Why man must explore Mars

For the first time in 20 years, there are spacecraft sitting on the surface of Mars, but, as Marsha Freeman reports, this is just the beginning.

The fact that millions of people around the world have been watching the Mars Pathfinder mission, which began on July 4, with great interest and excitement, should not be a big surprise to close observers of the human spirit.

Throughout the last 20 years, while the media and Hollywood have worked tirelessly to replace enthusiasm for space exploration with stories about aliens, being stranded in space, or the prevalence of UFOs, 10 million people a year have been visiting the National Air and Space Museum in Washington, learning about man's conquest of the skies and of space. Inaugurating the museum on the nation's bicentennial in 1976, President Gerald Ford declared the museum, "America's birthday present to itself."

Nineteen-seventy-six was a banner year for space exploration. Two Viking landers became the first spacecraft on the surface of Mars, while two Viking orbiters sent back thousands of images that revealed a planet with features so dramatic, they make the Grand Canyon and the Rocky Mountains pale by comparison. The images from Mars were a welcome relief from Watergate, Vietnam, and other warfare against the American psyche.

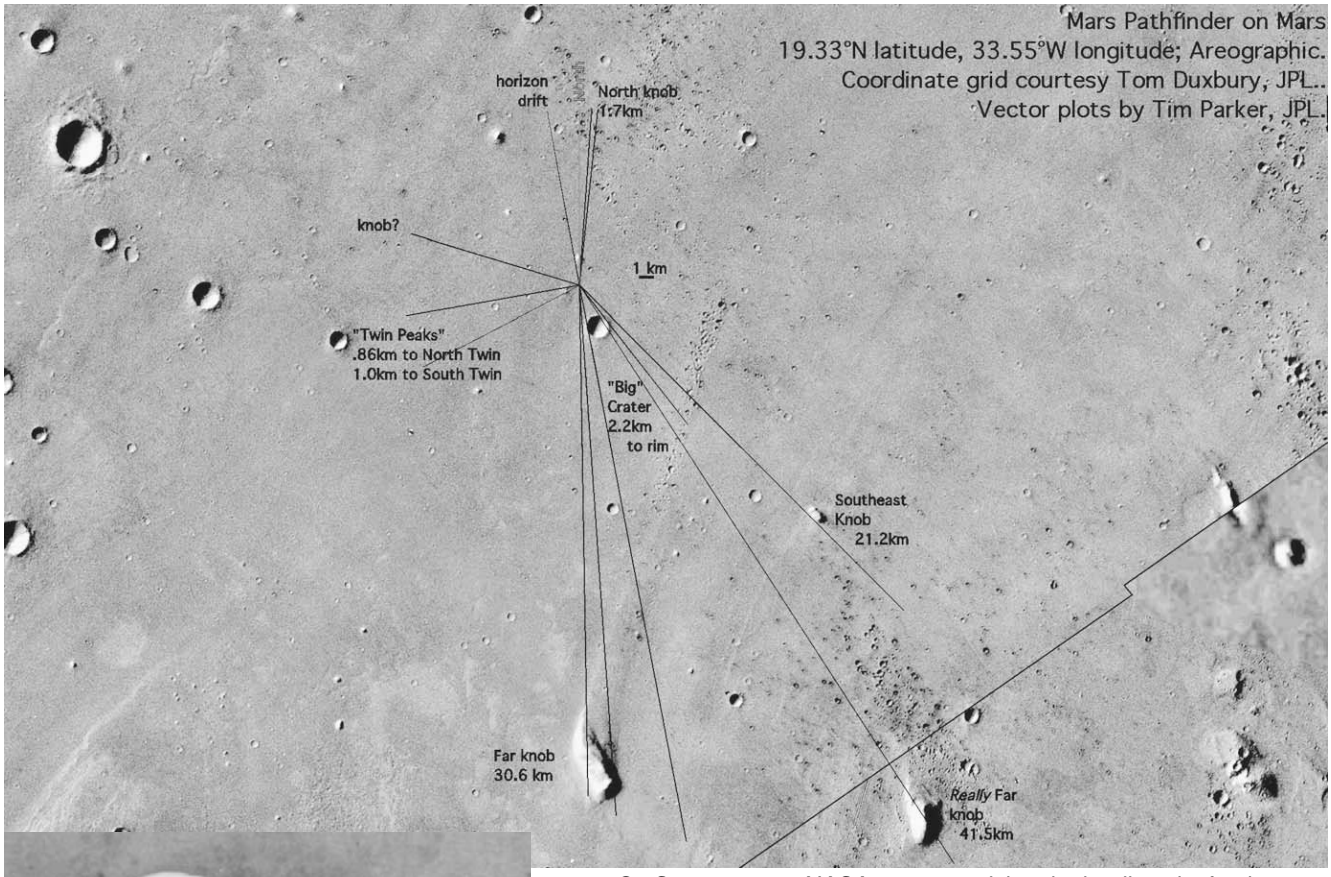
Five years later, Americans were thrilled with the return of their countrymen to space, with the first launch of the Space Shuttle Columbia, on April 12, 1981. The second Voyager spacecraft, which had already produced stunning close-up pictures of the distant planets Jupiter and Saturn and their families of moons, wound its way around the Solar System, to briefly visit, and unveil some of the secrets of Uranus and then Neptune, in 1986 and 1989.

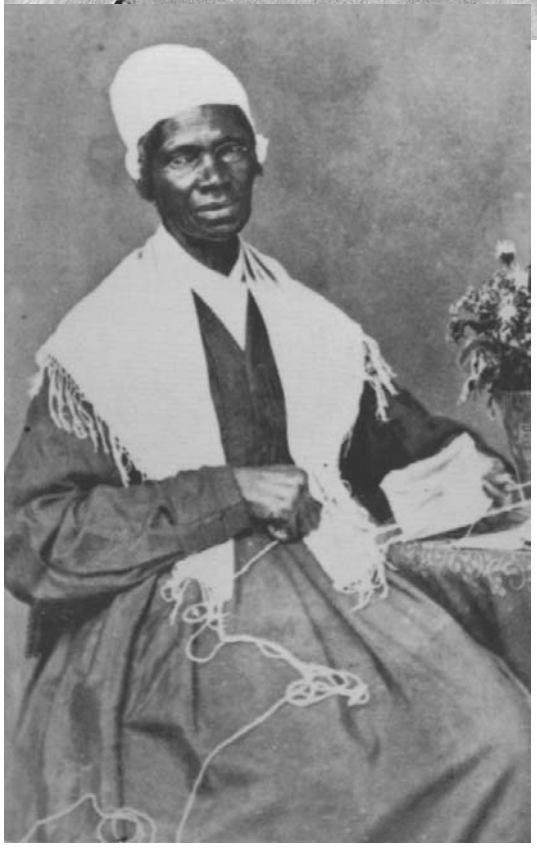
When Voyager had finished its mission, with its encounter of Neptune, Dr. Leonard Fisk, then Associate Administrator for Space Science and Applications for NASA, stated at a press conference on Aug. 26, 1989 that it was the end of an era in space exploration, because "it is the last time we will see a planet for the first time." But over the coming years, he said, NASA will send spacecraft to four planets, not to fly by, but to go into orbit for extended studies.

NASA sent the Magellan spacecraft to Venus, to see through its dense atmosphere for the first time, by using a radar mapper. The Mars Observer arrived at Mars in August 1993, but failed, as it was about to go into orbit. Since December 1995, the Galileo spacecraft has been in a series of highly elliptical orbits around Jupiter, sending back startling and puzzling images of its moons, which showed not only active volcanoes on Io, but the possibility that there is a liquid ocean under the surface of Europa. In October 1997, the Cassini spacecraft will be sent off to perform detailed studies of beautiful Saturn.

How much we will learn from these myriad space missions will be determined by the quality of hypotheses and creative thinking on the part of the scientists on whom we depend to interpret the bits and bytes of data that come back from space. But the excitement, the interest, and the attention paid to these events by people in all walks of life, cannot be killed by budget cuts, cultural warfare, or stupid newspaper editorials; it can be dulled and dumbed down, but it cannot be killed.

The human spirit is much more resilient than the Tavistock Institute's mind benders, or Prince Philip's World





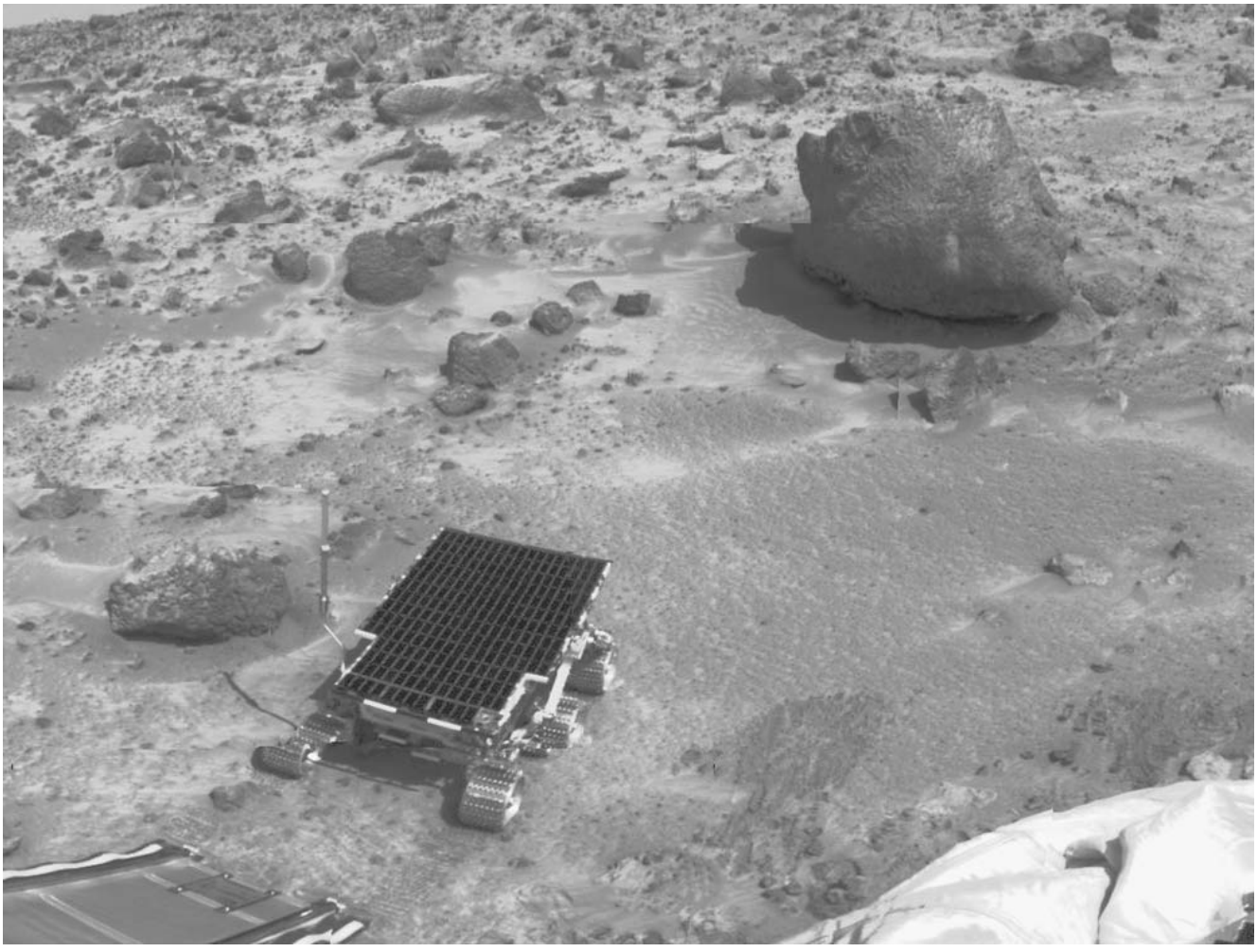
On Sept. 8, 1994, NASA announced that the landing site for the Pathfinder spacecraft, chosen after a workshop involving more than 60 scientists from the United States and Europe, was an ancient flood plain in an area of Mars known as Ares Valles. The site was chosen as one that would provide a "grab bag" of rock types, which had been washed down from the highlands onto the plain by a catastrophic flood.

After Pathfinder was safely on Mars, experts at JPL produced an aerograph that pinpoints the landing site, seen here, as a result of mapping the features in the landscape photos taken on the ground by the Pathfinder lander, onto the orbital images taken 20 years ago by Viking. Pathfinder is sitting about 500 miles southeast of the Viking 1 lander.

The accuracy required to land Pathfinder in the Ares Valles region of Mars, is equivalent to playing golf where the hole is in Houston, and the tee off is in Pasadena. During its seven-month journey from the Earth to Mars, four minor course corrections were made by the navigation team to ensure a direct hit.

Left: In January 1995, NASA and the Planetary Society invited students up to the age of 18, to participate in a contest to name the rover that would be exploring Mars on the Pathfinder mission. The name had to be that of a heroine, and an essay had to be submitted about her historical accomplishments. NASA received 3,500 entries, from half a dozen countries.

Valeria Ambroise, age 12, submitted the winning essay about Sojourner Truth, who, born a slave, became a champion of abolishing slavery and for women's rights. Born Isabella Van Wagener, Sojourner Truth made it her mission to "travel up and down the land" at the time of the Civil War, advocating the rights of all people and equality for women. Sojourner is a most appropriate name for the microrover, because it means "traveller."



Keeping in mind that Sojourner stands one foot tall, it provides a measuring stick for the rocks in this photograph, taken by the lander soon after Sojourner had rolled down the ramp to the surface of Mars. In the corner of the left foreground is the ramp, and in the right corner foreground is some of the deflated air bag material.

To the left of the rover is Barnacle Bill, so named because of the appearance of a rough and bumpy surface. To the upper right of the rover is Yogi, a considerably larger rock, which is estimated to be about three feet high. As project scientist Dr. Matthew Golombek from JPL explained, the objects were given common, up-beat names to help the scientists keep their sense of humor.

Wide Fund for Nature, think.

It is a testament to the determination of the people we entrust to carry out our exploration of space, that they continue to move this work forward, even if they lack enough money, have too few people, and are constrained by time. They rarely consider that commitments of family, earning a good living, or other ephemerals, should take precedence over their primary responsibility of making sure that the spacecraft sent to explore new worlds work as well as any scientist or engineer could expect.

It is that quality of *Entschlossenheit* which also makes the men and women who go into space real heroes, as well as the people who make sure that their journey is as safe and productive as possible.

Since the Apollo program of the late 1960s, in frustration at the daily ills suffered by nearly everyone in society, people have remarked, "If we can put a man on the Moon, why can't we . . ." solve the Earth-bound problems that plague us. The answer, of course, is that we can. If we decide we are going to, we will mobilize the resources, both human and material, that are needed. NASA engineers and space enthusiasts are already designing cities for the Moon and Mars. Why not build them first on Earth, and replace the ghettos, bloom the deserts, and build new cities in Africa, Asia, and other nations that must get ready for the 21st century?

The exuberance of the scientists as they briefed the press hourly on the developments from Pathfinder, was reflected in extensive positive coverage in the media. Here, a briefing during the first day of the mission by, from the left, Richard Cook, mission manager; Rob Manning, flight system chief engineer; Dr. Tim Schofield, meteorologist; and Dr. Matthew Golombek, project scientist.

The Pathfinder lander sitting on Mars, with its diminutive companion, Sojourner, roving about the landing site, reminds Americans, that as difficult as a task might seem, it can be accomplished. There are whole new worlds to explore, about which we know relatively little. There is enough exploring to do in space to keep the next hundred generations of humans busy.

The extraterrestrial imperative

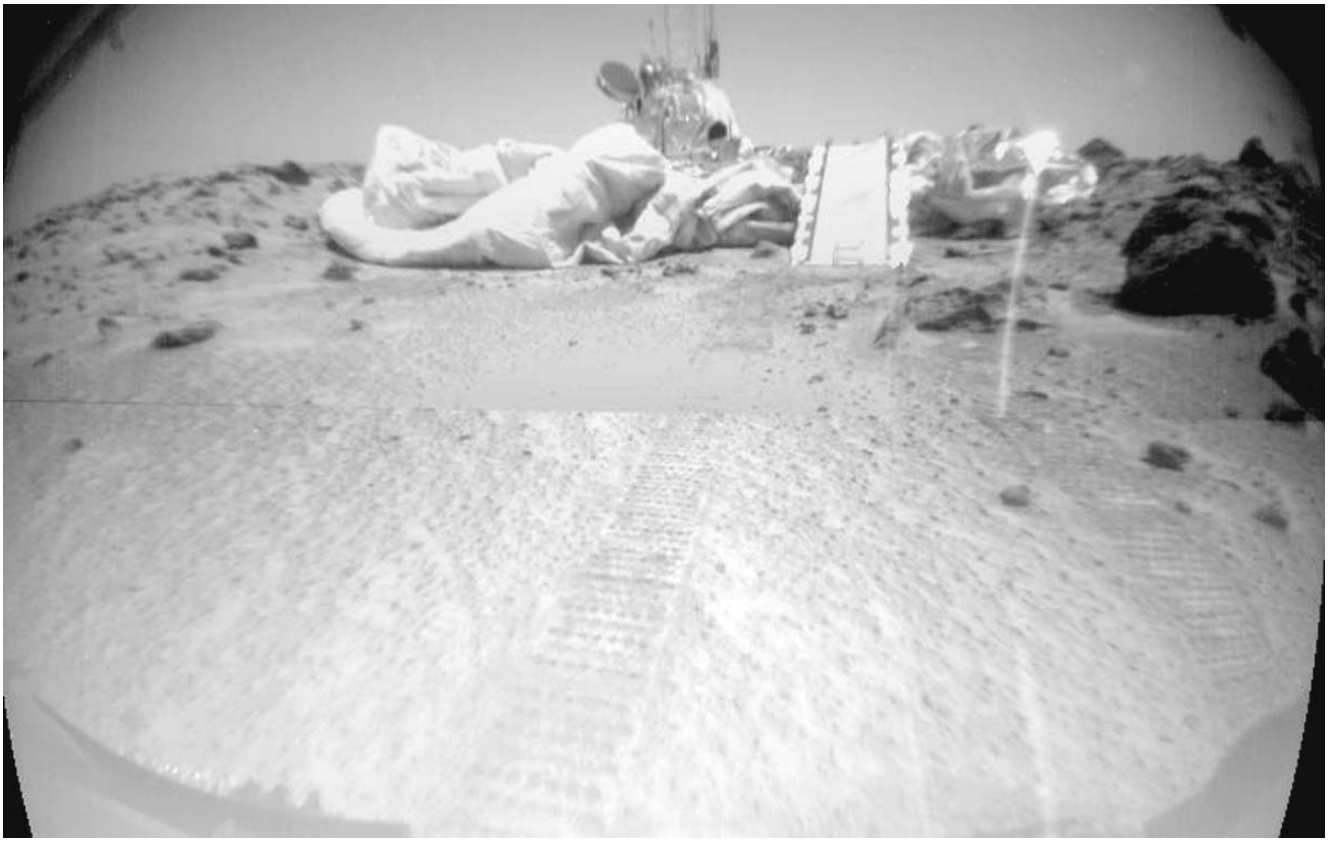
"If God had wanted man to explore space, He would have given him a Moon," space scientist Krafft Ehricke often stated in his writings and public presentations. He coined the term "extraterrestrial imperative," to convey the idea that this is not an arbitrary activity for mankind, but a necessary one.

Before a rapt audience in New York City in November 1981, Ehricke described how the Earth's biosphere has faced two great crises during its evolution. These were overcome, he said, through the development of photosynthesis, the ability of a plant to produce its own "resources," and the subsequent development of multicelled life that could make use of the new oxygen atmosphere that had been created by the plants. In each crisis, he said, "life had only three choices: Give up and perish, regress to a minimal state of existence, or advance and grow."

It was very clear to Ehricke that the human race is now faced with those same three choices. He showed, in graphic form, that the alternative of a no-growth policy would lead to the kinds of catastrophic convulsions we are experiencing today: "geopolitical power politics, wars over natural resources, waves of epidemics, death-oriented population stabilization, extreme poverty," and *real* ecological crises. In 1982, he wrote: "In 1979, of all things in the Year of the Child of the United Nations, there were 12 million children who did not reach their first birthday. That's 50% more than all battle deaths in World War I, in four years. And that is an outrage to a species that calls itself civilized."

By the 1960s, the concept of "growth" was being challenged by a melange of so-called environmentalists and Malthusian zero growthers. Ehricke developed the concept of the extraterrestrial imperative to confront head-on this attack on the unique nature of man.

The central concept Ehricke developed is "the distinction between multiplication and growth." In contrast to the *Limits to Growth* comparison of man's growth to the "mindless and senseless multiplication of lillies in a pond" (or today, Prince Philip's comparison of the growth of population to cancer), Ehricke stated in a 1982 article, "Growth, in contrast to multiplication, is the increase in knowledge, in wisdom, in the capacity to grow in new ways." As far as "limits" go, Ehricke pointed out that the Malthusians, who never consider space exploration



When the rover had left the lander and looked back to take this photograph, engineers could see why one air bag around the lander had to be re-retracted and deflated on command from mission control, after it had already done so once automatically, in order to be able to roll down the ramp for the rover deployment.

On the left side of the lander is an air bag seen after it deflated and retracted on its own, after landing. There is still a fair amount of the material billowing out and covering part of the lander. On the right, is the deployed rear ramp Sojourner used to reach the surface. In order for the ramp deployment to take place, mission control had to command the lander to lift one of its three petals, command the second deflation and then retraction of the air bag, and finish by lowering the petal back down. Despite worried questions from the press, the spacecraft designers had tested the vehicles for such contingencies and were confident the air bag could be righted, which it was.

as a domain of man's activity, see the Earth as a closed system. "I don't," he said. "Humanity's action world is no more closed than it is flat." Man is not the polluter of the Earth, but the "naysayers" are "the polluters of our future."

In a 1973 article about his mentor, Hermann Oberth, Ehricke wrote, "For me, the development of the idea of space travel was always the most logical and most noble consequence of the Renaissance ideal, which again placed man in an organic and active relationship with this surrounding universe and which perceived in the synthesis of knowledge and capabilities its highest ideas. . . . The concepts of 'limit' and 'impossibility' were each relegated to two clearly distinct regions, namely the 'limit' of our present state of knowledge and the 'impossbility' of a process running counter to the well-understood laws of nature."

Looking at the future from the standpoint of the past, Ehricke observed that "it is an extraordinary fact that we find ourselves at one of the very rare nodal points in an evolutionary history, in which the confluence of patient negentropic processes of eons accumulates a tremendous growth thrust potential whose acceptance and discharge will creatively play itself out over another eonic period." This thrust will be toward an Earth-based system, that is no longer closed.

Countering the anti-science description of the view of the Earth as seen by the Apollo astronauts on their way to the Moon, as a "fragile" globe that mankind is destroying, Ehricke wrote, "Earth is not merely a spaceship. It is a member of the Sun's convoy traversing the vast ocean of our Milky Way galaxy. . . . It is fortuitous that we need only to traverse open space to reach our remote terrestrial resources. . . . Our companion worlds

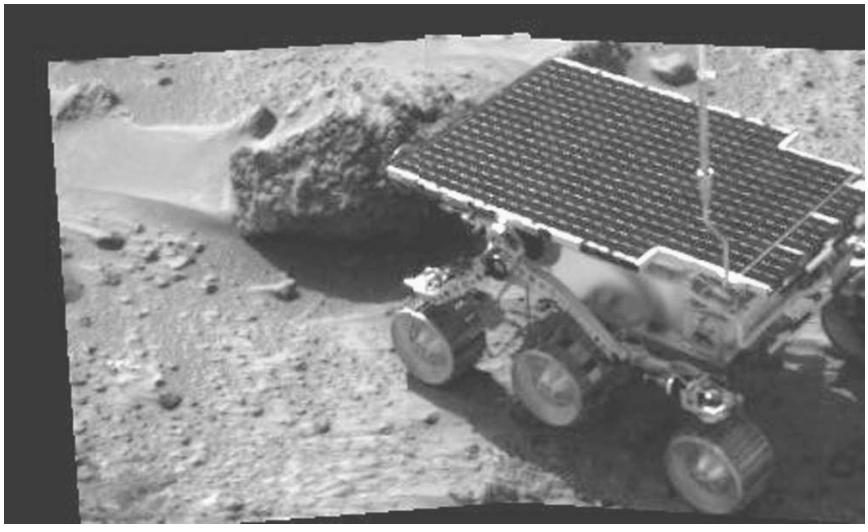
are underdeveloped. Earth is the only luxury passenger liner in a convoy of freighters loaded with resources. These resources are for us to use, after Earth has hatched us to the point where we have the intelligence and the means to gain partial independence from our planet."

Krafft Ehricke spent 20 years proving in exquisite detail, that man indeed does have the "intelligence and the means" to begin the creation of a new civilization on Earth's nearest neighbor, the Moon. From there, the next target is the most Earth-like planet in the Sun's convoy, traversing the ocean of space: Mars.

A true Pathfinder mission

After we have gathered first-hand knowledge about how to live in space on the International Space Station, we will be well-positioned to return to the Moon and set up shop there, for scientific observation, and to learn how to "live off the land," using the resources on the Moon with revolutionary new technology developed on Earth, to establish cities and a new civilization.

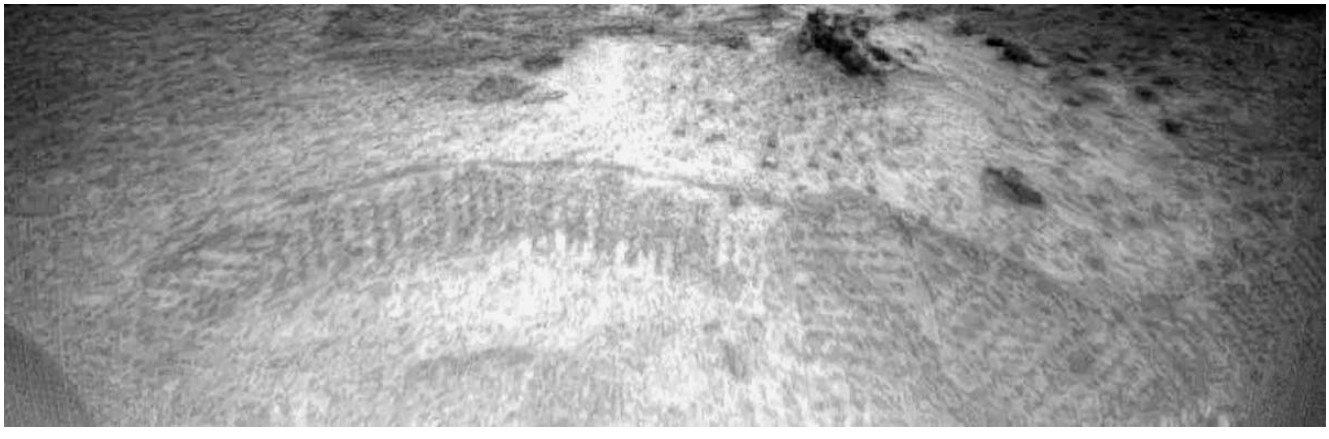
We will have to develop revolu-



This wonderfully clear and detailed photo of Sojourner studying Barnacle Bill was taken with the fully deployed Imager for Mars Pathfinder (IMP) camera on the lander, standing five feet seven inches tall, looking down on the surface of Mars. Data from Sojourner's Alpha Proton X-ray Spectrometer indicated that the major elemental constituents of Barnacle Bill are oxides of iron and silicon, with traces of magnesium, and other metals.

Scientists reviewing the ratios of the elements were surprised to learn that this could mean the presence of quartz in Barnacle Bill, and they are seeking analogous rocks on Earth to try to understand the composition of rocks on Mars. It is possible that this rock is similar to andesite, found in the Andes Mountains and the Pacific Rim, formed in volcanoes. It is also possible that Barnacle Bill is an example of fused breccia, formed from rock fragments exposed to heating by meteorite impacts.

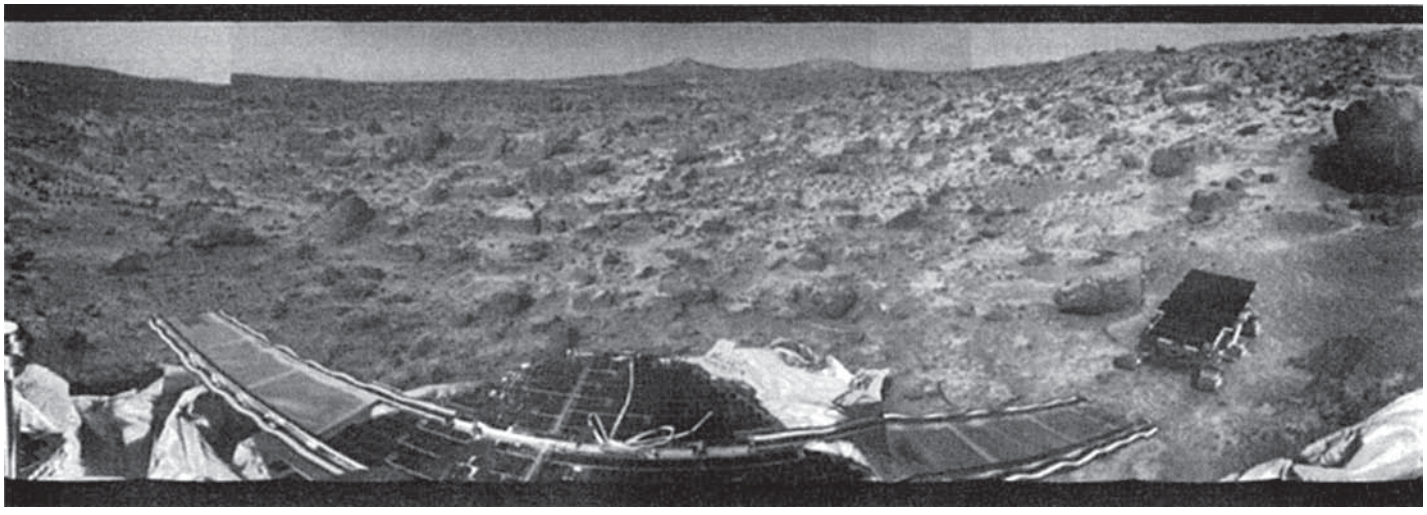
As Sojourner investigates a variety of rock types, scientists plan to use data from the Mars Global Surveyor, which will orbit the planet starting in September, to try to trace where on Mars the rocks in the Ares Vallis flood plain came from.



One of the most important investigations scientists will carry out from the Pathfinder data concerns the soil of Mars. Experts who did similar analyses of the lunar soil before and after astronauts visited the Moon, are trying to gain an understanding of the qualities of the Martian soil from the indirect data of images taken of experiments they can conduct with the rover.

This image shows the tracks created by the rover as it maneuvered toward an interrogation session with Barnacle Bill. Engineers, of course, know exactly how much the vehicle weighs, and they know what the tracks it makes in Earth soil look like. By comparing the tracks seen in images from Mars with those already known and understood, estimates will be made on the density, cohesiveness, and general composition of the Martian soil.

The rover is also taking soil measurements with its Alpha Proton X-ray Spectrometer, and first reports indicate the presence of iron, silicon, and magnesium, similar to the Viking soil, and to the composition of the rocks.



This "monster panorama" was created as a mosiac of photographs from the lander camera, and is a 360° full view around the spacecraft. Note the Twin Peaks feature on the left-hand side of the panorama. They appear to be layered, indicating the repeated action of water.

tionary new technologies, most notably fusion power, required for a trip that is tens of millions of miles from Earth, as opposed to the quarter-million-mile distance to the Moon. When we have finally sent the first fleet of ships carrying men off to Mars, we will be able to look back at the Age of Exploration of the Americas as just the first in a continuing series of ages of discovery.

With that ultimate goal in mind, NASA has designed a series of unmanned missions to Mars in order to answer the basic questions that sending men will require. Pathnder, as its name implies, was sent as a scout of sorts. The mission was conceived as a demonstration of untried technologies which, if successful, can be further developed and employed on follow-on missions. After one week on the surface, the mission can be rated an unquali ed success.

One major innovation of the mission actually went through its test of fire in the minutes *before* the spacecraft hit the surface. A number of years ago, the Russians proposed the use of air bags to cushion the landing of a machine on a planetary surface, instead of the system of firing rockets to slow down a spacecraft enough to enable it to land gently on its feet. Landing on fragile legs was possible in the Viking Mars mission, because a site was specifically chosen free of mountains, craters, and canyons, which would have made a feet-first landing nearly impossible. The same technique was possible for the Apollo lunar landings, because there was a human navigator.

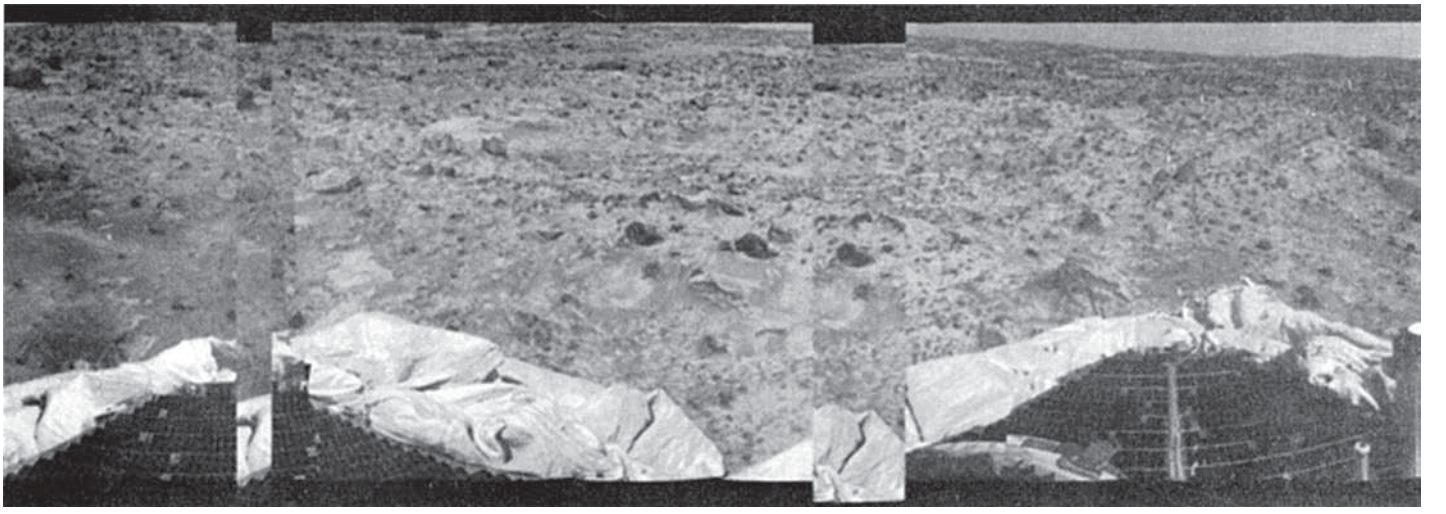
But to robotically traverse the geologically less homogenous and more interesting sites on Mars, the ones that actually will tell us about the ancient history of the planet, landing in a potentially "dangerous" area was required. The scientists aimed for the Ares Vallis region of Mars, which is a flood plain created when a catastrophic release of water, comparable to that in the Great Lakes, rushed over the terrain in a relatively short period of time. This region is of great geological interest, because it is assumed that such a flood would have washed many different kinds of rocks down into the area, including volcanic and sedimentary rocks, along with material thrown free from the subsurface by crater impacts and other activity.

The air bags succeeded wonderfully in protecting the Pathfinder lander with the rover inside, and will now be an option for future missions. An analysis of descent data taken by Pathfinder indicates that on its final bounce it hit the surface of Mars at a speed of 40 miles per hour, and that during its 2.5 minute series of 15 bounces on the surface, before it came to rest, the assembly was subjected to forces that would not be sustainable by a human being. But this technique could certainly be used to deliver cargo to the surface of Mars, in addition to future robotic explorers.

Red rover, red rover

A second critical technology which underwent its engineering demonstration test on the Pathfinder mission, and passed with flying colors, was the microrover, Sojourner. Engineers at the Jet Propulsion Laboratory, the Carnegie Mellon Robotics Institute, Sandia National Laboratory, the Massachusetts Institute of Technology, and other organizations in the United States, Russia, and Japan, have been developing families of Mars roving vehicles for more than a decade.

Prototype rovers have been tested on Earth in lava beds, deserts, crater rims, and any rugged terrain engineers can nd that is an analogue to the conditions that will be found on Mars. Donna Shirely, the manager for Mars programs

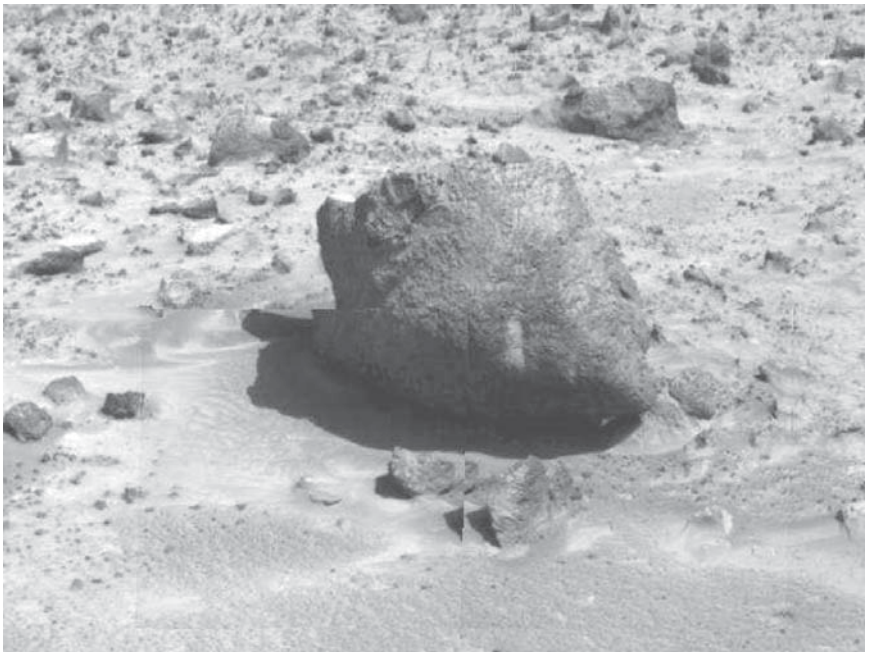


at JPL, explained to a radio audience during the Pathfinder mission, that the development of what became Sojourner started from a larger robot that had been developed, which was then "microminiaturized" to fit within the budgetary, weight, and time constraints of the Pathfinder mission.

Sojourner travels 0.4 inches per second on the Martian surface, and stands one foot tall. It is equipped with three cameras, which include a forward stereo system and rear color imaging system, which are used both to take pictures and, in conjuntion with a laser system, to detect and avoid obstacles. It is powered by a 1.9-square-foot solar array, which is sufficient to power the rover's operations during daylight hours, even in the worst dust storms.

For nighttime operations, and as a back-up, Sojourner is equipped with lithium thionol chloride D-cell-sized batteries, which are enclosed in the thermally protected electronics box, underneath the solar panel. While the batteries are not rechargeable, the rover uses very little power at night, and the batteries are not expected to be a limiting factor on how long the spacecraft is operational. The equipment inside the electronics box is kept warm by three radioisotope heater units, each about the size of a flashlight battery, containing less than one-tenth of an ounce of plutonium-238, which give off about 1 watt of heat each.

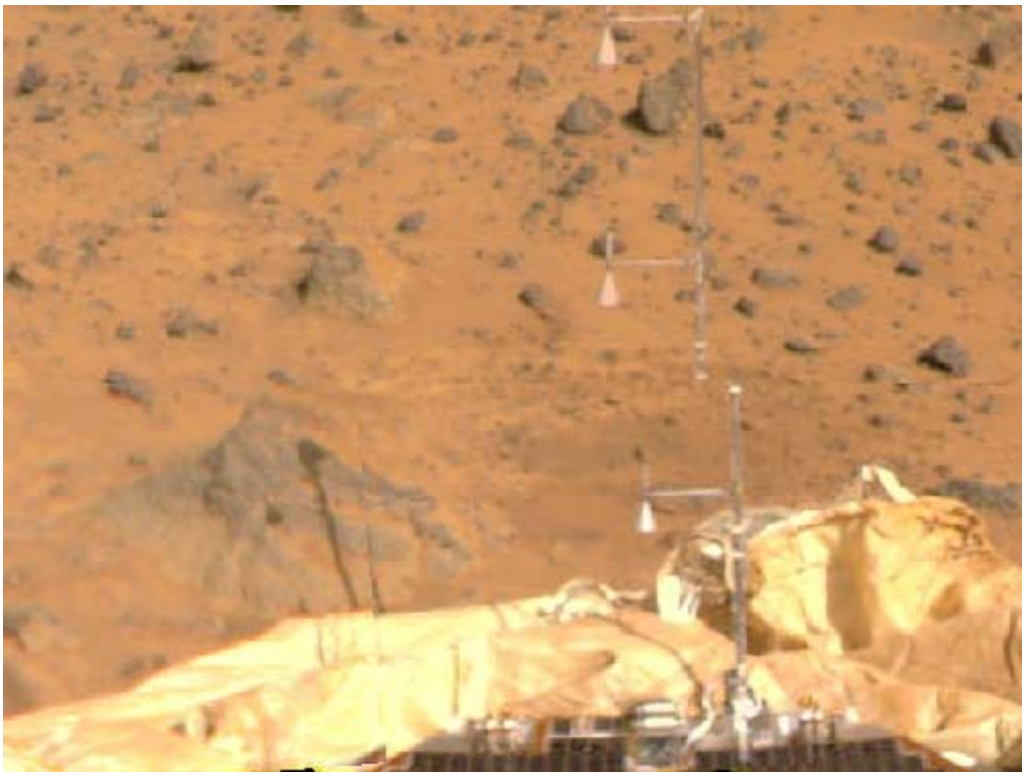
Sojourner's single scientific in-



This rock named Yogi was the second target for investigation by Sojourner, both because it has an unusual dark coloration, and because the smooth soil around it is an object of great interest. All of the photographs from the mission have confirmed the general history of this region as an ancient flood plain that saw the catastrophic release of an enormous amount of water over a very short period of time.

However, in examining photographs of some patches of soil at the Pathfinder site, including around Yogi, scientists believe that crusty looking material in these regions may be deposits of salts, left behind when puddles of water from the great flood evaporated. How long such puddles would have been around on the surface will tell us more about the ancient climate on Mars.

Scientists estimate that this "great flood" took place over a billion years ago on Mars, but not 3-4 billion years ago, which is the age of the Allen Hills meteorite, discussed last August as having the possible remains of single-celled organisms from Mars. If there were primitive life on Mars, there would have to have been liquid water. For there to be water in a liquid form, it would mean that there was an equilibrium between the atmosphere (temperature, air pressure, etc.) and water in the liquid state. No one knows how long this favorable condition might have lasted on Mars. If, however, there is evidence that as recently as 1-2 billion years ago there were the conditions for liquid water to remain on the surface, and not just be released in a catastrophic flood, this would widen the envelope for the possibility of life on Mars.



What's the weather on Mars? In this photo of the Pathfinder lander, the three wind socks on the Atmospheric Structure Instrument/Meteorology Package are visible. Meteorologists report from the Pathfinder data, that the summertime weather on Mars reaches a few degrees above zero Fahrenheit at mid-day, and can plunge down to minus 65°F during the night. Mars is 1.5 times further away from the Sun than Earth, and therefore, receives less sunlight. The winds are light, and there are blasts of cold air that breeze past the meteorology instruments during the night.

By the third Mars weather forecast made by Dr. Tim Schofield of JPL and his team of meteorologists, it was clear that the daily summer weather on Mars does not change very much. Stay tuned. In the next 60-90 days, when the season turns from summer to fall, there is expected to be a change in the weather on Mars, including increasing winds that kick up global dust storms.

Although the winds were very light on Mars the first week in July, scientists reported that there was more dust in the atmosphere than they had expected. Some compared it to a smoggy day in Los Angeles.

strument is an Alpha Proton X-ray Spectrometer (APXS), which is placed in contact with rocks and soil to measure the elemental composition of such material. The data gathered by Sojourner will provide a "ground truth" for orbital remote-sensing observations that will be made by the Mars Global Surveyor, after it arrives at Mars this fall. Before then, geologists are analyzing Sojourner's data to infer the mineral composition of Mars from the elemental data—as long as, as scientists assume, basic principles of chemistry are universal.

There is no question that for follow-on missions, rovers will have to be orders of magnitude more capable, in both the quality and amount of technical data they collect, and in their range. The rover that will be designed for launch to Mars in the 2001 launch opportunity will have a range of up to 50 miles, as compared to the tens of yards Sojourner can stray from the Pathfinder lander. Its job will be to scan a wide area, retrieve rocks of interest, and collect about five pounds of rock and soil samples to be returned to Earth, on a mission to be launched in the year 2005. For the sample return mission, rovers weighing up to 6,000 pounds are being considered, as compared to the 23-pound rover currently exploring Mars.

Like the air bag system on Pathfinder, Sojourner has performed beyond the expectations of its designers.

Considering the fact that Pathfinder was a technology demonstration mission, the science that it returns will be icing on the cake. NASA has already committed the funds to extend the mission for a year.

The consensus at NASA is that if there is no catastrophic event or failure, the rover and the lander can remain active for many months. One possible limiting factor will be the effect on their circuitry of cold/warm cycles that the two spacecraft experience from the day/night cycles on Mars. As fall and then winter approach on Mars, about the time of fall on Earth, the temperatures will plummet, and

This detail from the "monster panorama," produced from IMP images, provides striking evidence of the action of water on the surface of this flood plain. Note the group of rocks, from the lower left to the middle, are all pointing in a southwest to northeast direction. The simplest explanation for the placement of such a series of rocks is the action of large amounts of quickly rushing water.

In the lower right-hand cormer is Flat Top, a rock with a clearly visible deposit of dust on its flat surface. So far, Sojourner results indicate that the composition of the dust at this landing site is in no way different from the dust analyzed by the Viking landers. This is not unexpected, since dust is distributed across the surface of the entire planet by global dust storms.

At this site, however, there appears to be a "scouring" of the surface taking place, where the layer of dust is being removed, rather than more being deposited. This allows the exposure of some rock surfaces, down to the "native" rock under the dust, and also has revealed the crusty material apparent around Barnacle Bill and in other locations.

it is not known how this will effect the robustness of the electronics now sitting on Mars.

The Pathfinder mission has restored the faith of the scientists and engineers who agonized over the failure of the Mars Observer in 1993, and watched the Russian Mars '96 mission end up in the drink last December. It has uplifted the spirits of this nation and the world.

It is only natural that the expectation of most of those who have followed this extraordinary mission, is that after the series of necessary precursor missions, there will be a program in place to send people to Mars. At the present time, there is no such plan in place. There are some promoting a "get-rich-quick" manned Mars mission, to go as soon as possible, regardless of the danger to the crew or the limited science and technological development that would result.

President John F. Kennedy, in announcing the Apollo program four months after taking office, on May 25, 1961, had a different, long-term vision for this nation's space program. He said, "Now it is time to take longer strides, time for a great new American enterprise, time for this nation to take a clearly leading role in space achievement, which in many ways holds the key to our future on Earth."

Now is also, such a time.