NASA plans return to Moon, manned colony on Mars

21st Century Science and Technology Associate Editor Marsha Freeman details the new technologies we need for a U.S. planetary colonization program.

Flanked by Apollo 11 astronauts Neil Armstrong, Buzz Aldrin, and Michael Collins, President George Bush announced on July 20 that his administration would commit the United States to go back to the Moon to stay, and then on to Mars. NASA Administrator Richard Truly announced soon after that, that the space agency would do a 90-day "tiger team" study to make its first-cut recommendations to the National Space Council. Johnson Space Center director Dr. Aaron Cohen was brought in to Washington to head the NASA team. In November, NASA's report on Human Exploration of the Moon and Mars was submitted to the National Space Council, headed by Vice President Dan Quayle. It is now being reviewed there and, according to participants in the NASA study, the space council may have other groups, such as the National Research Council, review the space agency's report.

President Bush should be advised that time is of the essence. Every week there are press announcements of industry layoffs in the tens of thousands, now not only in automobile manufacturing and so-called "smokestack" industries, but also in high-technology sectors, such as computers and telecommunications.

The last great space initiative of the United States was the 1960s Apollo program to land a man on the Moon and return him safely to Earth. When that program ended, the engine pumping new technologies into the economy began to slow down. It has been at a near-standstill for the past eight years, as government research and development was drastically reduced or completely dismantled in important fields such as nuclear fission and fusion energy, next-generation transportation, and even the emerging fields, such as industrial applications of high-temperature superconductivity. High-technology industry has jumped on the leveraged buyout bandwagon and become more interested in selling off assets than investing in new technology to increase productivity. Numerous recent studies have demonstrated that by the turn of the century, there will not even be enough scientists and engineers to initiate large-scale science and engineering projects, if the nation should then decide to undertake them.

Though one could debate the merits of some of the details of the NASA report, the most important thing this administration must do, is to get the nation started on the Moon-Mars mission. Studies of the advanced technologies needed for the missions should continue. Technical specifications for the various new and highly sophisticated space systems required will be refined. But if we do not get started soon, this nation will find that it has *neither* the political will *nor* the physical economic means to carry out this effort, which is itself the means by which we will push ourselves into the 21st century.

As the NASA report states, "The initiative described in this report encompasses robotic as well as human missions. It is, nonetheless, a distinctly human adventure in the broadest sense, involving not only human space travelers, but also extending into the Solar System the skills, imagination, and support of many thousands of people who will never leave Earth." Hundreds of *millions* of people will benefit.

Sending robots first

"To enrich the human spirit, to contribute to national pride and international prestige, to inspire America's youth, to unlock the secrets of the universe, and to strengthen our nation's technological foundation: human exploration of the Moon and Mars will fulfill all these aspirations and more," states the NASA report. The initiative envisioned by NASA is a program following "an evolutionary pathway over a 30-year horizon." Both the Moon and the Mars segments of the program entail four phases, the way NASA describes it.

The first is the preparatory phase of robotic exploration. Before we can pack up our belongings and go off to live on other heavenly bodies, we must send sophisticated representatives of our human intelligence to reconnoiter. Though men have landed on the Moon in six of the Apollo missions, they explored only a very limited area. The unmanned reconnaissance missions preceding Apollo used technology that is now 20 years old. Both the previous manned and unmanned missions provided information essentially limited to a band around the equator of the Moon. Sensing instruments, using today's technology, can provide maps of the Moon as detailed as the Landsat photos of the Earth from a global standpoint. When the Galileo spacecraft, which has Jupiter for its ultimate destination, swings by the Earth for a gravity assist, for example, it will image the poles of the Moon for the first time.

The mid-1970s Viking orbiters and landers opened up a view of Mars that was unimagined, which included violent dust storms, huge volcanoes and canyons, ice frost, and dynamic polar caps. The 1992 Mars Observer will orbit the planet for a full Mars year, revealing more detail about the atmosphere, climate, geology, and weather of the planet. Later, rovers and sample return missions will also be required.

The NASA report recommends that the general practice of building and launching identical or nearly identical *pairs* of spacecraft be reinstituted in future mission plans. The sole reason for the design of singular unmanned spacecraft missions in the past decade was entirely because of budgetary constraints. Since neither unmanned launch vehicles nor unmanned spacecraft are "man-rated" and have a somewhat greater risk of failure, the probability of success is increased by having two of each ready to launch.

The report proposes that a two-spacecraft Lunar Observer mission be carried out to "verify the requirements for surface equipment and excursion vehicles, select the outpost site, and plan lunar surface operations."

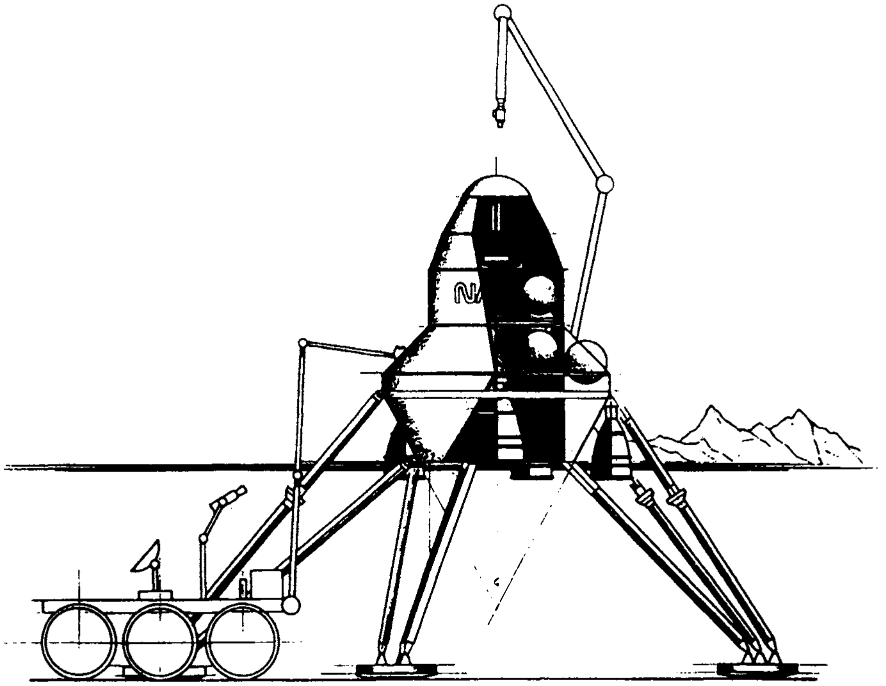
The flight plan calls for placing each spacecraft into an elliptical orbit in which a sub-satellite will be released to conduct gravitational mapping of the Moon, because previous data indicated mysterious gravity variations on the Moon. About a month later, the spacecraft's orbit will be circularized into a 100 kilometer-high polar mapping orbit, from which it will send back data for one year. This is similar to Landsat, which orbits from pole to pole, instead of around the equator, while the Earth rotates on its axis beneath the satellite. After the Lunar Observer mission's detailed and extensive survey of the Moon is completed, planners will be able to locate the best site for an initial lunar outpost, in terms of resources, science opportunities, and ease of landing and takeoff.

No human has ever set foot on Mars, and thus far, no robot has brought us samples back. So far, our exploration of the Red Planet has been vicarious, through the eyes and instruments of spacecraft. In 1992, NASA plans to launch the Mars Observer—a single spacecraft which will provide detailed data to address scientific issues, such as the origin, history, and current conditions on the planet; to provide engineering data, to help site selection; to provide atmospheric and climatic data to aid in designing manned vehicles and surface systems; to search for Martian resources; "and to generally demonstrate readiness to proceed with a human Mars mission." We would need an enhanced Mars Observer to allow for additional high-resolution mosaic pictures of the planet, higher data transmittal rates to Earth, and an extended period of operation, if this previously planned mission were now seen as a precursor to manned exploration. NASA states that if the 1992 mission were to fail to meet its objectives, "a modified 1996 mission will back it up."

It is proposed that a Mars Global Network Mission be conducted preceding a manned mission. Two spacecraft would each carry an orbiter and multiple landers, launched within 20 days of each other on two expendable launch vehicles. The landers would provide high-resolution data on the surface at multiple locations and obtain extended-duration seismic and meteorological measurements. They would also implant scientific instruments beneath the surface, as well as leave instruments on the surface, as Viking did before them. In one design, the small landers would be deployed to the surface at different times to different locations. The orbiter would relay the data collected from the landers to Earth.

NASA describes as the "centerpiece of the robotic Mars missions," a Mars Sample Return with Local Rover mission **(Figure 1)**. Most scientists agree that examining soil and rocks from Mars, using the most advanced techniques available in today's Earth laboratories, is a prerequisite to sending people millions of miles to go there. In addition to providing important scientific information, this mission would demonstrate the landing and launch technologies that would be needed for piloted missions to Mars. New technologies, such as using the atmosphere of the planet for aerobraking and aeromaneuvering, would be tested out before being tried with people. Techniques needed for hazard avoidance during landing, for automatic rendezvous and docking, and for coping with long communication delay times, all needed for operations on Mars, would be put to the test. The plan would be to bring five kilograms of Martian rocks, soil, and atmosphere back to Earth. The rover provides an important series of first tests of surface mobility—there has been much speculation but little practical development of vehicles to roam the Martian surface.

FIGURE 1
Mars sample return vehicle with local rover



After the sample return vehicle lands on Mars, its rover, which is shown on the left here, will separate and collect 5 kilograms of Martian soil, rocks, and atmosphere, and deliver these back to the sample return vehicle.

The top half of the vehicle is the ascent stage, which will blast off from the surface after one year. Carrying the precious sample inside it, it will automatically dock with a sample return orbiter which will be orbitting Mars. When docking has been completed, the cannister with the samples will be transferred to the sample return capsule part of the orbiter, which will head back to Earth a month later.

Source: NASA, "Report of the 90-Day Study on Human Exploration of the Moon and Mars," November 1989.

Two identical flight systems would be launched and aerocaptured into a circular orbit around Mars. The Mars ascent vehicle with its rover would land near one of the global network lander sites, while the sample return orbiter remains in orbit. The rover, able to traverse about 100 meters from the lander, would be deployed to collect samples in an area outside the region contaminated by the lander's propulsion system.

Ascent for the return to Earth would take place a year later, with the ascent vehicle docking with the sample return orbiter. "Once docking is completed, the sample canister assembly will be transferred to the sample return capsule of the Earth return portion of the sample return orbiter." Departure from Mars orbit is to take place about a month after ascent from the Martian surface.

At the same time, the Mars Site Reconnaissance Orbiter mission, consisting of two orbiters and two communication satellites, would be in progress. The orbiters would be Sun-synchronous and have a near-polar orbit at an altitude of 299 kilometers, so as to complete an orbit each Earth day. The orbiters would have the task of imaging between 30 and 50% of Mars, generally making moderate resolution visual maps. For selected regions of the planet, high-resolution images would be obtained. The two communications satellites would relay the data back to Earth. This preliminary communications infrastructure will be crucial to coordinate the multitude of landers, rovers, and orbiters even before people arrive.

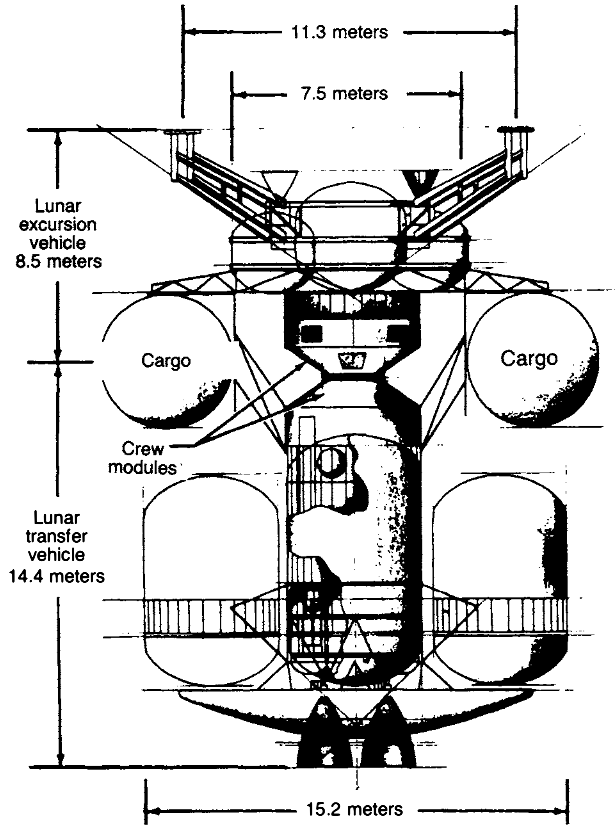
NASA estimates that up to five Mars rover missions to certify three sites may be needed in combination with the Mars Observer mission and Mars Global Network. Each will survey a different 10×10 kilometer area for "trafficability, subsurface structure, and mineral composition." Within each 100 square kilometer area, nine 100-meter sites will be selected for location of a power plant, a habitat, and a landing site for the manned missions which will follow.

Return to the Moon

The second phase of the human exploration initiative for both the Moon and Mars is the emplacement phase, where basic habitation infrastructure and the foundation for more complex future operations are laid. "During this phase, human operations take place within tens of kilometers of the outpost, and unmanned rovers are used to explore more distant areas." From the first flight, the commitment is made that the lunar outpost will be a permanent facility.

The crew, payload, and vehicle propellants for the manned return to the Moon are brought from Earth to Space Station Freedom. There they are loaded into the lunar transfer vehicles which will take them to low lunar orbit **(Figure 2)**. In lunar orbit, the transfer vehicle will rendezvous with an excursion vehicle, which will carry the crew and equipment to the surface of the Moon. The transfer vehicles return to Freedom to prepare for their next trip, and are serviced there. The excursion vehicles, in this plan, are serviced and main-

FIGURE 2
The lunar transportation system



Lunar excursion vehicle
Inert mass: 5.8 metric tons
Propellant load: 22.4 metric tons
Crew module, including crew: 4.4 metric tons

Lunar transfer vehicle
Propulsion/avionics module core
Inert mass: 8.1 metric tons
Propellant load: 7.0 metric tons
Crew module, including crew: 8.4 metric tons

Drop tanks
Inert mass total: 5.8 metric tons
Propellant load total: 129.8 metric tons

Source: NASA, "Report of the 90-Day Study on Human Exploration of the Moon and Mars," November 1989.

The lunar transfer vehicle which makes up the bottom half of the lunar transportation system is used to transport crews and cargo between Space Station Freedom and lunar orbit. In this design the vehicle consists of a reusable core, similar to the Space Shuttle main engines, and expendable propellant tanks, similar to the Shuttle's expendable External Tank. Using expendable drop-tanks, according to the NASA report, reduces the vehicle's propellant load by about 10%, compared to a single-stage, fully reusable lunar transfer vehicle. The transfer vehicle will provide shielding from solar flare radiation, probably using water.

When the first people are being ferried to the Moon, a lunar excursion vehicle with a crew module will sit on top of the lunar transfer vehicle. At other times, it will carry only cargo. When the crew module is attached to the transfer vehicle, the crew can override the automated rendezvous and docking system.

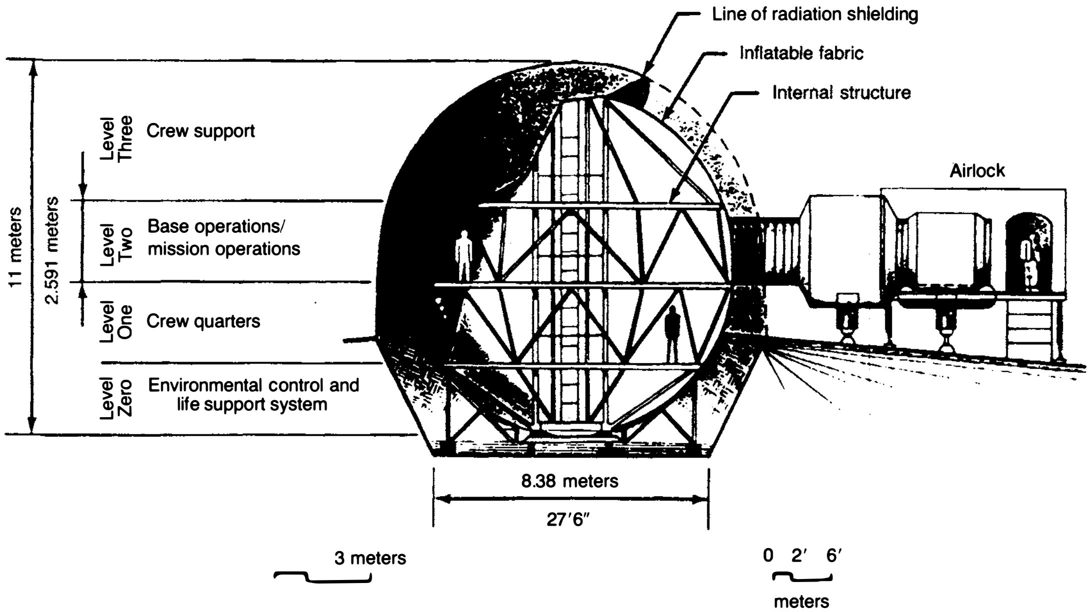
The lunar excursion vehicle is designed to deliver approximately 33 metric tons to the lunar surface in a cargo-only mode, or between 13-15 metric tons plus a crew module in a piloted mode. It includes a propulsion system, landing legs, crew cab, and other sub-systems.

tained at the outpost on the lunar surface. There have been other proposals to maintain the transport vehicles in low lunar orbit at a space station, rather than on the surface.

The current fleet of Space Shuttle orbiters carry both crew and cargo into Earth orbit. Because it is estimated that the freight needed to support men on the Moon will require at least doubling the tonnage of cargo the U.S. is able to launch now, specialized transport systems will have to be developed—some for crews, and others for cargo. During the early stages of lunar living, the cargo vehicles will either return empty from the Moon, or if they are not reusable, they will be expended. Eventually, some of the materials mined and manufactured on the Moon, such as lunar oxygen, will be used in space. Others will be exported to Earth. Studies being done at the University of Wisconsin and under consideration at NASA, indicate that the rare isotope helium-3, which is not available on Earth, can be mined from the upper layers of the lunar soil. Helium-3 will be needed to fuel the fusion energy power plants on Earth, and also on the Moon itself.

In the NASA report, the first manned lunar mission in the year 2001 is preceded by an unmanned cargo trip which delivers an unpressurized manned/robotic rover (the astronauts have to wear spacesuits in the rover), and the equipment needed to prepare the outpost site and unload payloads from the coming excursion vehicles. The second flight to the Moon will also be a cargo mission, delivering the initial permanent

FIGURE 3
Constructible habitat concept design



Source: NASA, "Report of the 90-Day Study on Human Exploration of the Moon and Mars," November 1989.

The first crews on the Moon and Mars will live in Freedom-derived habitat modules 4.45 meters in diameter and 8.2 meters long, which will be covered with lunar soil or regolith to protect them from radiation. As the NASA report described, "To accommodate larger crews and longer stays, and to provide larger pressurized volume for outpost and science operations, an expanded habitat is required."

An 11-meter diameter inflatable structure, partially buried in a crater or a prepared hole, could be constructed. When fully assembled, the constructible habitat pictured here provides three levels. The equipment required to outfit the new living and working quarters will be delivered in logistics modules, which are pressurized containers capable of docking with a specially designed cargo port on the habitat. The infrastructure needed to maintain the crew's artificial biosphere is on Level Zero of the habitat. The entire structure is covered with lunar soil for radiation shielding.

habitation facilities. These consist of a habitation module where the crew will live, an airlock to transfer from the module to the lunar surface, a power system which might initially be solar-powered but will later be nuclear, and other support equiment.

The first piloted mission with a crew of four in this reference design, would stay on the lunar surface for up to 30 days. The crew will check out all of the equipment, and use the rover to conduct geological studies. They will put scientific instruments in place, including the first elements of an astronomical telescope array.

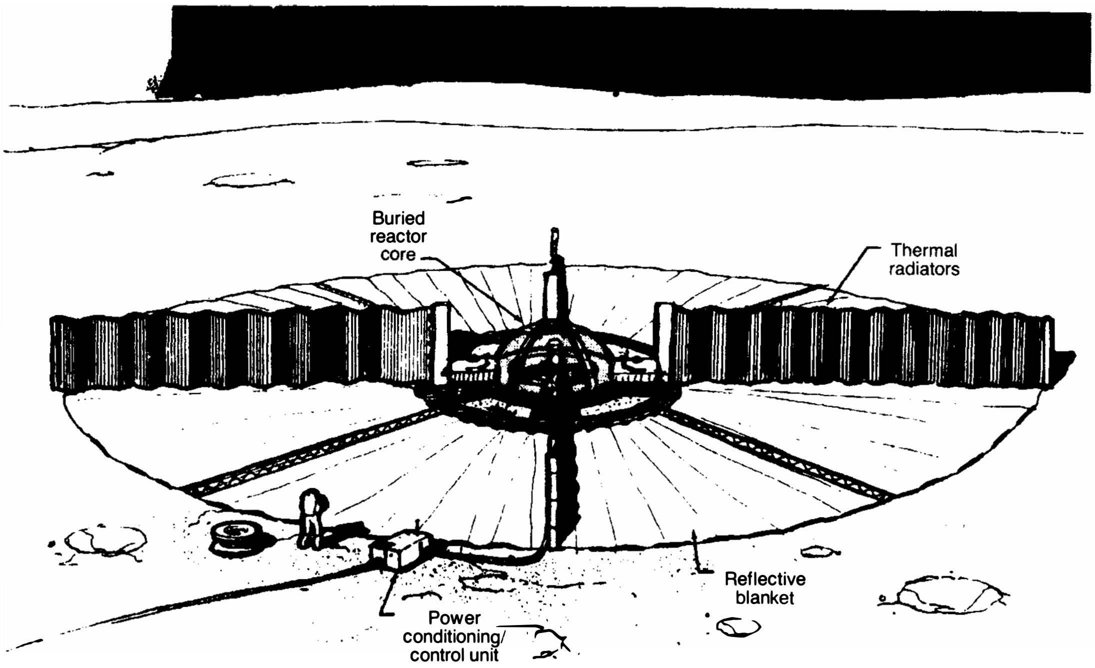
After additional cargo missions deliver more material, longer visits to the lunar base will begin, and the crews will quickly conduct a variety of experiments to demonstrate on-site resource utilization. "When the pressurized laboratory module is emplaced, geochemistry, life sciences, and biomedical research will begin." Man will truly be living and working on another celestial body, for the first time.

A major goal of the lunar development work will be to demonstrate, test, and further develop the systems which will be needed for the longer and more hazardous first journeys to Mars. The Moon is less than a quarter-million miles from Earth; at its nearest point, Mars is 35 million miles away.

Bridge to Mars

To expand the capabilities of the lunar outpost, a constructible habitat will be built **(Figure 3)**. The crews will get larger, and the stay-times longer. Crucial will be the biomedical and life sciences research, to discover how living systems adjust or react to the reduced gravity of the Moon. The lunar gravity is only one-seventh that of Earth, whereas the gravity on Mars is about 40% that of Earth. U.S. variable gravity studies so far have only been of relatively short duration, and only of near-zero gravity in orbiting Space Shuttles. The Soviets have not made the results of their extensive biomedical tests conducted on their space stations available to U.S. researchers. Initial studies indicate a serious disruption in the growth and reproduction of plants and insects in microgravity. The consolidation phase **(Figure 4)** "further extends human presence, both in complexity of operations and in distances traveled from the outpost, and continues to develop experience in living and working in a planetary

FIGURE 4
Nuclear dynamic power system



Source: NASA, "Report of the 90-Day Study on Human Exploration of the Moon and Mars," November 1989.

The two-week lunar night makes the use of solar-dependent energy systems uneconomical. On Mars, moreover, where there is an Earth-like day-night cycle, the atmospheric effects and weather disturbances make solar power as unattractive and uneconomical on Mars as it is on Earth.

Baseload (100-kilowatts), utility-style nuclear power generation will be needed on both the Moon and Mars soon after people arrive there. Before then, small systems using available radioisotope thermoelectric generators, similar to those on the Galileo spacecraft, can power unmanned robotic explorers. The SP-100 reactor, now under development by NASA, the Department of Defense, and the Department of Energy, is the prototype for the simplest operating nuclear system that will be available by the time crews could leave for the Moon in the year 2001. The SP-100 will use thermoelectric technology to convert the heat from the fission process into electricity. Dynamic conversion systems, with higher efficiencies, should be available by the turn of the century, which would improve the performance of the nuclear power systems.

More advanced still, and considerably more efficient, would be a direct-conversion magnetohydrodynamic (MHD) system with the nuclear power plant. Here, a working fluid which is energized by the fission reaction, produces electrical power using no moving parts. MHD direct conversion technology would also later be used with the fusion power plants in space.

environment." Humans extend their work hundreds of kilometers from the outpost.

Having come this far, the final stage is the operation phase, where people now depend upon on-site resources, and live and work with minimal dependence upon Earth. Mankind is finally becoming a multi-planet species.

Fifteen years after the first human footsteps since Apollo are taken on the Moon, the first crew will take off for Mars. Because of the much greater distance to Mars, systems there must be that much more autonomous and much less dependent upon help from Earth. This means that unmanned systems must be long-lived and durable, be able to survive a long journey, and operate on their own. This is even more the case, because of the almost 20-minute lag time in communications due to the distance between the Earth and Mars, which makes prohibitive having an engineer or geologist sit in front of a screen on Earth or at Freedom and "teleoperate" a rover on the surface of Mars, as he or she could a rover on the Moon, where the round-trip communication time is only three seconds. In the time it takes a communications signal to travel 70 million miles or more, a rover could rove off a cliff by the time the operator sent a message to the rover to stop.

For manned systems, little margin for error is acceptable, and technologies will have to be developed to be "self-healing," as repair shops will be millions of miles away. There must be a very high level of confidence and low risk in the vital life support systems for the crews, as the Martian atmosphere is not breathable, and we do not know yet if the soil will support the growth of plants.

Mars has certain similarities to Earth that the Moon does not. Because the two planets have atmospheres, aerobraking and aerocapture techniques can be developed on Earth, tested at Freedom, and used for landing both near Earth and near Mars. An aerobrake is a rigid structure like a shell, made of composite materials with advanced thermal protection. The aerobrake makes use of the friction of the approaching planetary atmosphere to slow down a spacecraft, rather than using heavy propellants to retrofire rockets to slow down. It is estimated in the NASA study that the use of aerobraking with conventional chemical propulsion reduces the required initial mass to launch into low-Earth orbit by more than 50%, in addition to reducing operating costs.

The chemical-aerobraking propulsion combination was used in this study as the baseline for the lunar transfer vehicle propulsion. As the study states, however, "for transportation from Earth orbit to Mars, nuclear propulsion shows a great deal of promise as an option for significantly enhancing mission performance." The major potential advantage of nuclear propulsion is the reduced time required for the trip. If interplanetary space radiation, in addition to the deleterious effects of microgravity, prove to be constraints on the manned exploration of Mars, which is likely, reducing travel time will be the major factor in choosing which propulsion technologies to develop. Chemical (liquid hydrogen-liquid oxygen) rockets would require about nine months for one-way travel to Mars. From 1955 to 1973, solid-core nuclear fission thermal rockets such as NERVA were designed, built, and tested in orbit by the space agency. Their major advantage was a savings of about 40% in the amount of mass needed to be hauled to low-Earth orbit. The NASA report states, "However, gas-core nuclear rockets, for which concepts were also formulated during the same time, offer the significant advantage of reducing round-trip travel time to Mars to less than 1 year."

Initial studies in the use of advanced nuclear fusion systems for transport to Mars indicate that a first-generation deuterium-helium-3 system, available by the beginning of the manned Mars initiative, could deliver a crew to Mars in about eight weeks. The NASA study has been criticized for not looking broadly enough at the technologies just now emerging, which should be pushed forward through the Moon-Mars program. Fusion propulsion is one such technology.

The colonization of Mars will push to the limit today's scientific and technological development. Every field of economic activity, from new materials, energy sources such as fusion, and biomedical devices to new ways to grow food, will be enhanced by the Mars initiative. Like the Apollo program of the 1960s, the 30-year Moon-Mars program will rejuvenate the physical economy and the cultural optimism of the people of this planet. One of the areas where this is most important is education. It has been predicted that there will be a shortage of 675,000 scientists and engineers by the year 2000. Recognizing that the demands for scientific and engineering manpower for the manned space initiative will outstrip the number of graduates projected from American colleges and universities, the report proposes to enhance its education programs, by adopting an initiative entitled, "Scientific Literacy for the 21st Century." This educational outreach program will "help to increase science literacy among four high-leverage groups: teachers, students, universities, and the adult general public. An exciting series of specialized educational programs will be designed for each of the four groups, and all will incorporate the space science and technology concepts and activities associated with the Human Exploration Initiative."

Getting started

The approach that the NASA study puts forward as the preferred schedule places the lunar return in 2001, and the first manned mission to Mars in 2016. Such a timetable allows enough time to develop new technologies, and test and deploy them, rather than rushing to get there and having to rely only on yesterday's already-proven technologies. The missions could be done more quickly, but nothing except public relations would be "gained."

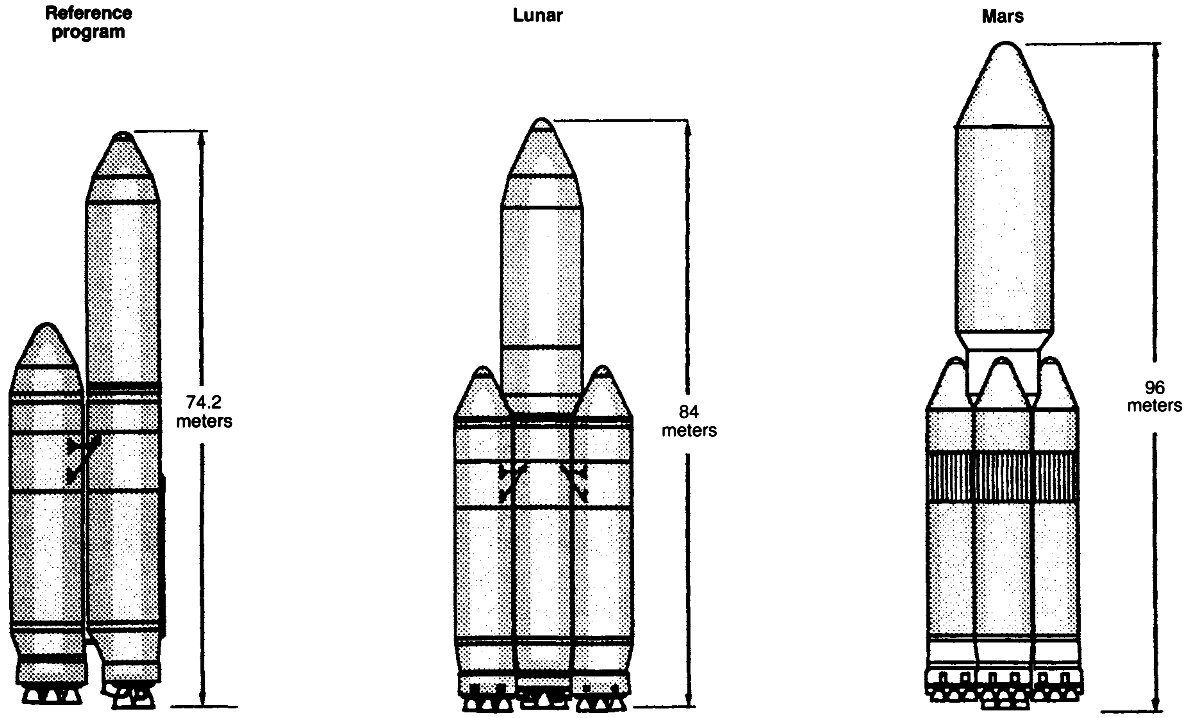
Delaying the effort, taking the approach of former Senator William Proxmire (D-Wis.)—the Moon will always be there, so what's the hurry?—will drag out the development and make the cost in resources and manpower, not to mention money, prohibitive. No one, inside or outside the space program, would maintain interest in an effort that had decades between major milestones.

To make use of the expertise and years of experience of the people who researched, built, and planned man's first adventure on the Moon, as well as the men who actually went there, the work must start now. In order to go back to the Moon in the year 2001, Space Station Freedom will have to be operational by 1997, not 1999 as currently planned. Lunar transfer vehicles must be checked out and tested from Freedom, before they are loaded with cargo and crews to go to the Moon.

Therefore, rather than stretching out the completion of Freedom each budget year, the work must be accelerated to *cut* two years from the schedule. Originally, the space station was to be operational in 1994. It has suffered more than $2 billion in budget cuts since the program began in 1984. A family of heavy-lift launch vehicles have to be produced, to carry double, and then double again, the tonnages that must go from Earth to the Moon, and then from the Earth and the Moon to Mars **(Figure 5)**.

For years, NASA and the Air Force have been trying to convince parsimonious administrations that heavy-lift vehicles are required for the Strategic Defense Initiative, for servicing Space Station Freedom, eventually for more complex robotic outer planetary missions, and most importantly, for

FIGURE 5
Advanced launch system heavy lift vehicles



	Reference program
Net payload	52.3 metric tons
Boosters	1 LOX/LH_2 w/6 STMEs ea.
Core stage	LOX/LH_2
Core propulsion	3 STMEs
Payload envelope	7.6 m diameter 30 m length

	Lunar
Net payload	98.2 metric tons
Boosters	2 LOX/LH_2 w/6 STMEs ea.
Core stage	LOX/LH_2
Core propulsion	3 STMEs
Payload envelope	10 m diameter 30 m length

	Mars
Net payload	140 metric tons
Boosters	3 LOX/LH_2 w/6 STMEs ea.
Core stage	LOX/LH_2
Core propulsion	3 STMEs
Payload envelope	12.5 m diameter 30 m length

Key:
m=meters
LOX=liquid oxygen
LH_2=liquid hydrogen
STMEs=space transportation main engines

Source: NASA, "Report of the 90-Day Study on Human Exploration of the Moon and Mars," November 1989.

For years an Advanced Launch System (ALS) for unmanned payloads has been under study. The reference program would lift over 50 metric tons of payload, using 1 liquid hydrogen booster, rather than solid rocket boosters, which are used on the Shuttle and today's expendable launch vehicles. Today's Shuttle orbiter carries 20 tons of payload. However, a more capable configuration would be required for the lunar effort, with a doubling of payload capability, using two boosters. The payload envelope or carrier would also be slightly larger. Manned missions to Mars will require a larger payload envelope, as well as an additional booster, to reach a 140 metric ton payload capacity. For comparison, the Soviet Energiya booster is designed for a 100 ton payload.

It is estimated that between five and seven ALS heavy-lift launch vehicle flights will be required for each Mars mission, depending upon the mission type and year, and the variation in distance between Earth and Mars. These flights are required to deliver between 550 and 850 metric tons, consisting of Mars transfer vehicles and propellants, to Space Station Freedom.

an aggressive manned planetary exploration program. Now is the time to start developing the Shuttle-derived, unmanned heavy lift vehicles, as well as new generations of rocket technology. These vehicles will get men and material to low-Earth orbit. Then the unique lunar transfer, lunar excursion, and Mars transport systems must be developed and tested.

As the NASA report states, "During the Apollo era, Wernher von Braun led a task force to develop long-range goals for the space program after Apollo: more lunar missions, a space transportation system, a space station, and human journeys to Mars." In 1986, Tom Paine, who had been NASA administrator in 1969 when the Apollo 11 crew landed on the Moon, released the report of the National Commission on Space, reiterating these long-range goals.

With the Space Shuttle and Space Station Freedom, two elements of the infrastructure to colonize the Moon and the planets will be in place. Now is the time to push forward without delay and return to the mission of space exploration.