EIR Science & Technology

The steps to human habitation on Mars

The National Commission on Space has made quite clear that the goal of space exploration is to make the Solar System "the home of humanity"—and that starts with Mars. Marsha Freeman reports.

On July 20, 1976, a representative of human intelligence, the Viking 1 lander, placed its four feet on Mars. Exactly seven years earlier, two astronauts had placed their feet on the Moon, becoming the first members of the human species to land on another body in the Solar System.

From July 21-23 of this year, in celebration of the 10th anniversary of the Viking landing, NASA held a conference on Mars at the National Academy of Sciences in Washington, D.C. It brought together the top scientists in the field for a three day meeting which heard a startling report of our knowledge about the planet most like the Earth.

This included exciting new scientific discoveries, which resulted from the reanalysis of the old Viking data, using 1980s computer imaging and other technology not available when Viking stopped transmitting data in 1982.

The reevaluated data revealed that it is too early to "close the book" on whether or not there is life on Mars. New photographs, prepared with more advanced techniques than the scientists had when they were receiving the data in real time, showed a planet with a dynamic history. Viking found evidence of catastrophic releases of flowing water, the largest volcano in the Solar System, canyons that dwarf anything on Earth, and the tantalizing possibility that Earth may not be the only planet that supports life.

Outlines for unmanned missions to Mars, required as a prerequisite for taking people to Mars, were presented at the conference, and the question of how and when a manned mission could take place was debated. The National Commission on Space, which presented its report, *Pioneering the Space Frontier,* to President Reagan on July 22 (during the conference), has proposed that mankind return to the Moon about the year 2005, and land on Mars a decade later.

With the Commission's recommendations as a rough guideline, a series of missions—U.S., Soviet, and international—were discussed, that could answer the scientific questions, and the technological challenges, involved in taking man to Mars.

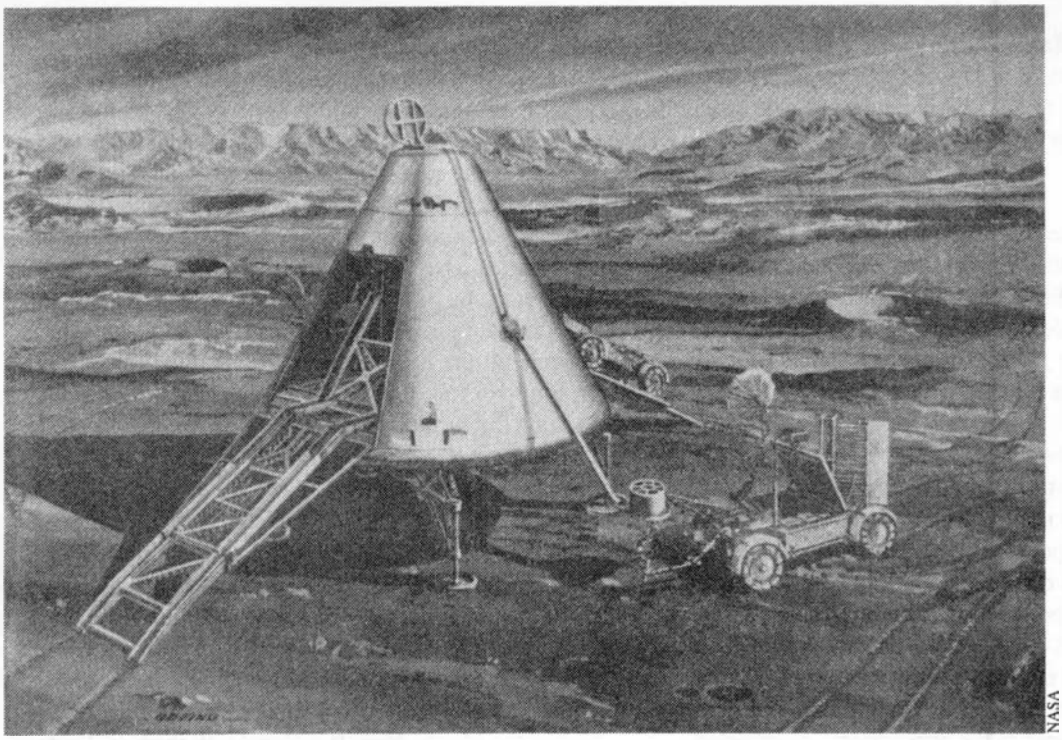
The challenge is enormous. Unlike the Moon, which at a quarter of a million miles distance from Earth, can be visited virtually over a weekend, covering the minimally 35-million-miles to Mars requires new propulsion technologies and energy-efficient trajectories to get there and back, and completely new ways to care for human explorers.

Why Mars?

What we will learn about Mars, even before we can get there ourselves, will contribute to our knowledge of the Earth and our Solar System.

The Mars we see today is not the Mars that existed in the past. How the water on Mars "disappeared," how the atmosphere may have evolved, whether or not there was life at some previous time, how the Martian weather and climate systems work, all have a bearing on what we know about our own planet.

In 1988, the Soviets will lead an international mission to do extensive exploration of the tiny Martian moon, Phobos. Two years later, the United States will launch the Mars Observer mission, to orbit the planet and comprehensively map its atmosphere, climate, and materials. The next two decades should start with these already initiated missions, and cul-



The Mars sample return mission, which will be necessary before a manned mission can take place, is the most sophisticated unmanned spacecraft ever proposed. A rover/lander will collect samples on the surface, and deliver them to the waiting spacecraft, which will take the samples to an orbiting ship, going back to the Earth.

minate with the first humans on Mars by 2015.

The long-range explorations of the Voyager missions to the outer planets, following decades of unmanned reconnaissance of the inner planets of Mercury and Venus, have made it clear that the only planet beside the Earth which could possibly support life is Mars. Unlike our dead Moon, Mars has water, an atmosphere, weather and climate, a rich geologic history, and therefore, a process of evolutionary development and change. It is also possible that Mars had, or has, primitive life forms. The search for life by the two Viking landers is inconclusive, but the potential to bring life to Mars from Earth absolutely exists.

Just after the turn of the millenium, the manned return to the Moon will lay the basis for the Mars journey by developing fuel and materials industries on the lunar surface. In addition, the long-duration agriculture, life support, robotic manufacturing, and other technologies needed for Mars, will be developed in the lunar laboratory test bed.

The Martian atmosphere is almost entirely made up of carbon dioxide, which would clearly not sustain higher forms of life, but could be the raw material to sustain plant life. Water had been located and identified at the Martian north pole as early as the Mariner-9 mission of 1971, but new data analysis has revealed that there is more water than originally thought. According to Dr. John Lewis of the University of Arizona, there is likely also water beneath the soil surface, in the crust. New estimates indicate that if the trapped and frozen water on Mars were melted and covered the entire planet, it would be 10 meters deep.

That there was once abundant, flowing water on Mars is undeniable, reported Dr. Victor Baker from the University of Arizona, who spoke at the conference. Huge channels, once imaginatively thought to be canals dug by intelligent beings, could have only been formed by a flowing liquid with the approximate viscosity of water.

Valles Marineris is an immense network of valleys that dwarfs the Great Rift Valley of Africa, which extends from Capetown to the Middle East. It is over 3,000 miles long, and on Earth, would stretch from New York to California. *Valles Marineris* is near the Martian equator, and the steep sides are deeper than the Grand Canyon.

Dr. Baker has calculated the amount of energy that it would take to carve out channels of this magnitude, and has concluded that there had to have been a catastrophic release of water and energy; these rifts could not have been formed by rainfall. The energy required, he stated, is greater than that in any other natural event, including storms, glaciers, and avalanches on Earth.

Dr. Larry Soderblom, who is a member of the Voyager imaging team, described the overall geology of Mars, which is quite distinct. The southern hemisphere of the planet is covered with many meteorite impact craters, and is an ancient, relatively undisturbed surface.

Most of the volcanoes of Mars are in the northern hemisphere, and the fact that there are very few impact craters near the volcanoes indicates these are younger formations, which covered the ancient craters over with lava.

The enormous Olympus Mons volcano, twice the height of Mt. Everest (16.7 miles high) and the largest volcano in the Solar System, must have dominated the entire planet during its active time in Martian history. The great mountain is 435 miles across, and on Earth would cover the entire state of Montana. We have yet to discover how recently the Martian volcanoes were active.

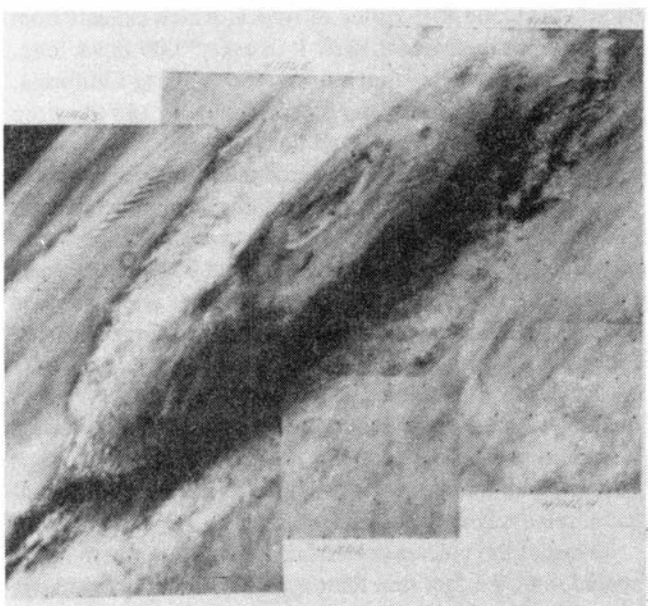
A changing planet

Mars is about the same size as the land area of the Earth. Its tilted axis produces Earth-like seasons, over a year that is nearly twice the 365-day Earth year. Though the temperature range of Mars is quite cold, never getting above 0° Fahrenheit, even at the equator in the summer, it could support lichens, or other primitive life forms that live at the Earth's poles.

The atmosphere is very thin, and does not shield the planet's surface from life-threatening ultraviolet solar radiation, but it remains to be seen whether primitive life forms could have somehow adapted to this condition.

Dr. Michael McElroy reported at the July 21-23 meeting that there have probably been changes in the Martian atmosphere over time. The fact that Mars has an atmosphere at all means that there has been interaction with the particles in the solar wind, and there continues to be evaporation and condensation of the water vapor in the atmosphere, as revealed in the Viking photos of frost forming on rocks.

The atmosphere and weather of Mars has also shaped the surface of the planet, reported Conway Leavy, from the University of Washington. The amount of sunlight received by the planet, which is between 35-70 million miles farther away from the Sun than the Earth at different points in its elliptical orbit, is only 44% that at the surface of the Earth. That lower absorption, and the three-eighths Earth gravity, contribute to the huge dust storms on Mars, which are generated during the summer in the southern hemisphere.



Olympus Mons, seen here with its multi-ringed caldera, or volcanic crater, only visible through a Martian dust storm, is the largest volcano in the Solar System. Note the ripples of clouds in the upper left, reminiscent of cloud formations on Earth.

Because the Viking landers, which were designed to last 90 days, lasted more than six years, they were able to observe the dust storms over nearly four Martian years. The storms can apparently be either local or global, and do not occur every Martian year. Though there is dust in the Martian atmosphere all the time, these intense storms shrouded the planet for weeks at a time, preventing the Viking orbiters from seeing the surface.

The storms can start very suddenly, with very high winds. Like Earth's weather, on Mars there are cyclones, traveling from west to east, and the water vapor produces condensation "bars" in the valleys.

This very active planet has seasonal polar caps, like Earth, which in the north consists of carbon dioxide from the atmosphere, forming a surface plating; residual water ice, which is there through the seasonal changes; and a series of fossil caps, made up of water ice and dust, which form layers.

Unlike the Moon, Mars is a planet rich in many kinds of volatiles, like water, which could be tapped from the atmosphere, the soil, and the polar caps to support human habitation. The promise of Mars is that mankind will not have to bring all of his oxygen, water, and other chemical building blocks with him, but will be able to "live off the land."

Considering the distance man will have to travel to get to Mars, this is not an inconsequential consideration. The more you have to take with you when you leave the Earth, just to sustain you during the trip, the exploration on Mars, and the trip home, the less payload weight of scientific experiments, instrumentation, and equipment you can carry along.

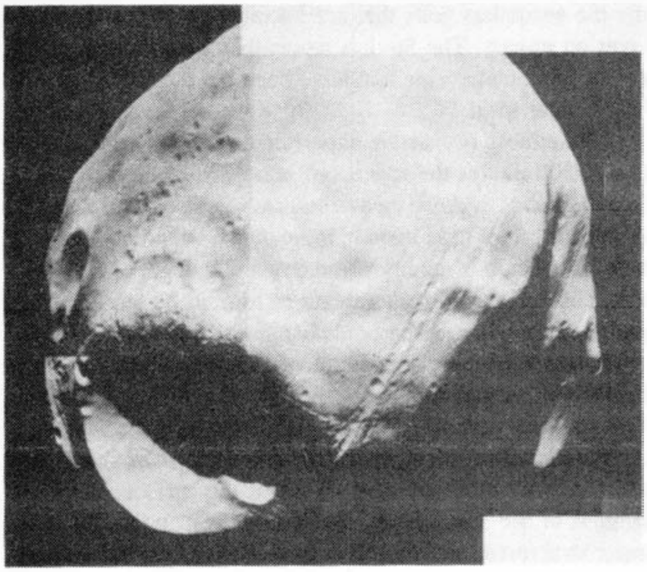
But the most intriguing question that Viking left unanswered was:

Is there already life on Mars?

The first missions the United States sent to Mars were the Mariner mission fly-bys, in 1964 and 1969. But the level of instrumentation and communication capability of these early missions showed Mars as a disappointingly Moon-like planet. Many scientists concluded that Mars was dead.

Mariner-9 radically changed that picture of Mars in its 12-month orbit around the planet during 1971, by revealing channels and other features that indicated there had at least been flowing water, at one time. When the first Viking spacecraft left Cape Canaveral for Mars on Aug. 20, 1975, its primary mission objective was to try to determine if there is life on Mars.

Three of Viking's scientific instruments were capable, within limits, of detecting life on Mars. The lander cameras could have photographed any living creatures large enough to be seen with the human eye, and could have detected



The tiny Martian moon Phobos is one of the most curiously shaped bodies in the Solar System. The huge crater Stickney, pictured here, is about one third the diameter of the entire moon, and the meteorite impact that produced it cracked the entire body.

growth changes in organisms, such as lichens.

In a 1984 publication, titled, *Viking: The Exploration of Mars,* NASA states, "The cameras found nothing that could be interpreted as living."

The second instrument, was the gas chromatograph/mass spectrometer (GCMS), which could have found organic molecules in the soil. The 1984 NASA publication states, "To the surprise of almost every Viking scientist, the GCMS, which easily finds organic matter in the most barren Earth soil, found no trace of any in the Martian samples."

The Viking biology instrument called the Labeled Release experiment, was the primary life-detection instrument. It was a one-cubic-foot box, "crammed with the most sophisticated scientific hardware ever built," consisting of three tiny instruments that searched the Martian soil for evidence of metabolic processes like those used by bacteria, green plants, and animals on Earth.

All of the experiments showed activity in the Martian soil which "mimicked" life, NASA reported. In 1984, however, NASA simply stated, "According to most scientists who worked on the data, it is clear that the chemical reactions were not caused by living things."

It was hypothesized at that time that the immediate release of oxygen, which was the positive result measured when the Martian soil contacted water vapor in the biology experiment, meant not that this chemical reaction was produced by life, but by oxidants, such as peroxides and superoxides, which break down organic matter and living tissue and would quickly destroy any life on Mars, were any there.

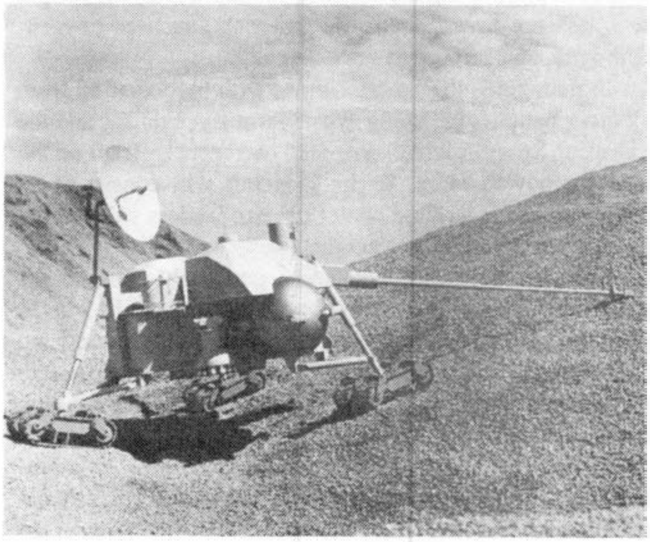
But even though no new scientific data has been transmitted from Viking since November 1982, over the past year, scientists planning for the 1990 Mars Observer mission have been able to use more sophisticated processing technology to reevaluate the tantalizing Viking data.

At the recent Mars conference, Dr. Gilbert Levin, president of Biospherics, Inc. presented a somewhat startling paper which stated, "Life on Mars is more probable than not." Dr. Levin, who designed the Labeled Release experiment, and his co-experimenter, Dr. Patricia Straat, stated in their paper that after 10 years, they had done "a detailed review and analysis of all theories and laboratory data generated by scientists around the world seeking to explain away the provocative results of the Labeled Released experiment on Mars."

The researchers contend that none of "these nonbiological explanations is consistent with their experimental results." For example, a bonded soil sample from Antarctica tested in each of the two types of biology experiments aboard Viking, showed no signs of life in the organic GCMS-type experiment, but did show signs of life with the Labeled Release experimental apparatus. "Laboratory analysis confirmed that the soil did indeed contain organic matter," Levin and Straat reported.

The hydrogen peroxide scientists thought to be in the Mars soil, to account for the Labeled Release results, was not actually there, which was discovered when 1971 Mariner-9 data was closely examined by William Maguire, of NASA's Goddard Space Flight Center.

Levin and Straat described how lichens could be a life form that would account for their experimental data, because even though the two Viking orbiters were not near the poles,



This scale model of a mobile Mars lander was built and tested by Martin Marietta Aerospace for NASA. The mobile laboratory travels on three loop tracks, and would be able to sample Martian soil, and repeat experiments at various locations on the planet.

where water definitely exists, they explained, these primitive life forms can live by extracting water from atmospheric vapor, which exists on Mars.

As a tour de force, Levin ended his presentation by showing two very provocative photos of the same rock on Mars taken by a Viking lander, at different times. These close-up pictures show a greenish patch on the rock, which changes over the time the two photographs were taken. Spectral analyses of the rock were similar to those obtained when the scientists viewed lichen-bearing rocks through a duplicate Viking lander camera, on Earth.

Dr. Levin concluded, "We have waited 10 years for all the theories and results from the many scientists investigating our experiment before voicing any conclusion. After examining these efforts in great detail, and after years of laboratory work on our part to duplicate our Mars data by nonbiological means, we find that the weight of scientific analysis makes it more probable than not that living organisms were detected on Mars."

It is clear that this argument may not finally be resolved, until we go there and look for ourselves. So, the question is, when, and how, can we get to Mars?

The Soviets to Phobos

There is a great deal we still have to learn about Mars and its neighbors before going there. We have the time over the next 20 years to send our robotic scientific instruments to do this reconnaissance, because we have not yet developed all of the technology we will need to send people.

Two of the most intriguing bodies in the Mars system are its tiny moons, Phobos and Deimos. These small bodies could hold an important key in actually settling people on Mars, because it has been hypothesized that these irregularly shaped bodies, which are only a few miles in diameter, might be a treasure trove of volatile materials, such as oxygen, hydrogen, and carbon.

In mid-1988, the Soviet Union, with participation from 12 other nations, including West Germany, France, and the European Space Agency, will send two spacecraft off on the long journey to Mars. Each spacecraft will consist of an orbiter and a lander, and one of the two landers will be able to "hop" from one spot to another.

The first spacecraft will come perilously close to the surface of Phobos, and "hover" above it for about 15 or 20 minutes, at a height of about 50 meters. The Soviets are considering sending the second Phobos mission spacecraft to perform similar experiments on the even smaller Martian moon, Deimos.

At the time of this close encounter, two of the 22 instruments aboard the spacecraft above Phobos will perform active experiments to examine the chemical composition of the small body. The first is a small laser which will be pointed at the surface and will analyze the evaporated and ionized soil that is freely scattered by the laser-beam impact.

The second instrument is an ion beam, which will measure the chemical composition of the surface soil by analyzing the secondary ions that are knocked out of the surface layer on impact. The Soviets report they hope to be able to determine the elements that have been implanted in the soil by the solar wind.

While these two active experiments are going on during the 15-20 minutes the spacecraft is hovering above the surface of Phobos, passive measurements will also be made from the spacecraft. These include radio signal soundings, which will study Phobos' composition down to a depth of 200 meters, and infrared measurements to look at its temperature profile and diurnal or seasonal changes.

In this very short time-frame of close encounter, a small lander will be dropped from the interplanetary spacecraft. This small laboratory, which is planned to be operational for one year, will contain instruments on board to study the chemical and mineral composition of the surface, the heat content of the small body, the seismology and large-scale inner structures, and the perturbations in its orbital motion around Mars.

The small lander which will be dropped off by the second spacecraft will be the hopper (see **Figure 1**). This small device contains a set of rods that control its position, and give it a little push, which enables it to hop up to 20 meters at a time. The instruments on board will be used to measure the magnetic fields, local gravitational anomalies on the small body (either Phobos or Deimos), and perform a chemical analysis at each site, to look for oxygen, magnesium, aluminum, silicon, cadmium, iron, and other elemental materials.

This hopper is a very challenging venture that will require extremely accurate control from Earth. The moons of Mars are so small, it is not hard to imagine the hopper hopping right off the edge. In addition, the gravitational force on each moon is one-thousandth Earth's gravity, and the escape velocity is so small, that if you threw a rock with normal strength, it would leave the moon never to return. Therefore, one would not want the hopper to hop with too much force.

The entire mission to explore Phobos requires extremely precise timing and maneuvering. When Viking 1 left the Earth, scientists hoped to have it land on Mars for the nation's bicentennial, on July 4, 1976. But when the orbiter showed the scientists where they had planned to set the lander, which had been picked from the photographs that were available from earlier, less capable missions, the scientists decided to look for another spot. The landing was delayed for over two weeks, until July 20.

The Soviets have not designed this mission to have a variety of opportunities to do the close-up experiments and landing at Phobos. Unfortunately, their past history of missions to Mars has been marred by 14 failures or partial failures out of 15 launches, or attempted launches.

The Soviets have not attempted a Mars mission since 1973, and some speculate that they knew at that time that they could not compete with the dramatic U.S. Viking lander

The Viking orbiter showed us the first high-resolution pictures of the Martian north pole. Visible are layers of ice, and defrosted soil material. The north pole contains both water and carbon dioxide ice, and has a layered terrain from eons of development.

mission, which was close to launch.

Undoubtedly to give the Phobos mission a higher probability of success, the Soviets have engaged many European countries to design and build the experiments, and help with the mission. For example, Bulgarian and West German scientists are developing a special laser mass spectrometer, the East Germans will supply optical systems, and there is a joint Soviet-French device for studying the chemical composition of the Martian atmosphere. Components for the complicated remote laser soil analyzer system, which is called LIMA-D, are being built by scientists from Austria, Bulgaria, East Germany, Czechoslovakia, and the Max Planck Institute for Nuclear Physics in West Germany, in addition to the Soviet Union.

The Phobos mission will be leaving for Mars in mid-1988. Two years later, according to the current schedule, the American Mars Observer mission should be taking off.

Mars Observer: the 'Landsat' of Mars

What the Viking orbiters showed us is that Mars has been geologically active in its past, including the formation of huge features such as canyons. The major objective of the Mars Observer is to do a thorough survey to try to answer the questions, when and how did the water carve out the canyons, where did this vast amount of water go, and where is it now?

This mission will be a two-year study—the equivalent of an entire Martian year—in which the spacecraft will be in the first near-polar orbit around Mars. The poles are crucial, as they contain a large concentration of water and other volatile materials.

The Mars Observer will orbit only 224 miles above the planet's surface, compared to the Viking's elliptical orbit in the thousands of miles, and in its near-polar orbit, will complete a global survey of the surface and atmosphere every 56 days.

The relatively small spacecraft will house three instruments that will map the surface of Mars. These will measure the gamma-ray, infrared, and thermal emissions from the surface, and will provide scientists information about the water, carbon dioxide, volcanic lava flows, rock types, and surface weathering effects that have shaped Mars' evolution.

The atmospheric chemistry, pressure, temperature, water content, and dust will be observed through measuring the infrared radiation. The spacecraft's radio communications system will map atmospheric pressure and structure by noting how the atmosphere effects the transmission of radio waves at different times, under different conditions.

The shape and interior of the planet, which we already know is not perfectly spherical, will be mapped by a radar altimeter, which will measure the height of slopes of ancient river channels, the exact depth of the great canyons, the shapes of the huge volcanoes, and the strength of the Martian crust. The more exact measure of all of these features is required to locate potential landing and exploration sites, for both people and robotic machines.

NASA is still determining whether or not a small camera for imaging will be included on the mission, but the overall concept is to overlay this atmospheric, geologic, and mineralogic data with the Viking images and produce a globe of Mars which is similar to the remote sensing data obtained by Landsat above the Earth.

Returning samples to Earth

When the planned U.S. and Soviet Mars missions have produced detailed maps of the surface, interior, atmosphere, and weather of Mars and its moons, the final step before sending people will be on-the-ground unmanned exploratory missions, where samples of Martian soil and rock, are brought back to laboratories on Earth, for the kind of detailed study that cannot be done by a small spacecraft on the surface of the planet.

The Soviets have indicated that after their Phobos mission, will come another Mars mission called Vesta, but no details have been released about its objectives. On the U.S. side, at the Mars conference, former Jet Propulsion Laboratory (JPL) Mars-mission designer James R. French described various options for a rover-sample return mission. The object of the adventure would be to return five kilograms of material to Earth.

The lowest-risk approach would consist of sending a spacecraft into orbit around Mars, which would make the final judgment on a suitable landing site. This scenario, which was used by Viking, allowed a safe site to be chosen at the last minute. The lander would include a rover, not that different in design from the lunar rovers that preceded the Apollo manned landings.

The difference, however, is that the at least 20 minute communication time between Earth and Mars (or nearly an hour, round-trip) means that the robot must have a much higher "intelligence," and be able to make decisions quickly, on its own. It cannot wait for commands from Earth in life-threatening situations. French has recommended that two rovers be sent together, to help fix each other if necessary, and to take pictures of each other!

In 1984, a Mars rover demonstration vehicle was built and tested at JPL, but French reported that the guidance was difficult, and that it would have to be highly intelligent to navigate autonomously. It is, therefore, likely that the rover will fulfill its mission with human intervention from Earth.

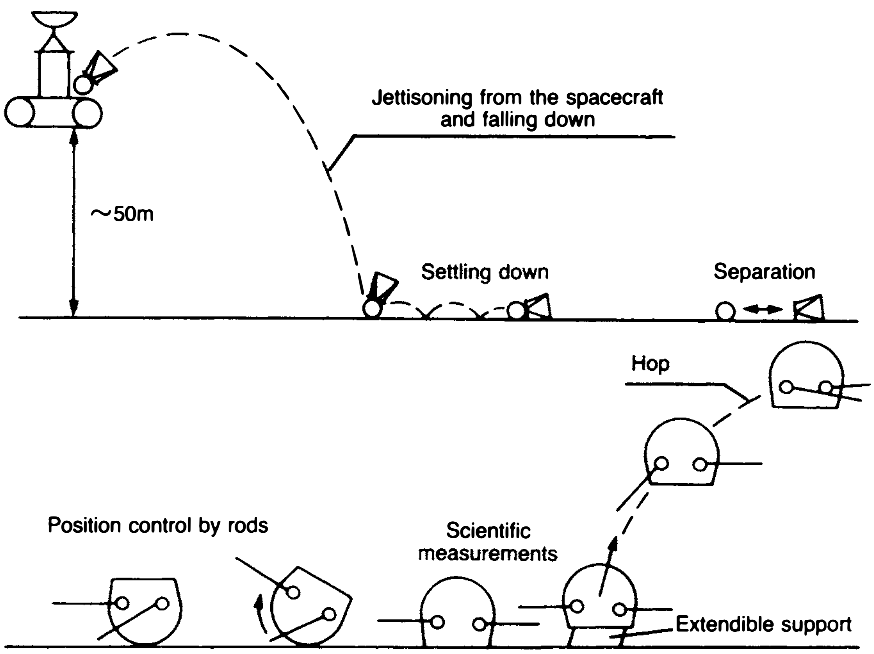
The rover would send back stereo images to the operator on Earth, who would select the path for the vehicle, after he determined that there were no obstacles, deep holes, or other potential dangers. French's estimate is that this kind of system could cover a few hundred kilometers in a year.

French presented to the conference detailed designs for mission scenarios, including the options for minimizing the amount of fuel that has to be taken to Mars for the mission, which allows more weight for payload. Unlike any of the previous, or currently planned missions, the sample return must have enough propulsive power to return to Earth orbit.

One concept is to take advantage of the fact that Mars has an atmosphere, and use the aerodynamic drag against the approaching spacecraft to slow it down. Repeated, and very precise passes through the planet's atmosphere (either Earth or Mars) can be used for aerocapture, to put the vehicle in orbit around the planet.

If this method were used, French estimated that about 80% of the vehicle weight can be payload in Mars orbit. If

FIGURE 1
Soviet hopping lander (hopper) for Phobos or Diemos mission



One of the landers planned for the 1988 Soviet Phobos mission is a hopper, seen here. It will be jettisoned from an orbiting spacecraft, settle down, and then hop from spot to spot to study the soil composition of the tiny moon. It will be able to hop about 20 meters at a time.

propulsion were used to slow the spacecraft down to achieve the same end, less than half of the weight would be payload.

This concept can also be applied to getting the lander from the orbiting spacecraft to the surface of Mars. If the lander has the ability to use aeromaneuver, like a glider, it can pick its landing site, rather than being limited to the area just beneath the orbiting craft. This requires that the lander have a high lift-to-drag ratio, and the JPL studies have suggested the shape of a bent conic, where the conical top is straight on one side.

The Mars rover-sample return mission will bring pieces of many parts of Mars right to our laboratories. Douglas Blanchard of the NASA Johnson Space Center explained that many tests, such as the precise isotopic dating of geologic samples, can only be done in sophisticated terrestrial laboratories.

The rover would have a be done in sophisticated terrestrial laboratories.

The rover would have a coring device to obtain subsurface, or fresh rock. Drills that go through permafrost will have to be developed without the use of contaminating fluids. Volatiles in the soil must be captured and preserved in their pristine state. Like the Apollo effort, one would also quarantine the samples, to prevent both back-contamination to the samples, and any possible contamination to the researchers.

The return of pieces of Mars to scientists on the Earth, would be of major importance in laying the basis for the quintessential Mars mission—the first one that brings human explorers.

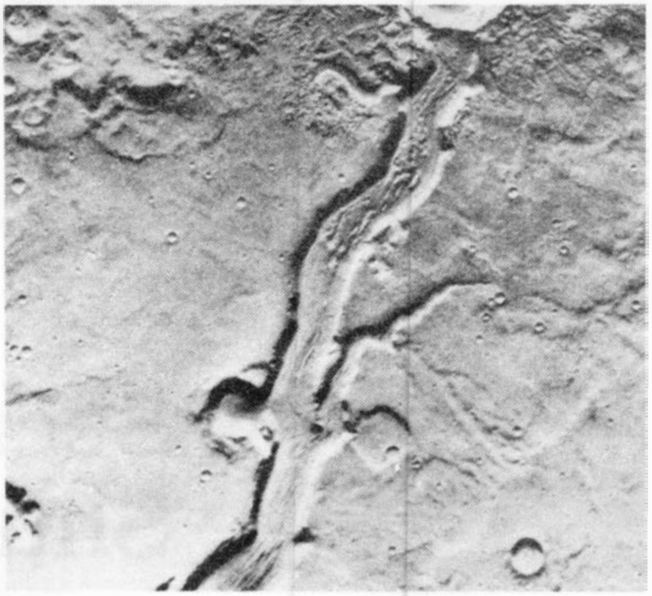
Why send people?

Over the next 20 years, while we are sending our robotic spacecraft to Mars to give us a more complete map of the planet's origin, history, evolution, weather systems, and current stock of raw materials, we will have the time to develop the next-generation technologies that will make it easier to send people.

The one, somewhat puzzling short-coming in the presentations at the Mars conference, was the reliance of the scientists on the propulsion technologies available today for the manned mission to Mars. According to the National Commission on Space timetable, that venture will take place around the year 2015.

Years before that, the Strategic Defense Initiative program will have deployed systems requiring multi-megawatt nuclear reactors in space, and other frontier technologies, which will surely be available for applications in the civilian space effort.

The question of what propulsion technologies are available for the manned Mars mission is a pivotal one. As discussed at the conference by Dr. Nicogossian, the head of the life science programs at NASA, the experience of the Soviet long-duration space-station flights has shown marked and long-lasting deleterious physical effects on the cosmonauts.



Scientists believe that the huge channels on Mars were carved into the soil from catastrophic releases of flowing water. This small channel is about 1.5 miles across and shows the relative age of this channeling, by the craters which have been created since.

There are only two methods for providing a simulated Earth gravity on the voyage to Mars. One is to rotate the spacecraft, using the resulting centrifugal force as an artificial gravity. Dr. Nicogossian pointed out, however, that you have very limited movement without becoming disoriented, when "up" is actually the outer section of a spinning spacecraft.

The other alternative is to use a propulsion system that does not drift on a ballistic trajectory, but is constantly accelerating. This rate of acceleration produces a simulated gravity, with a most important bonus of also traveling faster and getting the crew to Mars in considerably less time than the six months today's chemical propulsion systems could get them there.

Though the Mars scientists are trying to make the point that it is not necessary to wait yet another 30 years, or to develop exotic new technologies to take man to Mars, it is short-sighted not to start planning missions that will make use of the technologies that will be available at that time, even if it is not just NASA that pays for their development. These new technologies may well make the mission actually possible.

Within the next five years, three more spacecraft will make their way to Mars; the two to Phobos and the Mars Observer mission. The National Commission on Space has made quite clear that the goal of space exploration should be to make the Solar System "the home of humanity." After the industrial development of our Moon, which will prove to be an *in situ* test bed for space-living technologies, the goal is the only other planet in the Earth's neighborhood which can potentially support life—Mars.