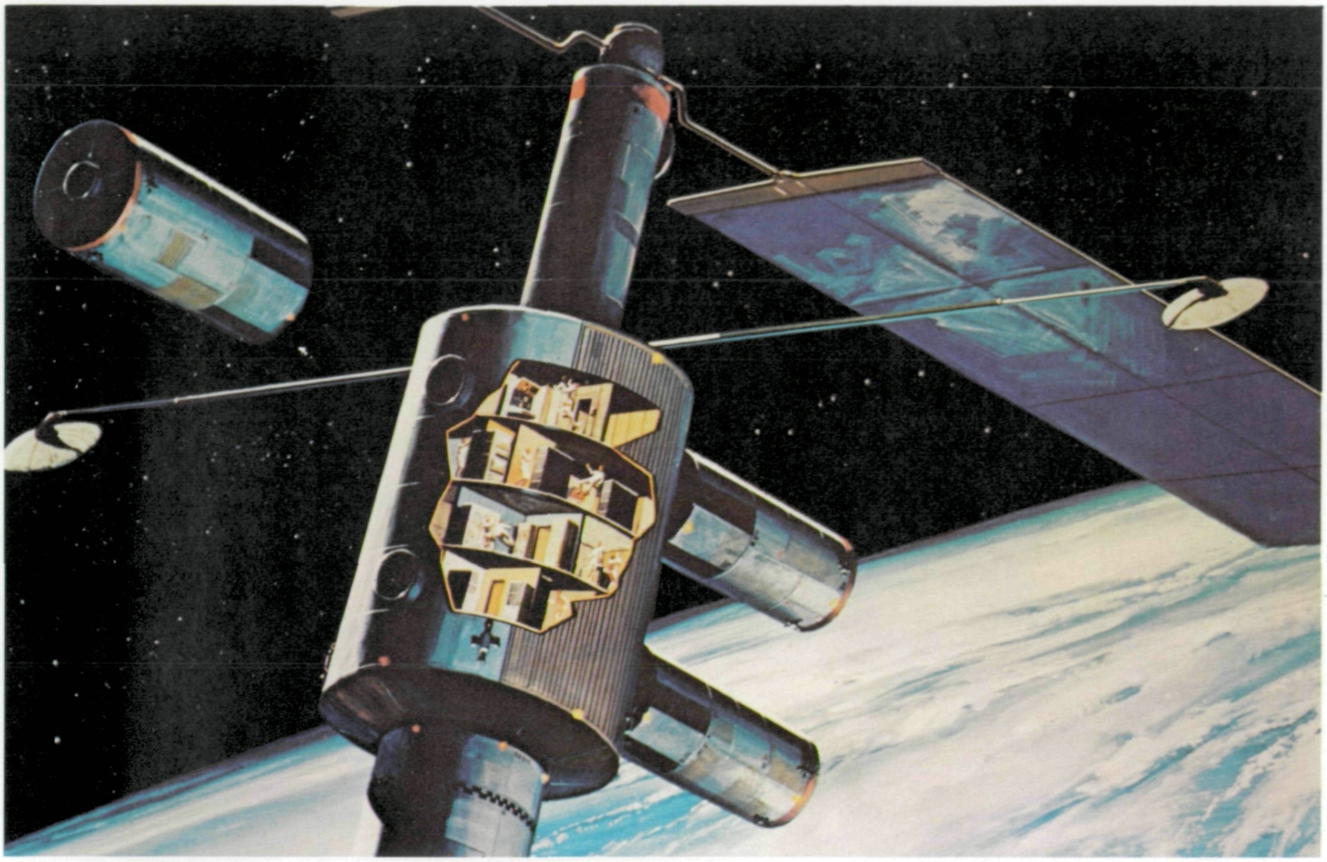
Centralized permanent space stations can support many diverse activities, can be modified and expanded as required, and can be operated at much lower unit costs because of the economy inherent in large-scale operations. These space stations would be national research, development and operations centers 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 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.

As now envisioned, a space base would encompass a cluster of such space stations—or modules—individually launched into orbit and assembled in space around a hub or core. Passengers arriving in a shuttle would enter the hub through hatches



A cutaway view of a 12-man, triple-decked, space station.



An expanded space station with two specialized experiment modules attached, while one module floats freely nearby. The wing-like arrays of solar panels provide electric power.

and from there walk or ride to any attached station or module through the hub's corridors and connecting tunnels. To receive additional stations or modules, the hub is surrounded by berth-like multiple docking adapters similar to those to be tested in Skylab.

The interior of one attached module might be outfitted as a physics laboratory for the study of fundamental particles. Another module might contain a biological laboratory for long-duration studies of the effects of zero gravity on small animals or plants over several generations. Still other modules might be equipped and staffed for communications experiments, meteorological observations which can best be done at extreme altitudes, and astronomical work requiring the absence of atmospheric distortion and obstruction.

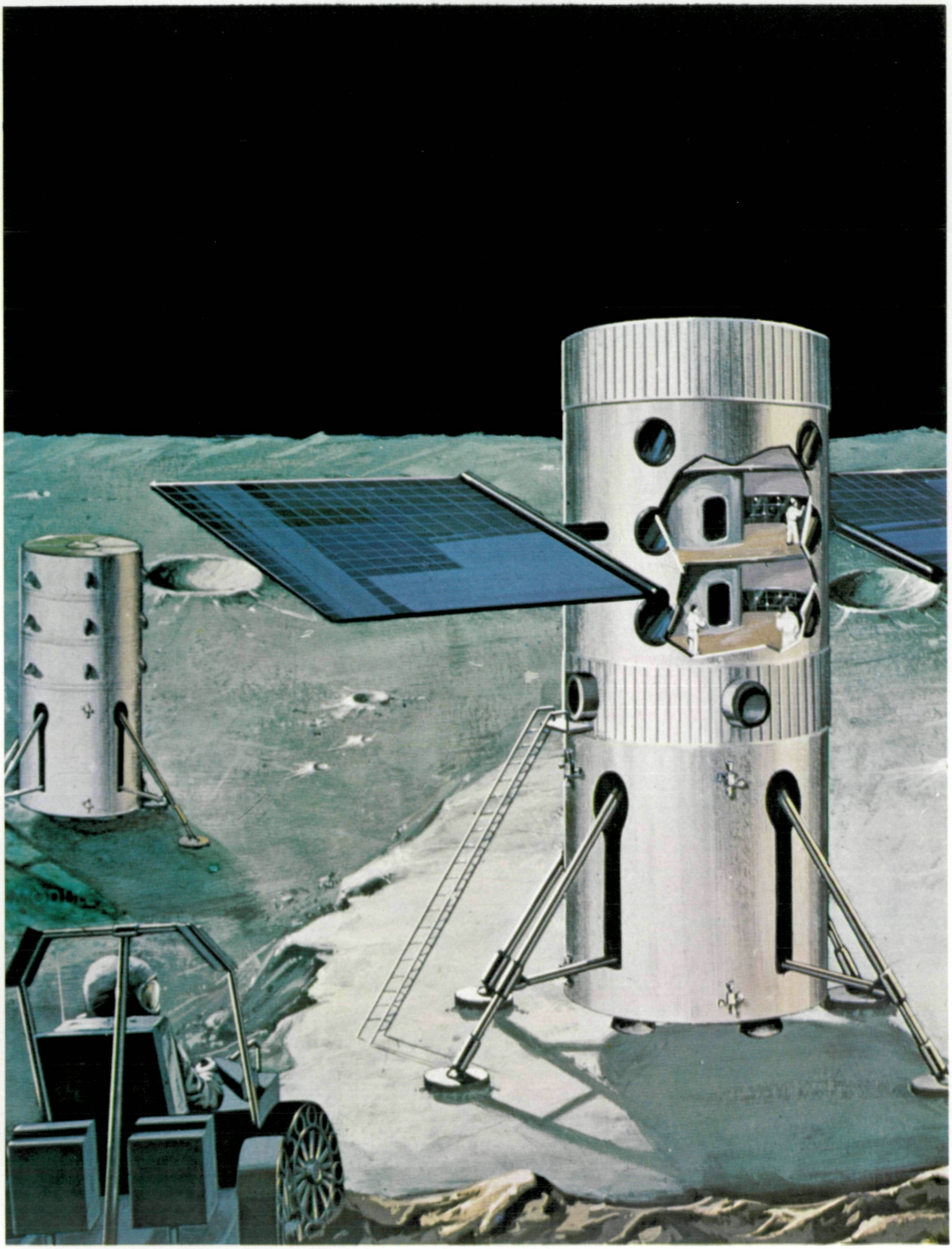
The space city—orbiting between 100 and 300 miles above the Earth—might also have suburbs. Because certain experiments require freedom from vibration or contamination, or because a module might have to remain pointed precisely in the same direction for a long period of time, some modules might remain detached from the base. They would remain free-floating in the base's neighborhood, close enough to draw on the base's facilities when needed.

As some equipment became obsolete, an entire module could be replaced by a newly outfitted one shipped from Earth. Thus the base would renew itself to meet current needs. The base's lifetime could extend for 10 years or more.

Several bases could eventually be established at varying altitudes and in different orbital paths to give researchers a choice related to the needs of their particular research projects. Some modules might be equipped as repair, supply and maintenance stations for stop-overs by manned and unmanned satellites and spacecraft on the way to or from the Moon or other solar system destinations. An on-board nuclear reactor would provide ample electric power for all base needs.

Rotating the entire base at a steady rate around its hub would create varying levels of artificial gravity, the pull of artificial gravity increasing with distance from the center. Experiments could be carried out at locations in the base providing the desired gravity levels. For the comfort of base residents, living quarters could be located at a distance from the hub where artificial gravity would equal normal gravity on Earth.

The flow of information and discoveries from a space base would enrich the store of knowledge about the Earth, its resources, its environment and the life upon it. In turn, that new knowledge would provide foundations for improving the quality of life and for building a better world.



This lunar surface base will permit extensive exploration of the Moon and the establishment later of a permanent lunar base.

"The great explorations of history, carried out by many nations, have always opened up new vistas of the possible. And the sights of all men have been raised and their hearts inspired. The exploration of space is in that great tradition."

Dr. Thomas O. Paine, Administrator, National Aeronautics and Space Administration, November, 1969

A LONG LOOK AHEAD:

From the 1970's into the 1980's

The bridge men built to the Moon in the 1960's is only the first step into the infinite universe. Because of that bridge, neither the Moon nor man will ever be the same again.

The Moon—which in the past was subject only to brute, inanimate forces such as meteoroids, radiation, temperature extremes and vulcanism—is the object now of a very different force, the intellect and will of man. In time, man will probably leave as formidable an imprint on the Moon as have the mute, harsh forces of nature. The evidence of man's presence may become as tangible on the face of the Moon as it has become on the face of the Earth.

For man, that bridge is his first possible escape from the confines of the Earth where he has been a prisoner since his creation. For the first time in his long history, man has the tools to leave Earth to explore companion worlds. Judging by history, it is not man's nature, nor in his long-term interest, to let these tools lie idle.

In his long sojourn on Earth, man's advance up to 10,000 years ago had gone no further than learning to use skins of animals to cover himself. Then he emerged from the cave to construct other kinds of shelter. It was about 5,000 years ago that man learned to write and use a cart with wheels; 500 years ago movable type came into use; about 200 years ago the steam engine first provided usable power, and only in this century did electricity, automobiles and airplanes become more than curiosities. Only in the last 25 years have atomic energy and television been turned to public use, and just in the last 10 years has technology advanced to open space beyond the atmosphere for exploration by men.

During the 1960's, men first overcame the bond of gravity that had always chained them close to the Earth's surface. On July 20, 1969, two men became the first of their species to set foot upon the Moon. In November 1969, two other men repeated that achievement.

More Moon landing flights are planned for the 1970's.

The United States is building Skylab and designing a Space Shuttle to be followed by a Space Station and Space Base. In the foreseeable future, space will open to many non-astronauts, although probably not to the public at large. The economies of long-lasting reusable vehicles will lower the cost of space travel to one-tenth of what it is with today's expendable vehicles.

A semi-permanent lunar base that includes an inflatable laboratory, a workshop and a control center.

As shuttles begin to ferry passengers and equipment in frequent runs on a timetable, perhaps beginning early in the 1980's, the convenience and reliability of this service is bound to attract many visitors into space.

As the load-carrying capacity of spacecraft increases, many desirable space research projects will become feasible. The demand for space facilities will rise.

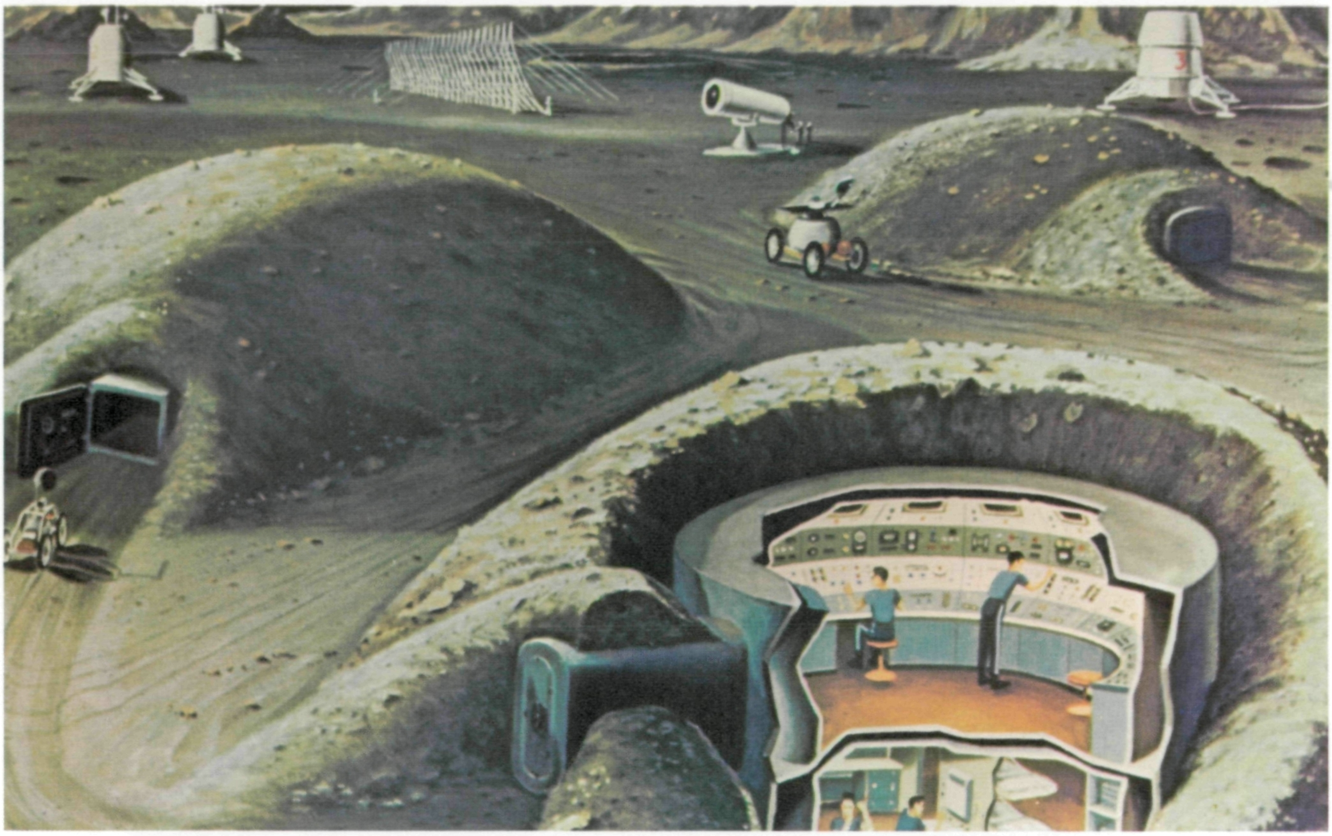
Work is continuing on the development of a nuclear rocket—project NERVA (Nuclear Engine for Rocket Vehicle Application). NERVA is expected to deliver more total thrust over long periods than present chemical rockets of equal size and weight. The planned 75,000-pound-thrust engine can be throttled and restarted repeatedly. It is to be used mainly as an upper stage for moving orbital vehicles onto deep-space trajectories and for controlling the velocities of these vehicles deep in space.

A concept is also under consideration for a space tug intended for taxiing between points in space. The tug would hop from orbit to orbit to reposition or otherwise service manned and unmanned satellites; ferry persons and equipment between Moon bases and Moon-orbiting craft, and help assemble space bases and large Mars-bound craft which would be put together in Earth orbit from sections delivered from the ground.

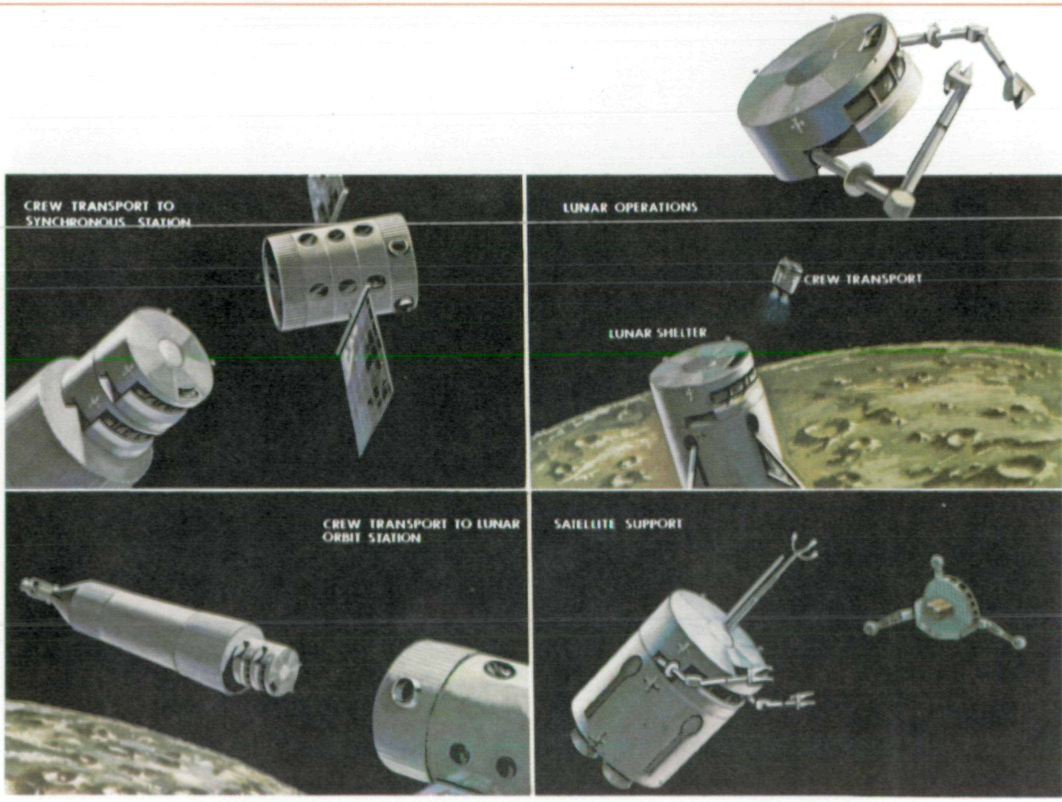
Unmanned craft, which traditionally precede man on space missions are to be launched in the 1970's toward the vicinity of every planet in the solar system. At least two such craft will be sent into Mars orbit. Each of these craft will release a landing vehicle to set down softly on Mars' surface and relay its findings to Earth.

Land lies abundant in the sky. Men will almost certainly learn to reach it and adapt there. The machines, techniques and skills to be developed in the 1970's will bring closer the time of a spacefaring world. By the end of the 1970's, Mars and perhaps other celestial destinations will have become more realistic objectives for space voyages in the 1980's.

Instead of looking upward, we can now look outward. From a tenant on Earth, man is turning into a citizen of the solar system. From a mere spectator he is maturing into a participant in the universe. Whatever man's destiny may be, space exploration is now certain to be a part of it.

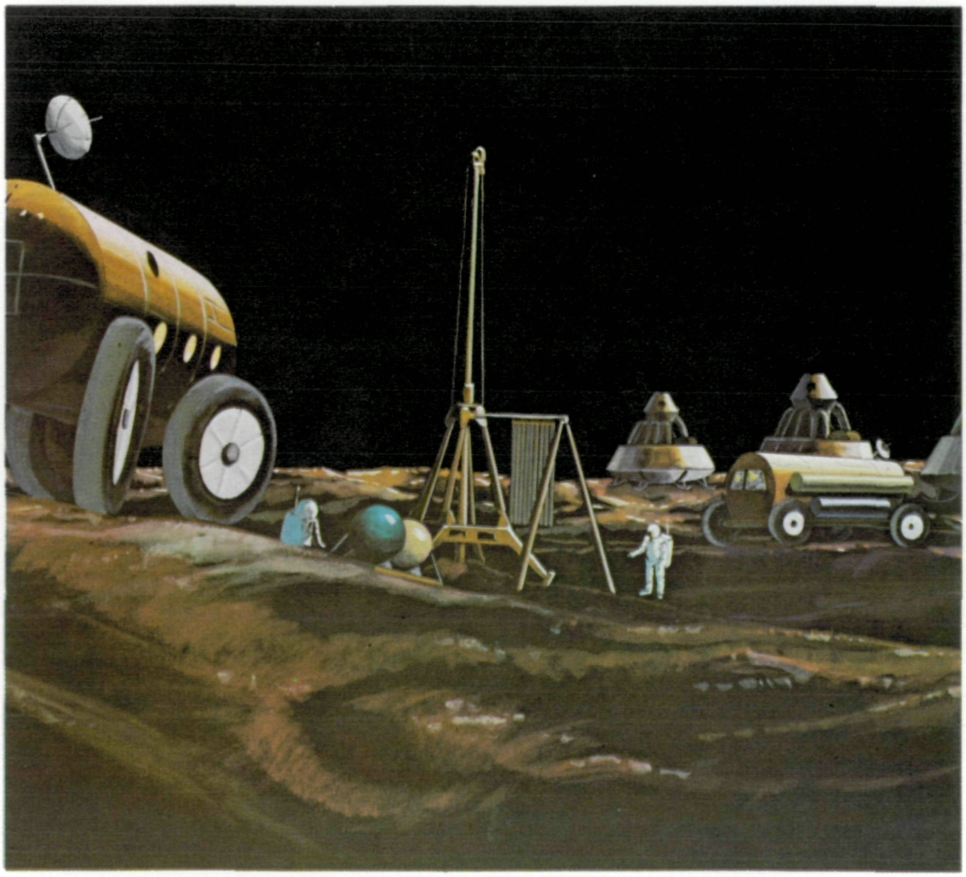


A permanent lunar base. The crew quarters and control center are in the right foreground and the laboratories, telescope and cargo modules are in the background.



The ferrying of men and supplies between an orbiting satellite, a space shuttle and a space station will be effected by the Space Tug/Crew Module.

A temporary Mars base might develop as shown in this illustration. Included are Mars Excursion Modules (MEMs) and pressurized Mars Rover Vehicles (MRVs) for long-distance mobility.



WHAT'S AHEAD IN U.S. MANNED SPACE EXPLORATION IN THE 1970's

MOON JOURNEYS
Apollo 14 through 17 in 1971–72 will extend manned Moon exploration. In Apollo 14 a hand-pulled, two-wheel cart, nicknamed "rickshaw," will help astronauts transport equipment and collected Moon rocks over greater distances. Beginning with Apollo 15, later in 1971, astronauts will drive across the Moon in a battery-powered, four-wheel Rover with a range of about 65 miles. Improved life-support equipment will permit astronauts on the later missions to live on the Moon for 66 hours and remain outside the landing craft for a total of 40 man-hours. The spacecraft will have a greater life support capacity to extend the standard Moon roundtrip to 16 days, thus allowing the crews to carry on more scientific research.

SKYLAB
The first American experimental space station, Skylab, is to be launched into Earth orbit in 1972. As big as a five-room house, it will provide living and working quarters for a crew of three astronauts. The first crew will remain in the station for 28 days. After that crew has departed another crew will arrive, also in an Apollo spacecraft, and remain in the station 56 days. A third crew will later repeat that visit. The men will study the Sun with an on-board solar laboratory, conduct Earth observations, carry on industrial research requiring vacuum and zero-gravity conditions, and test their own reactions to lengthy exposure to space conditions. They will assess tools and furnishings for possible use in later long-duration manned space missions.

SHUTTLE
A vehicle piloted by astronauts that can take up to 12 non-astronauts into space is to make its maiden flight in 1977 or shortly thereafter. The shuttle lands horizontally like an airplane and can be used for numerous flights, thus drastically reducing the cost of space travel. Scientists and other specialists without astronaut training will be able to carry on research in Earth orbit from the shuttle or fly in it to orbiting space stations. Shuttle passengers can wear conventional clothes and need no special training amid the "shirtsleeve environment" of the cabin that will resemble the passenger compartment of modern airliners.

A LOOK AHEAD
A combination hotel and research center with accommodations for 100 persons or more may eventually emerge from research and experiments in the 1970's. This space base in the 1980's would permit large varieties of in-space work over long periods. Scientists and other specialists could live and work in the base for years, if desired, and make periodic visits to Earth by shuttle. The base would consist of smaller space stations assembled around a hub. Also considered are space tugs which—like ferry boats on the ocean of space—would move from orbit to orbit carrying men and equipment between small satellites, space stations and space bases.

Additional Reading

For titles of books and teaching aids related to the subjects discussed in this booklet, see NASA's educational publication EP-48, Aerospace Bibliography.

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MAN IN SPACE

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