What future for space exploration?

Marsha Freeman reports on a meeting of the American Astronautical Society, which discussed the steps to be taken "Beyond the Space Station."

Sometime in February, the White House will host a bipartisan summit with the leadership of Congress to discuss the future of the U.S. space program. The way the budget now stands, funding for the civilian space program, managed by the National Aeronautics and Space Administration (NASA), will decline by about 25% over the next five years. Neither a majority of Republicans nor Democrats considers this a viable future for the space program, and it is hoped that a more reasonable funding level will be agreed upon at the summit.

Although, as many observers of the space effort are saying, the best that can be expected from the summit is a flat budget that simply holds the line on cuts—enabling NASA to fly the Space Shuttle, begin construction of the International Space Station, and continue a modest space science program—it is the understanding of everyone involved in space exploration, that without long-term planning and visionary goals, the space program has no real future.

The focus of the 43rd annual meeting of the American Astronautical Society (AAS), held in Houston, Texas on Dec. 9-11, 1996, was a discussion among NASA scientists and engineers, government managers, industry representatives, and university professors involved in the space program, on what the next steps should be. The conference was entitled: "Space Exploration and Development: Beyond the Space Station."

Many of the conference participants have worked in the space program for more than 30 years, including sporadic work, since the early 1960s, on long-term plans for space exploration. They have seen one and yet another study recommend returning to the Moon and then going on to Mars, but a political commitment to these goals has not been forthcoming. So, an important debate that occurred at the AAS conference concerned what goals these space professionals should promote, and how to try to enlist public support to accomplish them.

Getting to Mars on the cheap

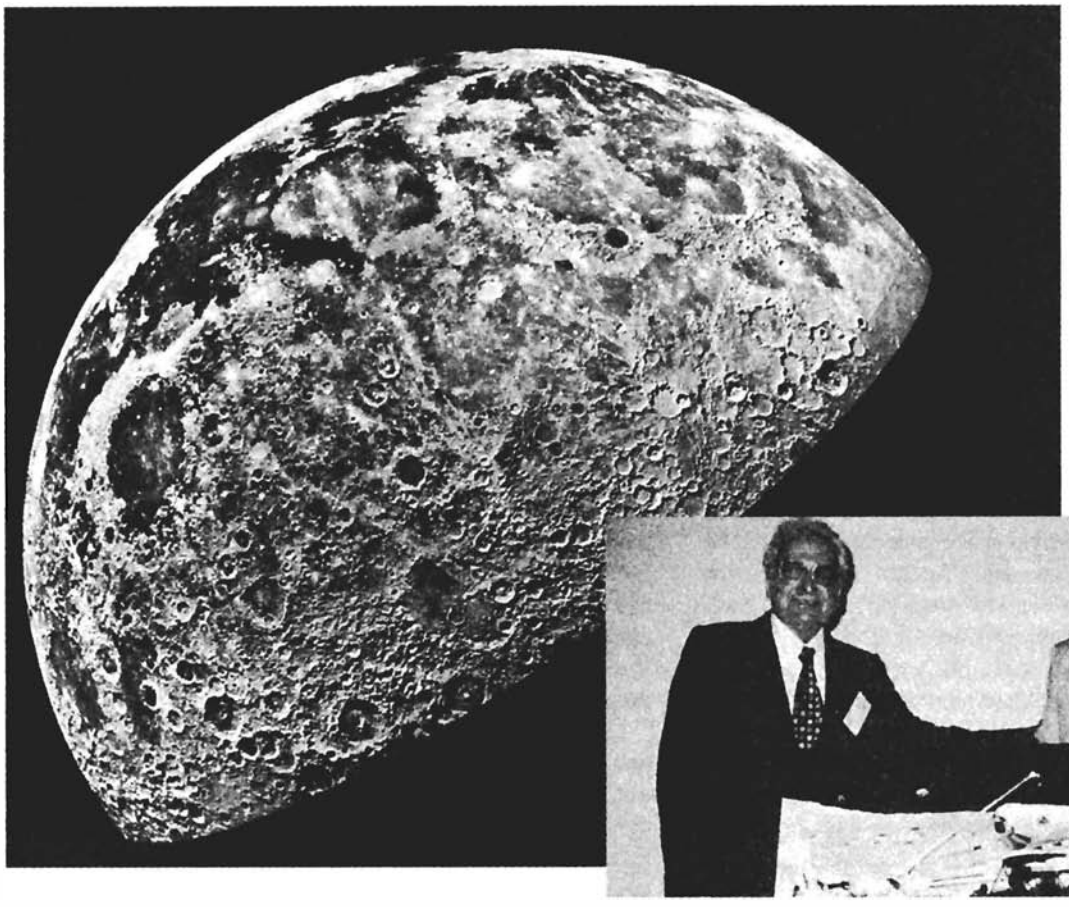
From the beginning of the manned space program, visionary planners have consistently proposed that, after gaining experience working in Earth orbit, the Moon should be the target for exploration and development. Lunar resources could be exploited to build a manufacturing base on the Moon, and to function as a way station, providing fuel, and possibly other supplies, to space travellers heading farther away from Earth. Also, it has been assumed that any mistakes in technology design, development, or testing, should be made under circumstances in which the crew can be brought back to Earth in a couple of days, not where they are millions of miles and months away from Earth, such as on Mars.

Over the past few years, however, a new school of thought has gained popularity, which proposes that man go directly to Mars without first learning to live in space or developing the Moon. This view has been most energetically promoted by Dr. Robert Zubrin, a former engineer for Martin Marietta, who spoke at the AAS conference on his "Mars Direct" plan. In this scheme, virtually no new technologies, such as nuclear or fusion propulsion, would be developed. Astronauts would go to Mars using 1960s chemical rockets; they would have to spend more than a year traveling there and back, and up to 500 days on the surface of the planet. They would not carry their return fuel with them, but would be dependent on an automated fuel production factory that would have arrived on Mars earlier. Zubrin admits that this is a very high-risk mission profile.

Even so, this plan, which has been relentlessly promoted by the media, has gained some support among space planners, because they have been demoralized by the fact that the United States has had no serious long-range exploration plan for nearly three decades. "Mars Direct" is put forward as a quick, cheap, "exciting" way to revitalize interest in the space program. That some have fallen for this siren song was evident in a few of the presentations at the meeting.

For example, Elric McHenry, who has been at NASA's Johnson Space Center in Houston since 1963, said that "after the space station, we must be ready to make a 'go/no go' decision to send people to Mars." The Mars plan should be completable in eight years—that is, within the timeframe of a President's two terms, he said.

Zubrin, in his presentation, insisted that because the interest of the President or Congress cannot be sustained for long, "you cannot get to Mars in 30 years, or 20 years. It has to be



A view of the northern regions of the Moon taken by the Galileo spacecraft's imaging system on Dec. 7, 1992. Inset: Dr. Michael Duke (right), who spoke at the AAS meeting, presenting a painting of lunar exploration to the late Krafft Ehricke (left), at an October 1984 NASA meeting on a manned return to the Moon. Ehricke drafted a comprehensive program for industrializing the Moon.

in 10 years or less. . . . We've got to get there quick."

Although NASA Administrator Dan Goldin has promoted the goal of manned missions to Mars, particularly in response to the excitement after the Aug. 7, 1996 announcement that there is evidence that life may have developed there, the space agency, so far, has held to its plan for a rational progression of exploration, proposing that lunar development should be a precursor to sending people to Mars.

Back to the Moon with robots and people

The plan of the space agency was presented to the AAS conference by Michael Mott, deputy associate administrator of NASA in Washington, who stressed that after the completion of the international space station in 2002, "We're going back to the Moon and on to Mars."

We need a long-range commitment to space exploration, he said, to increase our knowledge of the universe, learn and discover, and "excite kids to study." Mott said that the United States should have "preeminence in technological innovation and space leadership"—which was a breath of fresh air, after years of blather from Washington that the United States can't expect to be "preeminent" in science and technology.

Rejecting the "Mars Direct" proposal, Mott said that on the Moon, we will learn the lessons we need to go to Mars. We will use the Moon as a "technological test bed, tap lunar and solar energy resources, and use it as a way station for exploration." We are not going to go "rushing off for Mars," he said.

During the question period, when asked his opinion whether the next step should be to develop the Moon or to go directly to Mars, Mott said that going to Mars without going to the Moon first would be "totally illogical." The United States has "72 hours of total experience living on another body," from the Apollo Moon flights, he said, and that is not enough of a basis for sending crews to live on Mars for 500 days.

This view was also expressed by European, Japanese, Russian, and other American participants at the AAS conference.

In a paper submitted by Mikhail Marov from the Russian Space Agency, the view was put forward that "both an International Space Station and a lunar base" are needed "as intermediate platforms" before manned missions are sent on to Mars. "This collective effort of the whole [of] mankind should match the long-term strategy of space colonization and the utilization of extraterrestrial resources . . . rather than to be simply an adventurous journey," Marov states. "This is why, quite logically, this expansion should not miss the celestial body closest to the Earth."

Marov described the dreadful state of the Russian space program, which does not, at the present time, include missions to the Moon. "Russia is currently undergoing the experience of three simultaneous, traumatic changes: the breakdown of the Soviet Union, free market reforms, and democratization," he explained. "The resulting massive social, economic, and political turmoil [has] had a substantial impact on the Russian space infrastructure and space program, which currently continues, although [on] a much lower level."

The Japanese program

But, in Japan, two unmanned missions are being developed, which are part of a multi-decade lunar program that will culminate with manned missions to the Moon in the next century.

At the AAS conference, Junichi Haruyama, from the Tsukuba Space Center of the National Space Development Agency of Japan (NASDA), described a mission under development in Japan called Selene, for Selenological and Engineering Explorer. Selene will be an ambitious space science project, requiring the use of a new, high-capacity H-IIA launch vehicle powerful enough to send a two-ton spacecraft to the Moon.

Selene will be launched in 2003, Haruyama said, during a solar maximum phase of increased activity from the Sun. It will be a unique opportunity to study the Earth's plasma environment from outside. Instruments on Selene will take magnetospheric and plasma measurements of the cislunar space (between the Earth and the Moon), imaging the Earth in wavelengths from the extreme ultraviolet (UV) to visible radiation, to contribute to clarifying the global dynamics of the terrestrial magnetosphere. Selene will obtain scientific data concerning the origin and evolution of the Moon. (Even though men have brought back pieces of the Moon, it is still not known where the Moon came from.) A most important goal of the Selene project is to develop and test technology for future lunar exploration. The scientific data will also be used for exploring the possibility of future utilization of resources on the Moon.

More than 200 Japanese scientists and engineers are involved in the mission, Haruyama reported. Selene will consist of a lunar polar orbiter at a 100-kilometer altitude, a lander designed to survive for 20 days, and a small relay satellite. The instruments include an X-ray spectrometer, gamma-ray spectrometer, camera, radar sounder, laser altimeter, magnetometer, dust analyzer (plasma detector), plasma imager, and charged particle spectrometer. The relay satellite will help determine the gravity field and the remnant magnetic field of the Moon.

Already completed, and nearing its summer 1997 launch date, is Japan's Lunar-A spacecraft. It is aimed at studying the internal structure of the Moon. Lunar-A weighs 1,200 pounds and will be launched on a smaller M-5 rocket. The Lunar-A orbiter will fire three surface penetrators into both the near and far side of the Moon, to obtain seismic and thermal data. These will be the first surface investigations of the Moon since Apollo 17.

Each penetrator has an individual solid rocket de-orbit motor and attitude control system, so that it can be precisely aimed. The penetrators will impact the surface at speeds of 825 to 990 feet per second, and should be able to penetrate several feet below the surface. Each penetrator carries a seismometer, heat flow sensors, two batteries, a data-processing unit, transmitter-receiver, and UHF antenna. This network of penetrators will provide a precise plotting for moonquakes and heat flow characteristics, which could help determine if the Moon has a molten core.

The Moon is special

The European Space Agency (ESA) also has lunar exploration on its agenda. Geraldine Naja, from ESA headquarters in Paris, told the AAS conference attendees that "the Moon is a very special place and object. It is close, everyone can identify it in the night sky. It takes three days to get there; it is special in European activities."

She described the Moon is a "natural space station," and observed that an important advantage of manned missions is that the crews are exposed to zero gravity and radiation hazards for manageable periods of time. A return home in case of problems, such as hardware or health, is only a question of days.

European interest in lunar missions started in 1994, Naja stated, and they have planned out a four-phase strategy. Phase I focuses on unmanned explorers and surface operations, to inventory lunar surface features and resources by remote sensing and orbiters; this could start in the year 2000. Phase II includes a permanent robotic presence, and makes use of the Moon for scientific operations. In Phase III, the Moon will be exploited for resources such as oxygen, and robots would deploy scientific instruments. Phase IV would involve establishing the first human outpost, in about 2020.

ESA is considering development of a mission called Elspex, or European Lunar South Pole Expedition. Naja described it as a "no frills" program, which should be within the range of what the European nations can afford. Elspex would include a lander and an orbiter, and could be ready for launch in the year 2000, if there is a go-ahead next year. The plan is to land on the western rim of the south polar crater in the Aitken basin, in "eternal light." This is the region where scientists interpreting data from the Clementine spacecraft believe they have located ice.

In addition, the United States plans to launch the Lunar Prospector orbiter on Sept. 24. It will carry neutron spectrometers, which will take precise readings that could confirm or contradict the existence of ice at the lunar south pole. The primary task of Lunar Prospector is to obtain precise data on the composition of the lunar regolith and to search for volatiles, such as oxygen. The exploitation of such resources

would allow human prospectors to "live off the land" in the next century.

Preparations for lunar colonization

While these lunar missions from the United States and Japan are being readied for launch, industrial concerns in Japan are developing hardware and conducting preliminary experiments, in order to be ready for lunar colonization. Tetsuji Yoshida, from the Shimizu Corp. in Tokyo, outlined the work his company is doing in space development.

Shimizu is an architectural and engineering company established in 1804, which started looking into space technology in 1984. It aims to utilize construction technology developed for use on Earth in space, and to develop new techniques for space construction that can also be used on Earth. In the last 10 years, the firm has developed a concept for a lunar base using concrete modules produced from lunar materials. The modules are hexagonal shaped, which allow multi-directional extension of the base. They are self-assembling structures using membranes and air-inflation systems. Shimizu has carried out several joint studies on lunar base reference designs with McDonnell Douglas.

Shimizu is also developing technologies for lunar resource utilization. Yoshida explained that his company is looking at lunar oxygen production, and that it has a small experiment using a simulated lunar oxygen plant. Since 1991, Shimizu and Carbotek in the United States have been conducting joint studies on lunar oxygen production, focussing on hydrogen reduction of ilmenite as one of the most realistic processes. More than 30 grams of lunar soil samples (from Apollo 17) have been supplied by NASA for their studies. Tests have been performed using NASA's KC-135 variable gravity aircraft to study the behavior of solid particles under lunar gravity conditions.

Shimizu is also looking at construction materials that can be produced from material on the lunar surface, such as ceramics, glass, metals, and cast materials. Because NASA has only a limited amount of lunar soil to provide to researchers for experimentation, simulants of lunar soil are used. Near Mt. Fuji in Japan, scientists at Shimizu found a good lunar soil simulant of basaltic rock. They are melting the samples to examine their characteristics for use as construction materials.

Yoshida explained that Shimizu has also been thinking about the construction of hotels and other large-scale structures on the Moon. Japanese scientists and industry are planning for manned lunar operations in the next century.

The prerequisite technology for Mars

While the debate is continuing in the space community over whether returning to the Moon should be put off until after an eye-catching mission to Mars, the space agency is embarked on an outreach effort to develop the new and even revolutionary technologies that should be prerequisite to sending people to Mars.

John Mankins, program manager in the Advanced Concepts Division at NASA headquarters in Washington, told conference participants that "enabling a first human expedition to Mars that is affordable will require both revolutionary new technologies and innovative new systems concepts." Low-cost orbital transportation sytems for lunar and Mars missions, and affordable transportation between low Earth orbit and lunar and Mars orbits, are the priorities.

For trips to Mars, where the distance to Earth is measured in the tens of millions of miles, we need "exceptionally reliable, almost fully autonomous in-space operations," Mankins said.

What is required includes advanced propulsion for lunar and Mars vehicles. Options for development include nuclear thermal rocket propulsion, based on the 1960s NERVA technology; magnetohydrodynamics, or MHD; and fusion. The use of tethers in space, to provide artificial gravity, should be further investigated, Mankins said.

Advanced life support systems, including greenhouses, will be needed to recycle the liquid and gaseous human wastes. Highly robust surface mobility systems must be developed, and *in situ* resource utilization will increase the economy of the missions. Space exploration will require high levels of electrical power, Mankins stated—which is also true on Earth. "As the new century approaches, population growth is driving the demand for new energy and various concepts and technologies," he said.

Gary Lyles, from the Marshall Space Flight Center in Huntsville, Alabama, told conference participants that NASA is also looking 25 years into future, at more "revolutionary" technology options. "The leverage in reducing cost is in technology," Lyles said, in juxtaposition to the "Mars Direct" idea that reducing cost is achieved by increasing the risk to the astronauts.

Proposals for examining the possibility of using magnetic levitation, MHD, pulse detonation engines, and fusion energy are being considered, Lyles reported. "Fusion propulsion is nearer term than a power generation system, and it is possible that it's nearer than we think it is," he remarked. Some experimental data from astronomy, astrophysics, and other fields are yielding information not consistent with currently accepted theory, Lyles said. He mentioned that NASA is supporting work on gravity modification at the University of Alabama, in Huntsville.

Steven Broday, Executive for Strategic Planning, Education, and Outreach in NASA's Office of Space Science, outlined the advantages of an early return to the Moon: First, to build confidence in the area of autonomous operations in space. Second, to establish the "international strategic interdependence for human exploration" with potential international partners who are already interested in the Moon

(i.e., Japan and Europe). Third, to engage the private sector in reducing the cost. And fourth, to engage the public in the missions of space exploration. "Lunar activities would sustain interest and is nearer term," Broday said. He suggested that there could be a "lunar globe program," with young people in different countries having charge of a robot on the lunar surface, which allows them to map a part of the Moon.

"We need a sustained, incremental program, not a big push to Mars," Broday said.

The synergy between the Moon and Mars

The final session of the AAS conference explored the synergy between lunar and Mars missions, to see how each could enhance the other. Mike Duke, for years a scientist at the Johnson Space Center and now with the Lunar and Planetary Institute in Houston, stated, "For the past 10 years, the challenge has been to link the exploration of the Moon and Mars, and this has not been successful, largely because the lunar missions were done as cheaply as possible, without the development of much new technology.

"You can go to the Moon with existing vehicles," Duke explained, "but this is not true for Mars, which needs new propulsion" systems. He suggested that we should build on common technology, in life support, surface operations, power, resource utilization, and heavy lift vehicles, and create complementary infrastructure which will be needed to develop both the Moon and Mars.

There are certainly "synergisms in the approach to fundamental science problems, such as the origin of life, origin of the planets, and evolution of the atmosphere," Duke said. "We can link the science and exploration goals, such as the discovery of ice on the Moon. . . . Perhaps it is possible to make propellant for the Mars trip from the ice on the Moon," or for lunar trips from Martian resources.

NASA is now doing a Moon-Mars study to emphasize the shared development of technologies, Duke reported, and international organizations are doing similar studies.

George Morganthaler, who has been involved with space exploration since the 1960s, reported on the work that the International Academy of Astronautics has been involved in. In 1990, IAA published its Lunar Cosmic Study, "The Case for an International Lunar Base." Then, in October 1991, at the 41st World Space Congress in Montreal, a subcommittee on the International Exploration of Mars was established. It is now completing its report, "International Exploration of Mars." The study involved 87 members of the IAA from 13 countries.

The experts participating in these studies believe that there is no question that a lunar base will greatly help to develop extraterrestrial technologies and operational procedures required to live and work on Mars. They have also found that there is a great deal of commonality with respect to the space transportation systems required to logistically support lunar bases and Mars missions. Finally, according to the executive summary which was released in 1996, they conclude that "the financial burden of lunar-based development and crewed Mars programs cannot peak at the same time, so that one has to come first and the other must come later, and be adjusted in such a way that a nearly constant financial burden results."

According to Morganthaler, the IAA is forming a new committee on lunar-Mars exploration to produce a cosmic study with three scenarios: going to the Moon, and then Mars; missions to Mars, and then the Moon; and, doing both with synergy. The IAA is trying to examine the synergistic benefits, and possible negatives, that would result from collaboration between these two major astronautical efforts of the 21st century.

There is a natural order to the placement of the bodies of the Solar System, and there is a natural progression according to which they should be inhabited. An attempt to perform a spectacular and dangerous high-wire act to catch the public's attention, is not a viable substitute for a difficult, challenging, well-planned, and long-term movement of human civilization into space.

What it will take to get a national commitment to such an effort, was addressed during a luncheon at the AAS meeting by Rep. Sheila Jackson-Lee (D-Tex.), whose district does not include the Johnson Space Center, but the city of Houston. She called on the space community to educate the new 105th Congress. Research and the space program are "the work of the 21st century," she said. As a member of the House Science Committee, she worked to ensure that, in the 104th Congress, NASA's budget was not cut as much as some members wanted, she reported.

Forty-three members of the incoming 105th Congress are freshmen Democrats, the congresswoman said, and they will have to be reeducated. The space program has a major responsibility for creating highly skilled jobs for the nation, she said, quoting from the 1958 act that created NASA: "Congress declares that the general welfare of the U.S. requires that NASA seek and encourage, to the maximum extent possible, the fullest commercial use of space." We have to work, along with the President, to create the jobs of the 21st century, she said.

In her appeal to the scientists, engineers, and industry representatives at the meeting, Jackson-Lee said that "space and its related technologies" can be "the ignition for the economic engine that takes us into the next century." If policymakers in the space community heed Jackson-Lee's advice on the educational effort needed in Washington, the excitement of the recent scientific discoveries, including the possibility of past life on Mars and water on the Moon, will inform the decisions that the White House and Congress will be making at the upcoming space summit.