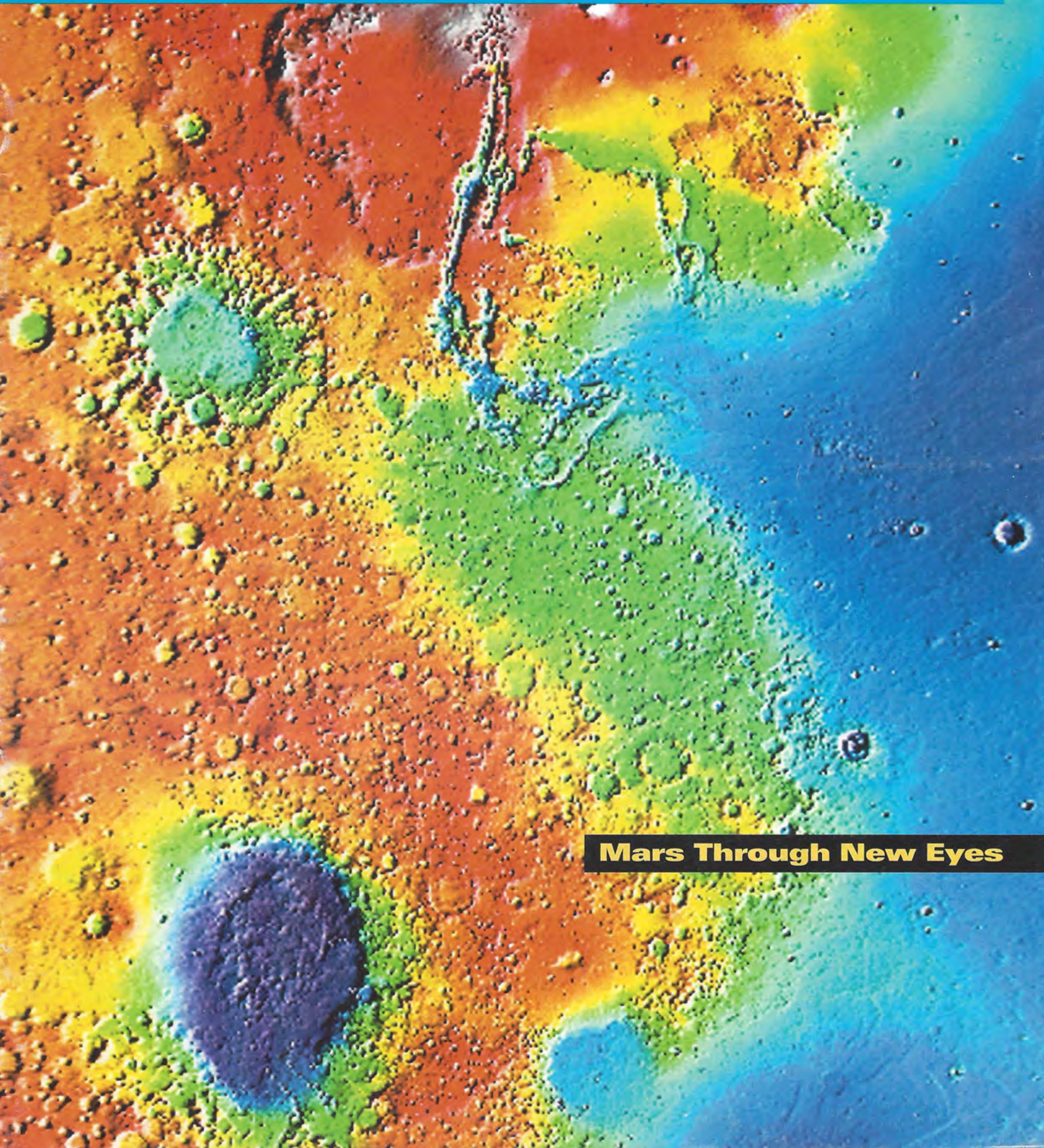
The PLANETARY REPORT

Volume XIX Number 5 September/October 1999



Mars Through New Eyes

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On the Cover:

Generated by the Mars Orbiter Laser Altimeter (MOLA), an instrument aboard NASA's *Mars Global Surveyor*, this high-resolution map of Mars represents 27 million elevation measurements gathered in 1998 and 1999. The datum, or Martian sea-level, is marked by medium blue, most easily seen at the right edge of the image. Darker blue to violet tones indicate low regions, 1,000 to 3,000 meters below the datum, and reds indicate areas that are more than 3,000 meters higher than the datum. The massive Hellas impact basin (bottom left) is deep enough to swallow Mount Everest —nearly 9 kilometers (6 miles) deep and 2,100 kilometers (1,300 miles) wide. The basin is surrounded by a ring of ejected material that rises about 2 kilometers (1.25 miles) above the surroundings and stretches out to 4,000 kilometers (2,500 miles) from the basin center. The Valles Marineris canyon system (top center) slopes away from nearby outflow channels where water once flowed in early Martian history, with part of it lying about 1 kilometer (roughly, half a mile) below the level of these channels. The large blue area (right) is the low, smooth northern polar region, surprisingly different than the southern hemisphere (left), which is heavily cratered and sits, on average, about 5 kilometers (3 miles) higher than the north.

Image: Mars Orbiter Laser Altimeter Team/NASA

Features

If you're a long-time Planetary Society member, you'll remember fondly the days of the Mars Balloon, when in member-supported tests we gleefully chased giant balloons, dragging the Society-built Snake guide-rope, for kilometers across barren desert landscapes. While the Mars Balloon has yet to fly on that nearby planet, the Society's tests were a great success in this way: they helped convince NASA's Jet Propulsion Laboratory (JPL) to take up the challenge of flying robot-bearing balloons on other worlds. Here JPL "aerobot" team members tell how they've been working toward Mars . . . and Venus and Titan . . .

Red Rover Goes to Mars may turn out to be the most ambitious project The Planetary Society has ever undertaken. We are reaching out to children around the world, and our goal is to enable them to reach Mars. Each one of us involved with the Society probably remembers some moment in childhood when a fascination with the universe around us took hold and shaped our lives. With Red Rover Goes to Mars, we hope to provide many such moments. Not only are these children future supporters of planetary exploration, they are the astronauts who will walk on other worlds. This project could be their first steps toward Mars.

Departments

This year we will not be publishing our annual sales catalog for the holiday season. In the interests of efficiency—and to squeeze every penny into our program budget—we've incorporated our sales pages into the back of *The Planetary Report*. But don't let that discourage you from buying your holiday presents from The Planetary Society! And, remember, giving gift memberships is an easy way to do your shopping. Use the card bound into this issue, and you can help the Society grow while pleasing your friends and relations. (That way we'll deliver the gift for you six times a year.)

From The Editor

Well, Planetary Society members may look forward to an expansive future among the planets for themselves and their robotic counterparts, but you certainly don't want to give up the old-fashioned pleasures of reading ink on paper. I want to thank all of you who contacted me, both electronically and with paper, for helping us plan the future of publications at The Planetary Society.

We will continue to focus our efforts on *The Planetary Report*, which, in every way we've yet found to measure, comes out on top as the prime benefit of membership in the Society.

We will still publish special-interest newsletters. I'm working on new formats and focuses for the *Bioastronomy News* and the *Mars Underground News*, and those changes will probably even extend to their names. Much has changed in the search for extraterrestrial life and Mars exploration since we began the newsletters more than a decade ago, and they should reflect this new world. As for *The NEO News*, this has always had the smallest circulation among our newsletters, and this will be the one we will experiment with electronically.

Our World Wide Web site has proven to be extremely effective at reaching people outside our membership, and I hope you are finding it exciting as well. Visit **planetary.org** regularly, if you have Internet access, and sign up for the e-mail list. There are many ways to keep in contact; let's use them all.

—*Charlene M. Anderson*

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Members' **Dialogue**

Thinking About SETI

I enjoyed reading Christopher Chyba's article, "Some Thoughts on SETI," in the May/June 1999 issue of *The Planetary Report.*

The Fermi Paradox is much more profound, I think, because astronomers examining the universe with new instruments (radio, microwave, infrared, optical, ultraviolet, X-ray, gamma ray) and increasing resolution see no evidence of the presence or work of technological civilizations. It should be easy to detect civilizations with technology spanning the breadth of galaxies. But instead there is nothing obvious.

It may be that despite all our knowledge we are still like fish in the ocean and totally unaware of what lies right above our heads. The Fermi Paradox does not discourage me at all but makes me wonder even more.

—AL ABURTO Jr.,
San Diego, California

Most of the SETI-related articles I have read in these pages subscribe to a "linear" model of technological civilizations—that is, that civilizations just keep growing more powerful forever. History shows that every civilization (including our own) assumes itself to be immortal. This assumption colors thinking about SETI because it is hard for us mortals to grasp the distances, and hence light times, involved.

When thinking about SETI, it is useful to ask the question: for how long a continuous period of time are technological civilizations viable? We only have a few centuries of our own history with which to judge, but I think the answer is not long enough to maintain sophisticated listening devices and/or beacons for the centuries or millennia required for "contact."

We simply won't be able to listen for long enough periods at a time, and they won't be transmitting long enough at a time for the two to ever match up. In spite of this, I hope we keep listening.

—MURRAY NICHOLSON,
Paradise, Canada

Reality Check

Biosphere II was not a total failure. [See Lydia Kimberly's letter in the May/June 1999 issue.] I imagine very few experiments work perfectly the first time. Even though the project may not have accomplished all of its goals, much can be learned from an experiment that does not work out perfectly. They now know that much more about what is needed to live under those conditions—like how much oxygen can be made, the amount of land needed to grow food, and more.

The technology to build the Biosphere was new then. If I remember correctly, even the seals for the glass panes were untried as a system. I attended the seminar that The Planetary Society sponsored, and we were told that they were not sure how many people could live in there at one time. Originally they were willing to pull out or add people as needed, depending on how good the air was. Maybe the experiment was too public and the pressure to succeed clouded their judgment, or their priorities changed. Also, since that was the first time any people tried to live like that, everybody was an "amateur."

But I do agree that learning to live in that environment should be a much higher priority than it is. We have to prove we can live like that here before we try to do it elsewhere.

—JIM DAVIES,
Chandler, Arizona

The Dream Is Alive

It was great to read Annika Fitzpatrick's letter in the May/June 1999 issue. The dream is obviously still alive in Lake Worth, Texas, despite launch delays, budget cuts, and general pessimism that we haven't progressed as far as we could have. The only acceptable future seems a little more certain after reading this letter.

—MIKE DOUGHTY,
Dursley, Gloucestershire, England

In the May/June issue of *The Planetary Report,* I was delighted to read two outstanding letters on opening up our immediate neck of the woods to human settlement. I wholeheartedly agree with Annika Fitzpatrick that a human mission to Mars would refresh the human spirit. Like Gerald Black, I believe Mars to be a more viable goal than the Moon if only because of the greater abundance of raw consumables there, such as water, ferrous oxide, silicates, and carbon dioxide.

Endeavors on such a grand scale as getting our collective tails to Mars are not unknown to previous human experience: the *Apollo* program comes to mind, but what about Magellan, Marco Polo, Lewis and Clark, and all those who went before? It is also my hope that people like Lydia Kimberly not forget the time-spanning genii of Leonardo da Vinci and Benjamin Franklin.

In the spirit of science we can work out the answers—to test our ideas, to find out what works, to get real. We can do this thing as long as we remain involved.

—BRIAN WYATT,
Lexington, Kentucky

Erratum

The credit line for the image of Mars on the cover of the March/April 1999 issue of *The Planetary Report* was incorrect. It should have read: Mars Orbiter Laser Altimeter Team/NASA.

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Exploring With Aerobots: A New Way to See the Worlds

IT SEEMS A FANCIFUL NOTION, conjuring images of Phileas Fogg crossing the Alps, the Wizard of Oz returning to Kansas, or the Montgolfier brothers startling picnickers in the French countryside. But ballooning may well be an efficient and effective way to explore alien worlds.

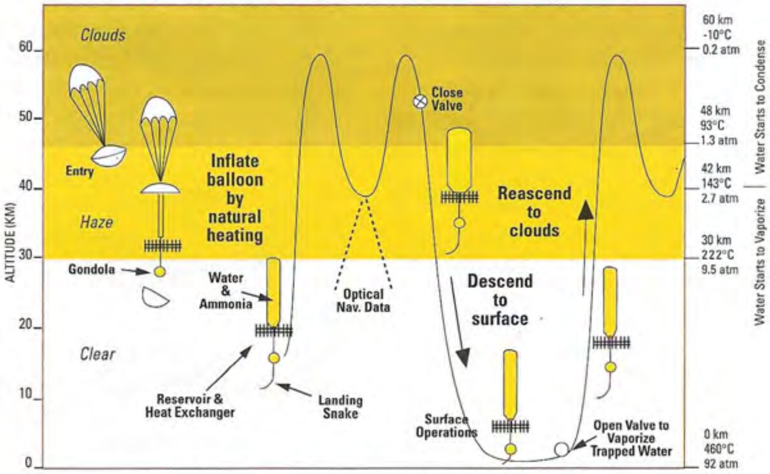
In the mid-1980s, Planetary Society Advisor Jacques Blamont, fresh from the success of the VEGA balloons on Venus, suggested to Society leaders that there was a role we could play in developing this new idea. Jacques' vision soon reached reality in the Californian desert, where a French-built balloon, carrying a guide-rope created by the Society, was tested in preparation for flight on the Soviet Mars '92 mission.

But history intervened, and we lost our chance to fly the balloon on Mars. Still, the Society's test program continued at a reduced level until a few years ago, when NASA's Jet Propulsion Laboratory (JPL) began serious study of ballooning on other planets. Recognizing that JPL had far more resources than we could muster, the Society gave the last balloon in our program to the lab.

Still, we remain close to the action. Author Jim Cutts is a former student of Society President Bruce Murray. Viktor Kerzhanovich may be familiar to long-time Society members as a leader in both our balloon and rover test programs.

Here they share with members the results of their latest work. *–Charlene M. Anderson, Associate Director*

A Typical Venus Aerobot Mission Trajectory



A balloon explorer on Venus would be able to investigate four different regimes: the cloud deck, the haze layer, and the clear lower atmosphere as well as the surface. Chart: JPL/NASA

by James A. Cutts and Viktor V. Kerzhanovich

Six other planets—Mars, Venus, Jupiter, Saturn, Uranus, and Neptune, in addition to Saturn's moon Titan—have enough atmosphere to support a balloon in flight. Still, to date, balloons have floated in only one planetary atmosphere other than Earth's—that of Venus in 1985. But scientists are coming to realize the potential of robotic balloons—or aerobots—and the technology of lighter-than-air flight on Earth and other planets. A new age of planetary aerobot exploration is dawning.

Someday, perhaps in the next decade, we will use aerobots to study the atmospheric composition and circulation of all seven planets where they can fly. In this article, we'll focus on three bodies with solid or liquid surfaces: Mars, Venus, and Titan. Aerobots can readily explore those surfaces and what lies beneath them. These flying robots can serve as platforms for remote or in-situ sensing, vehicles for precision deployment of probes, stations for relaying communications between other vehicles, and collectors of samples for return to Earth.

***Above:* The Venus Geoscience Aerobot, a descendant of the VEGA balloons, would repeatedly travel between the cool upper atmosphere, with temperatures around 0 degrees Celsius (32 degrees Fahrenheit), to the quite nasty lower atmosphere, where it would have to endure temperatures up to 460 degrees Celsius (about 860 degrees Fahrenheit).** *Illustration: JPL/NASA*

***Right:* Balloons from Earth have already flown on Venus. In 1985, the Soviet-led VEGA mission dropped off two balloons in the Venusian atmosphere on the way to Halley's comet. The French space agency, the Centre National d'Etudes Spatiales, built the balloons under the guidance of Jacques Blamont, a Planetary Society Advisor. They returned valuable information about the planet's winds as they drifted about one-third of the way around the planet. This is a test balloon in the benign terrestrial air.** *Photo: JPL/NASA*

Venus: Yesterday and Tomorrow

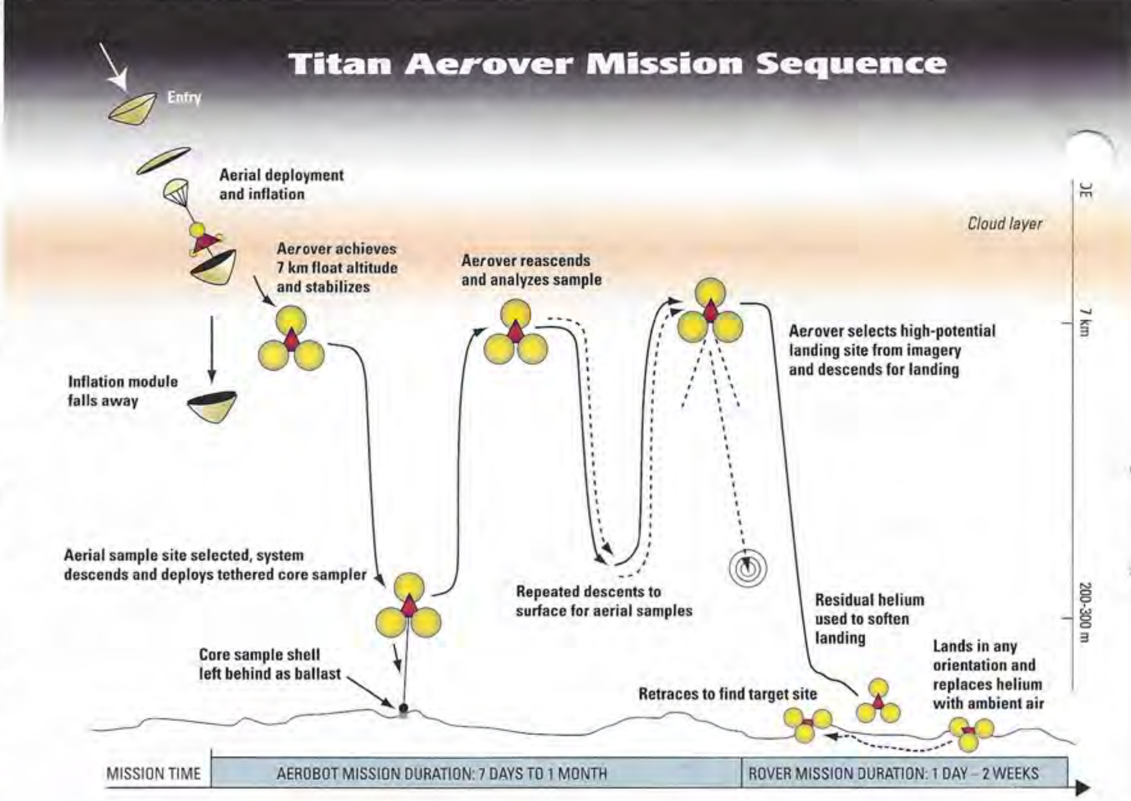
In 1985, the Soviet Union, in collaboration with France and the United States, led the first balloon mission to Venus. That planet is comparable in size to the Earth but has a very thick atmosphere, composed primarily of carbon dioxide, and a surface pressure more than 90 times that of Earth. Its surface temperature rises to 460 degrees Celsius (860 degrees Fahrenheit).

The VEGA mission deployed balloons in the atmosphere at an altitude of 54 kilometers (34 miles). Each operated for about 48 hours and traveled a third of the way around the planet, thus confirming the existence of strong, high-altitude winds. Instruments inside the balloon gondola measured temperature and pressure in situ.

Future balloon exploration of Venus will build on the VEGA balloon heritage but focus on the surface, which is difficult to observe from orbit and impractical to explore with landers and rovers. Although *Magellan* mapped the surface with radar in the early 1990s, the thick Venusian atmosphere makes it impractical for a future orbital mission to obtain high-resolution optical and infrared images of the surface. In fact, haze and atmospheric scattering would make images of the surface useless, even from the altitude of the VEGA balloons.

The severe heat and pressure in the lower atmosphere, where surface imaging is possible, strongly limit the lifetime of surface vehicles—none of the Soviet or US craft that have reached Venus' lower atmosphere lasted more than two hours. Given this, we are pursuing several innovative aerobot-based approaches.

The Venus Aerobot Multisonde (VAMUS), drifting in the cool upper reaches of the atmosphere explored by VEGA, would deploy several small probes, or sondes, to the surface. They would take high-resolution images and gather spectro-



Right: A balloon-rover hybrid—an aerover—could provide a novel way to explore the as-yet-unknown surface of Saturn's large moon Titan. Traveling through Titan's dense nitrogen atmosphere might prove the easiest mode of transport on this world; its surface seems to contain both rocky landmasses and hydrocarbon oceans. Exploring those would certainly test the limits of technology.
Chart: JPL/NASA

Below: This is what the hybrid aerover might look like: a combination of balloons and wheels. It's seen here in the "Mars yard" at JPL, where engineers test the capability of different rover designs. The terrestrial life-form is shown to provide scale. *Photo: JPL/NASA*

scopic data that could help unlock the secrets of the evolution of Venus. From an altitude of about 55 to 60 kilometers (roughly, 35 miles), moving rapidly with the zonal winds, an aerobot would deploy precisely timed sondes into the surface features of highest scientific significance.

At JPL, we have already demonstrated for this mission a highly efficient deployment and inflation system as well as lightweight, sulfuric-acid-resistant balloons and compact thermal- and pressure-protection sonde technology.

A more ambitious mission concept, the Venus Geoscience Aerobot, would make repeated short trips—perhaps a few hours long—from the upper atmosphere to the surface and back again. At JPL in 1995, we demonstrated a reversible fluid-buoyancy system capable of making a large number of descents and ascents without having to drop ballast or release inflation gas. Near the surface, heat is absorbed by a reservoir containing liquid water or ammonia, which turns to gas and is fed to the balloon envelope, causing it to expand. The balloon rises rapidly, but when it reaches the upper atmosphere, heat is rejected to the atmosphere, liquefying the water or ammonia and causing the balloon to descend again. The use of heat to provide mechanical energy means this system is a heat engine. It is also possible to convert some of the energy to electrical power for instruments and communications systems.

The scientific sensors and electronics would be protected from the hellish environment by a special gondola, a heavily insulated pressure-vessel made of titanium and thick enough to resist the weight of the Venus atmosphere, which is equivalent to submergence to a depth of 3,000 feet in the ocean. In addition, a "phase change material" would be contained in the gondola. As this material melts, it will stabilize the temperature inside the gondola at a level at which electronics can operate, in just the same way as ice in a picnic cooler keeps the contents cool.

Once the balloon is back in the upper atmosphere, a heat pipe will cool the gondola and refreeze the phase-change material, preparing the vehicle for another descent. Such a balloon could explore in much the same way as deep-sea submersibles have explored the floor of Earth's deep ocean.

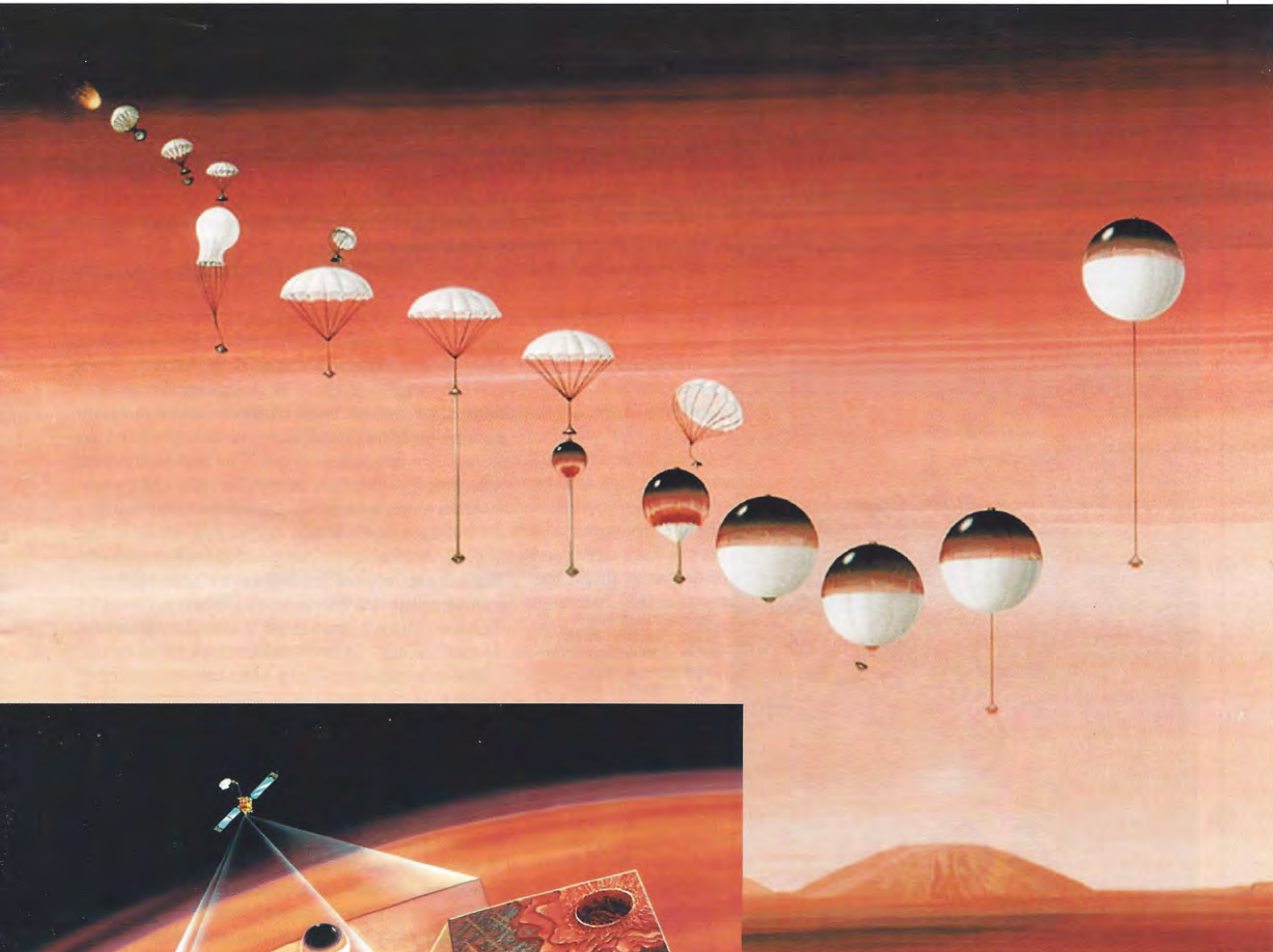
We've also built and tested a prototype gondola. Other key technologies that have been developed include polybenzoxazole (PBO) balloon-envelope materials tolerant of high temperatures. However, we'll need more technology work before we can begin this challenging project.

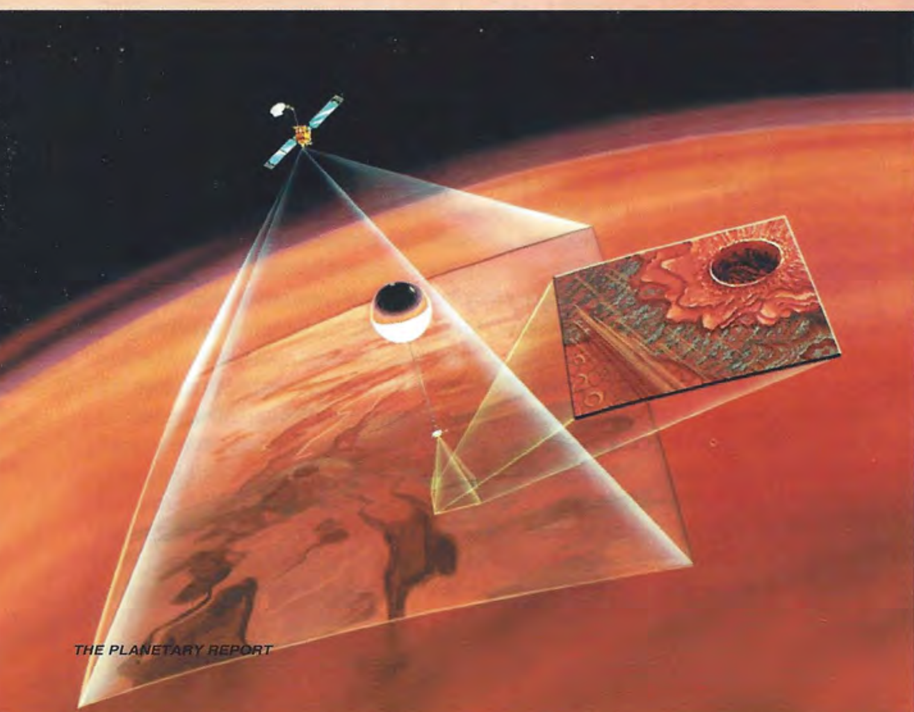
If scientists are to further understand Venus, they will need surface samples returned to Earth. Two teams are studying such a Venus Sample Return mission, one at the European Space Agency and the other at JPL. Both teams agree that the only way to return a sample is to use a balloon to lift it to an altitude of about 60 kilometers (roughly, 40 miles). From that altitude, the sample would be launched into Venus orbit on a rocket. From there, the sample would be transferred to another spacecraft and ejected on a trajectory toward Earth.

To Tour Titan

Saturn's moon Titan may preserve prebiotic organic chemicals, lost on Earth, that relate to the evolution of life. Photochemical reactions in the atmosphere appear to be generating organic materials—some of which form an orange haze that masked the surface when the *Voyager 1* spacecraft flew close by in 1981. Scientists once speculated that Titan might have a global ocean of liquid hydrocarbons beneath this haze. But we now know that there are fixed surface features and impact craters that may have served as vast cauldrons of warm water within which organic compounds polymerized into prebiotic molecules.

Titan seems to be a heterogeneous world with seas of hydrocarbons broken by solid surfaces. Like the Venusian surface, that of Titan is difficult to observe from orbit except with radar. Although exploration with rovers may be practical, the cold temperatures and the uncertain surface conditions —whether solid, liquid, or somewhere in between—make a mission difficult to plan. On the other hand, atmospheric conditions on Titan favor balloon flight, and such aerial platforms would provide an ideal approach to exploration.

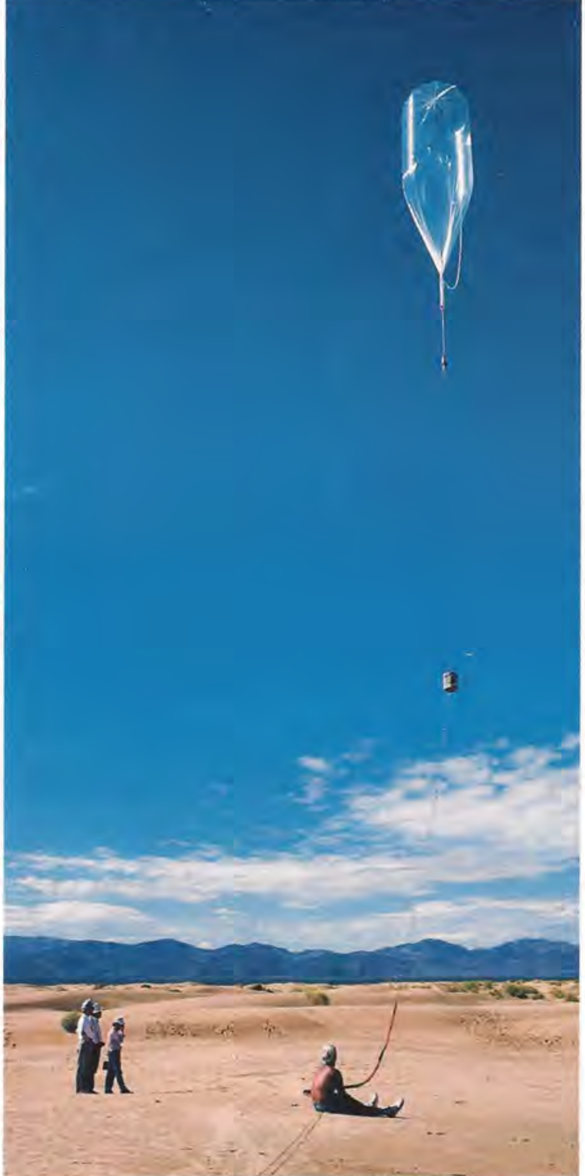




***Above:** So far, we know the Martian surface from three perspectives: from telescopes at Earth, from orbiting spacecraft, and from landers. What we lack is the equivalent of viewing the surface from a high vantage point, such as a mountaintop or an airplane. A Mars aerobot could provide such a perspective, giving us highly detailed pictures of surface features.*

***Left:** An orbiting satellite and a balloon could work in concert to explore Mars. The satellite takes the long view and gives context to the images and data collected by the balloon, operating much closer to the ground.*

Illustrations: JPL/NASA



This is a familiar sight to long-time Planetary Society members: the Mars Balloon on a test flight over Earth's Mojave Desert. In the late 1980s and early 1990s, the Society worked closely with the Soviet space program and the French space agency to test technology to explore Mars. Chasing errant balloons across sand dunes and lava fields became a favorite pastime of Society members and the scientists they sponsored.

The major contribution of The Planetary Society to Mars ballooning was the Snake—a guide-rope designed to stabilize the balloon at low altitudes. The Snake design had the added ability to carry scientific and engineering instruments, enabling the balloon to make in-situ measurements of both the Martian atmosphere and surface. This Snake design was the brainchild of Planetary Report *Technical Editor Jim Burke and Society volunteer Jim Cantrell of Utah State University.*

Photos: The Planetary Society

Titan's atmosphere, which is predominantly nitrogen with a few percent of methane, is about four times as dense as Earth's at sea level. But it is extremely cold—just warm enough to prevent the atmosphere from liquefying. There, even a small balloon can carry quite a large payload. The temperature gradients on Titan are not sufficient to operate a reversible fluid-buoyancy system, as planned for Venus. However, there are many other ways to modulate the lift of a small balloon, using waste heat from the electrical power source. Thus an aerobot could also make multiple descents to observe and sample the surface without committing to a landing.

In 2004, the *Huygens* probe of the European Space Agency will detach from NASA's *Cassini* spacecraft and descend into Titan's atmosphere. As it descends, it will take the first pictures of the surface. If the probe survives impact and lands on a liquid surface, it will also measure the composition of that liquid.

NASA is now in the early phases of defining a Titan Explorer mission. It would use an aerobot or aerover, a hybrid robotic-balloon/inflatable surface-rover, to traverse thousands of kilometers.

The Mars Balloon

While the case for aerobot exploration of Venus and Titan is almost self-evident, the rationale for exploring Mars with aerobots requires some explanation. There are many ways to explore Mars. Except during dust storms, the surface can be clearly seen from orbit—cameras on *Mars Global Surveyor* have revealed features only a few meters in size. The pioneering rover tests with *Sojourner* are now being followed by new rover missions, with *Marie Curie* to be launched in 2001 and the sophisticated *Athena* planned for launch in 2003. Airplanes are being added to the ranks of Martian explorers with a flight planned in 2003 to commemorate the Wright brothers' first powered flight, which took place in 1903 near Kitty Hawk, North Carolina.

But an aerobot exploring Mars can add a unique vantage point. It can travel a thousand times closer to the surface than an orbiter, reach a thousand times higher than a rover, and operate a thousand times longer than an airplane. Thus an aerobot is the ideal platform for conducting regional and global surveys—of remnant magnetism, electromagnetic soundings for subsurface water, and ultra-high-resolution imaging and spectroscopic surveys of potential biological habitats—that require a combination of surface proximity and global reach.

Compared to Venus and Titan, with their dense atmospheres, Mars is more challenging for flying aerobots. The atmospheric density at mean Martian "sea level" is only 15 grams per cubic meter—comparable to the Earth's stratosphere at an altitude of 32 kilometers (20 miles). Fortunately, we can apply recent technology developments in long-duration stratospheric balloons and design so-called superpressure balloons that will remain aloft for months.

In the late 1980s, Soviet and French scientists and The Planetary Society pioneered the concept of a Mars balloon, designed to float several kilometers high in the atmosphere during the day and sink to the surface at night. It used a heavy "snake" or guide-rope to prevent the balloon itself from contacting the surface. Subsequently, Russia and France collaborated on the Mars Aerostat mission, equipped with both a scientific gondola containing an imaging system and a guide-rope containing chemical and physical sensors. Unfortunately, the Mars Aerostat mission was canceled in 1995 because of Russia's financial problems. Some of the key technical issues of balloon deployment still remained to be solved.

Emerging Balloon Technology

In 1997, JPL began work on some of the key technologies needed for a Mars Aerobot Technology Experiment (MABTEX). This effort benefited from the experience of CNES, the French space agency, in developing a deployment system. In August 1998, we tested a lightweight aerial inflation system that introduces helium or hydrogen gas from beneath the balloon rather than from above. This new inflation system is smaller and lighter than earlier designs and can fill the balloon with gas with less risk of damage to the envelope. In the summer of 1999, we tested it under Mars-like conditions in the stratosphere. MABTEX development has also benefited from pioneering work by The Planetary Society and NASA Ames Research Center on a superpressure balloon designed for flights as long as 100 days. Several balloons now being built with advanced materials will be tested in the stratosphere.

We are also pursuing other Mars aerobot concepts that do not use hydrogen or helium. A team led by Jack Jones of JPL is demonstrating aerial inflation of a solar Montgolfiere balloon—a type that is filled with ambient atmosphere and relies on solar heating for buoyancy. This vehicle could soft-land payloads on the Mars surface. Robert Zubrin of Pioneer Astronautics is developing an innovative hybrid Montgolfiere balloon potentially capable of lifting even larger payloads.

Successes in superpressure balloon design have led to a multi-lobed "pumpkin" balloon that could carry even larger payloads at higher altitudes. A JPL-led collaboration has now formed to apply these technologies to powered aerobots, or steerable airships, that will use solar-powered propellers and will be capable of navigating anywhere on Mars except the highest mountains.

On that desert world, whose surface area equals that of the Earth's continents, vehicles floating in the atmosphere are destined to play the role in exploration that vehicles floating on the ocean have played on Earth. As technology advances, these lighter-than-air craft will be able to stay aloft indefinitely, just as their terrestrial marine counterparts remain afloat effortlessly in the oceans. They will cruise between Martian robotic outposts, while far beneath them heavy-lift surface vehicles will labor across the rocky plains, building a robotic infrastructure that will enable humans to establish themselves on Mars in the decades that follow.

James A. Cutts is Manager of the Special Projects Office at JPL; Viktor V. Kerzhanovich, also of JPL, is a Senior Member of the Technical Staff.

Above: NASA is testing various designs for ultra-long-duration balloons in Earth's atmosphere, and some of these superpressure designs might someday fly on Mars. This is the pumpkin design from the space agency's Wallops Flight Facility.
Photo: NASA

Below: In 18th-century France, relaxing picnickers might have been startled by the sight of large hot-air balloons drifting over the countryside, flown by the Montgolfier brothers. Descendants of their balloons, now called Montgolfieres, might someday fly on Mars. A Martian Montgolfiere, instead of heating its bag of atmospheric gases by flames, will be made of materials that absorb infrared radiation from the Sun, heating the atmospheric gases and causing the balloon to rise. *Illustration: JPL/NASA*

Red Rover, Red Rover,
Send Future Astronauts

Planetary Society Project

We stand on the threshold of an exciting millennium of exploration, one where the global public will become participants in the exploration of other worlds. Red Rover Goes to Mars will take students from around the world to a new frontier—Mars.
Louis D. Friedman, Executive Director

Using Red Rover, Red Rover software, students teleoperate rovers on simulated Mars terrains, either in their own classrooms or in remote locations, such as the Mars terrain at Society headquarters.

Imagine the day when everyday people from all over the world will be able to actively participate in a space mission . . . when students will work alongside mission scientists and engineers, then share their experiences with the world via the Internet. Imagine raw data from Mars coming to homes and classrooms worldwide, so that mission activities can be recreated in near real-time. Then imagine the global enthusiasm of knowing that a child in your community—maybe even you, your neighbor, or someone in your family—may be chosen to help operate a real rover on Mars.

What a dream! International cooperation, public participation in a space mission, boundless educational opportunities, and real Mars exploration—sounds like something The Planetary Society would be involved in, and we are! We are thrilled to announce our newest, and perhaps most ambitious, project, called Red Rover Goes to Mars (RRGTM). In an unprecedented decision by NASA, The Planetary Society has been chosen to conduct an educational experiment that will allow a group of student astronauts and student scientists to work with NASA's Mars Surveyor 2001 team during mission operations. The student team will become the first citizens ever to have firsthand experience conducting science experiments and operating a rover and robotic arm on another planet.

As exciting as that sounds, students working on a real space mission make up only part of our educational experiment. Red Rover Goes to Mars is an entire program intended to bring real Mars science into classrooms and homes around the world, through the selection process required to establish the RRGTM team and through the experiences of the students during mission operations.

Red Rover Who?

Since 1995, our Red Rover, Red Rover program, a joint venture with Visionary Products, Inc. and the LEGO Company, has been bringing real rover mechanics into the hands of children. Using simple LEGO blocks, students build mini rovers equipped with motors, gears, and tiny cameras. Then, through a series of computer commands, the rovers traverse a simulated Mars terrain created by the students themselves. Red Rover, Red Rover students can control the rovers in their own classroom or log in via the Internet to drive a rover

Two Los Angeles students build their LEGO rovers while their teacher looks on. Red Rover, Red Rover provides a uniquely active way for students to challenge and hone their knowledge of planetary geology, math, and mechanics.

in a classroom hundreds, maybe thousands, of miles away. Red Rover, Red Rover is now in more than 400 schools around the world, and that number is rapidly expanding, allowing thousands of children the experience of control-

Over!

by Jennifer Vaughn

Flies on 2001 Mission

The space program is a powerful symbol of the value of education and achievement. LEGO is proud to work on this novel experiment with The Planetary Society and with NASA to provide new opportunities for educational outreach.
Torben Sorensen, LEGO Senior Vice President

ling a remote roving vehicle, very much the way NASA teams controlled the *Sojourner* rover on Mars.

Early in 2002, after Mars Surveyor 2001 touches down on the Red Planet, the newest Red Rover, Red Rover site will be Mars. Anyone with Internet access will be able to look on as a select group of students puts their Red Rover, Red Rover work to the test. Mission data will be posted along with comments from the Red Rover Goes to Mars team, so that mission activities can be simulated here on Earth almost simultaneously.

Looking for the Right Stuff

Red Rover Goes to Mars begins with two student contests with very different requirements and outcomes to help us find our final RRGTM team. The first one, called the Student Scientist Selection Essay Contest, begins on October 1, 1999.

Selecting the Student Scientists

Because we want true global participation, we chose an essay contest to begin this program. Interested students from anywhere in the world can compete to become one of the final team members without the need for computers, access to the Internet, or any understanding of Red Rover, Red Rover.

The objective of the essay is to define, in 1,500 words or less, the mission goals for the robotic arm on the 2001 lander and for the next rover to traverse Mars, named *Marie Curie*. In order to suggest realistic mission goals, students will need to learn more about the Martian environment, the possible obstacles that the rover and robotic arm might encounter, and the technology that might help overcome some of these obstacles.

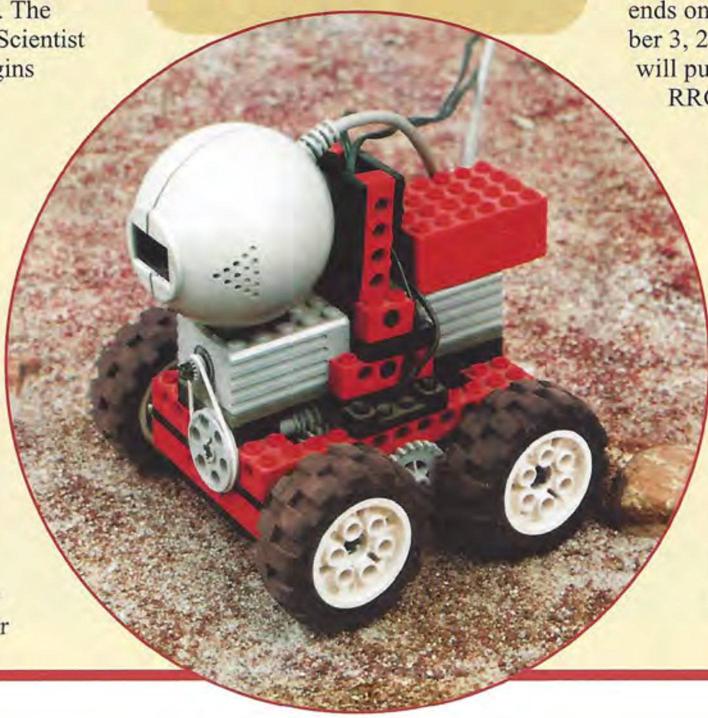
Essays must also explain how the student, if he or she were in charge, would handle a conflict between two principal investigators who both want to be first to test their lander instruments. This question requires team thinking and challenges students to demonstrate decision-making skills using their knowledge of the 2001 lander experiments and Martian environmental factors.

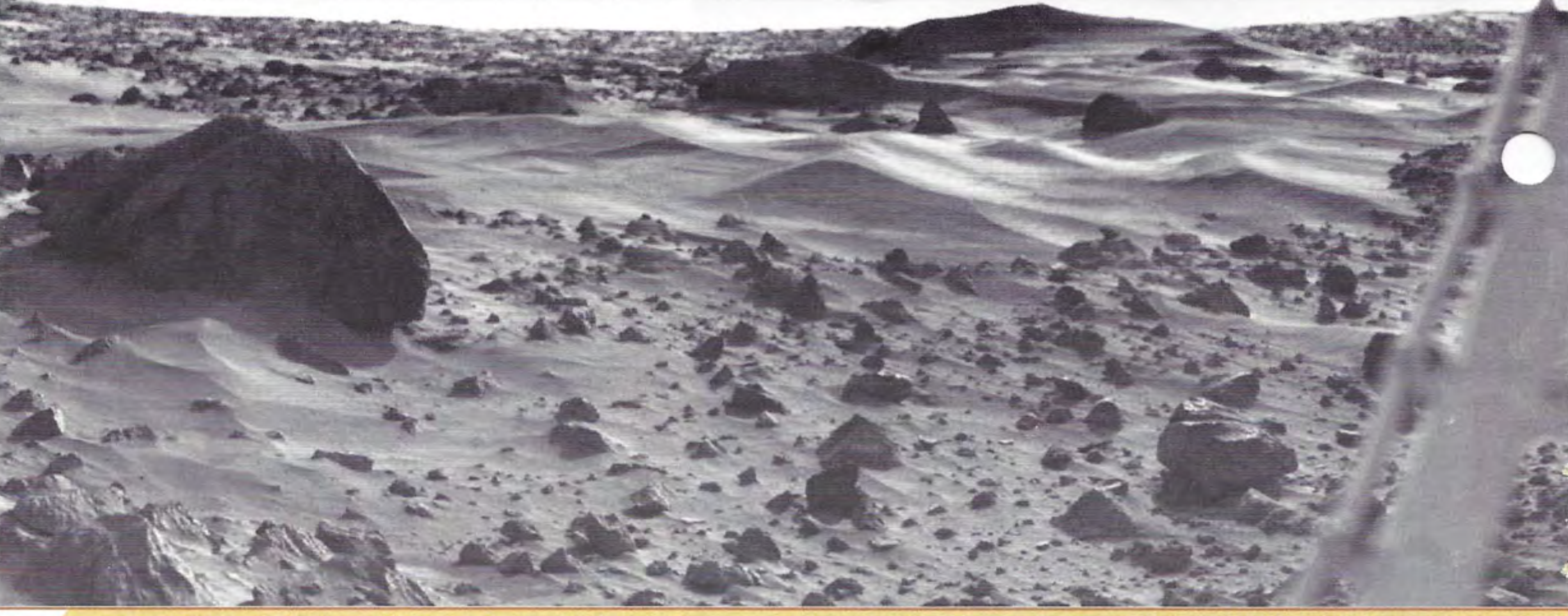
Completed essays will be submitted to the nearest Regional Center for quarterfinal judging. Regional Centers choose winning essays in each of three age categories: entrants who will be 11-12, 13-14, or 15-18 as of January 31, 2002. The winning essays will then be submitted to a National Center in each participating country for semifinal judging. The National Center will select the best essay in each age category and then, if necessary, translate the three semifinalist essays into English before forwarding them to The Planetary Society for final judging. The contest officially ends on June 15, 2000, and on October 3, 2000, The Planetary Society will publicly announce the official RRGTM Student Scientist Team.

The team of Student Scientists will undergo 15 months of specialized training to become experts on the Mars Surveyor 2001 mission, the lander instruments, and the planned mission experiments as well as particular Red Rover Goes to Mars experiments, including The Planetary Society-sponsored, student-designed "NanoExperiment" (for details on the Student NanoExperiment Challenge, see Society News in the

(continued on page 14)

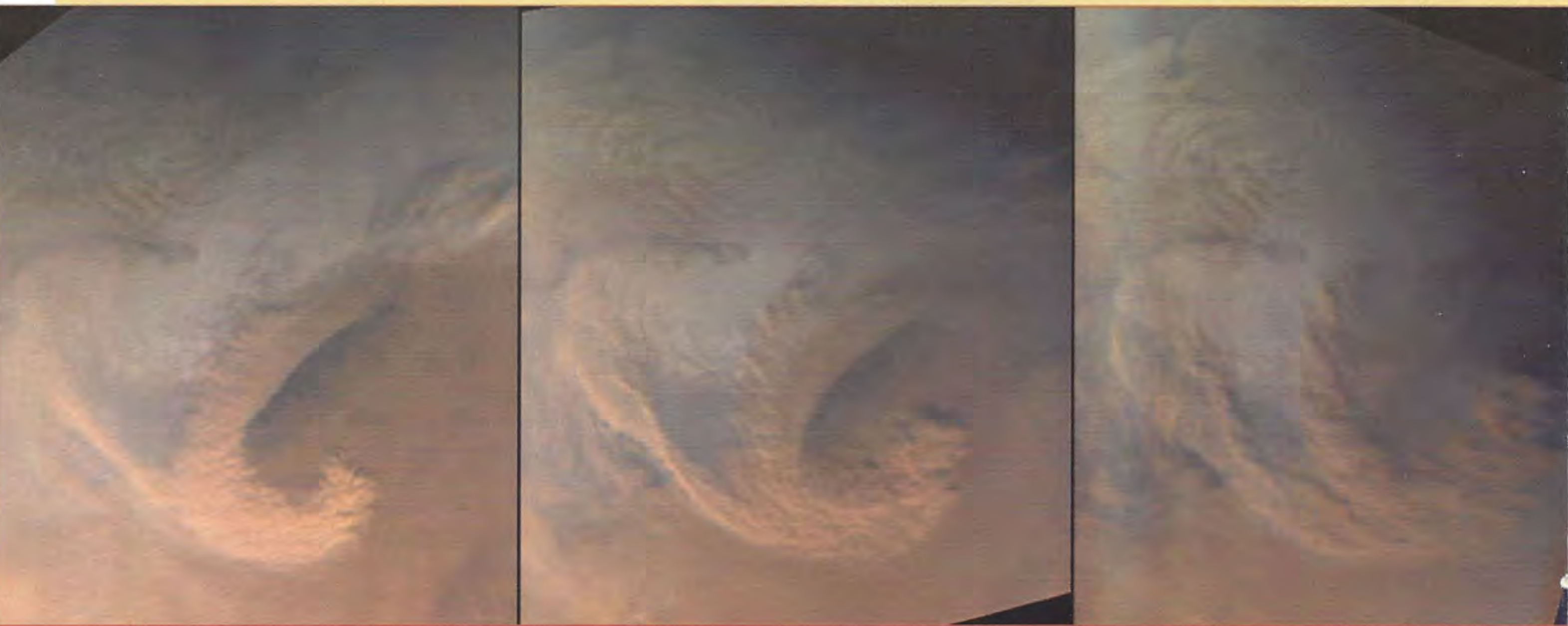
Add creative minds to this standard Red Rover, Red Rover design, and the options are unlimited. Mechanical arms, scoops, and alternative wheel designs are all possibilities—they might not all work, but part of the fun is finding out.
Photos: The Planetary Society





Above: This spectacular picture of the Martian landscape by the Viking 1 *lander shows a dune field with features remarkably similar to many seen in the deserts of Earth. The dramatic early morning lighting reveals subtle details and shading. The sharp dune crests indicate the most recent wind storms moved from upper left to lower right. Small deposits downwind of rocks also indicate this wind direction. The large boulder at left is about 8 meters (25 feet) from the spacecraft and measures about 1 by 3 meters (3 by 10 feet).* Viking*'s meteorology boom, which contained a miniature weather station, cuts through the picture's center.* Image: JPL/NASA

Below: The wide-angle cameras of Mars Global Surveyor*'s Mars Orbiter Camera (MOC) have been documenting the changing weather patterns of the Red Planet nearly every day since global mapp began in March 1999. These three still-frame images show the evolution of a storm system over th Martian north polar region on June 30, 1999. The pictures were taken at approximately two-hour intervals. The north polar ice cap is the white feature at the center of each frame. Clouds that appe white consist mainly of water ice. The curling of the clouds behind the largest of the storms could indicate a flow vortex following the storm front. The clouds that appear brownish contain dust, suggesting that high surface-winds raised dust and mixed it with water vapor in the atmosphere ov the summertime polar cap. Storm systems similar to the one shown here continued throughout Ju and into August. Over the next several months, the north polar cap will grow dark as the region transitions through autumn and into winter. When northern winter begins in December 1999, this region will be dark and obscured by clouds.* Images: MSSS/NASA



	October 4, 1999 — June 15, 2000	June 16, 2000 — July 31, 2000	August 1, 2000 —
Student Scientist Selection Process	Student essays submitted to Regional Centers	Regional Centers choose quarterfinal-winning essays and forward to National Centers	National Centers choo essays and forward to

	March 2, 2000 — November 15, 2000	November 16, 2000 — December 15, 2000
Student Astronaut Selection Process	Student journals submitted to Regional Centers	Regional Centers choose quarterfinal-winning journals and forward to National Centers

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Above: On July 4, 1997, Mars Pathfinder *bounced down on the Martian surface and unleashed the rover* Sojourner *to explore the rocky landscape. By the time the batteries ran out a little more than two months later,* Sojourner *had recorded more than 500 images, and the* Pathfinder *lander had collected more than 16,000 images of Mars' Ares Vallis region.* Sojourner*'s camera revealed rock textures not visible to the lander's camera. This image, for example, shows the vesicular and pitted textures of Soufflé Rock (32 centimeters, or about one foot, wide). On Earth, features like these can be formed by a variety of geologic processes, from the eroding power of floods and glaciers to lava flows and pyroclastic eruptions. Images like this one provide clues to Mars' dynamic past—one that more closely resembles the geologic history of our own planet.*

Right: Sojourner*'s observations in the Ares Vallis region on Mars raised questions about the origins of the rocks and other deposits found there. Here,* Sojourner *is perched atop Mermaid Dune, a place of scientific interest because of the unusual dark material distinct from the surrounding bright surface. The rover's tracks exposed a deeper layer of dark red soil. Upcoming missions, such as the* Mars Polar Lander *and the Mars Surveyor 2001 lander and rover, will analyze Martian dust and surface soils in more detail.* *Images: JPL/NASA*

August 31, 2000 — e semifinal-winning The Planetary Society

September 4, 2000 — October 2, 2000 — The Planetary Society selects final Student Scientist Team

October 2000 — January 2002 — Student Scientist specialized training

December 18, 2000 – January 15, 2001 — National Centers choose semifinal-winning journals and forward to The Planetary Society

January 16, 2001 – February 1, 2001 — The Planetary Society selects final Astronaut candidates

April 2001 — January 2002 — Specialized training for Student Astronaut Team and Astronaut Backup Team

April 10, 2001 — Mars Surveyor 2001 launches

January 22, 2002 — Mars Surveyor 2001 lands on Mars and mission operations begin

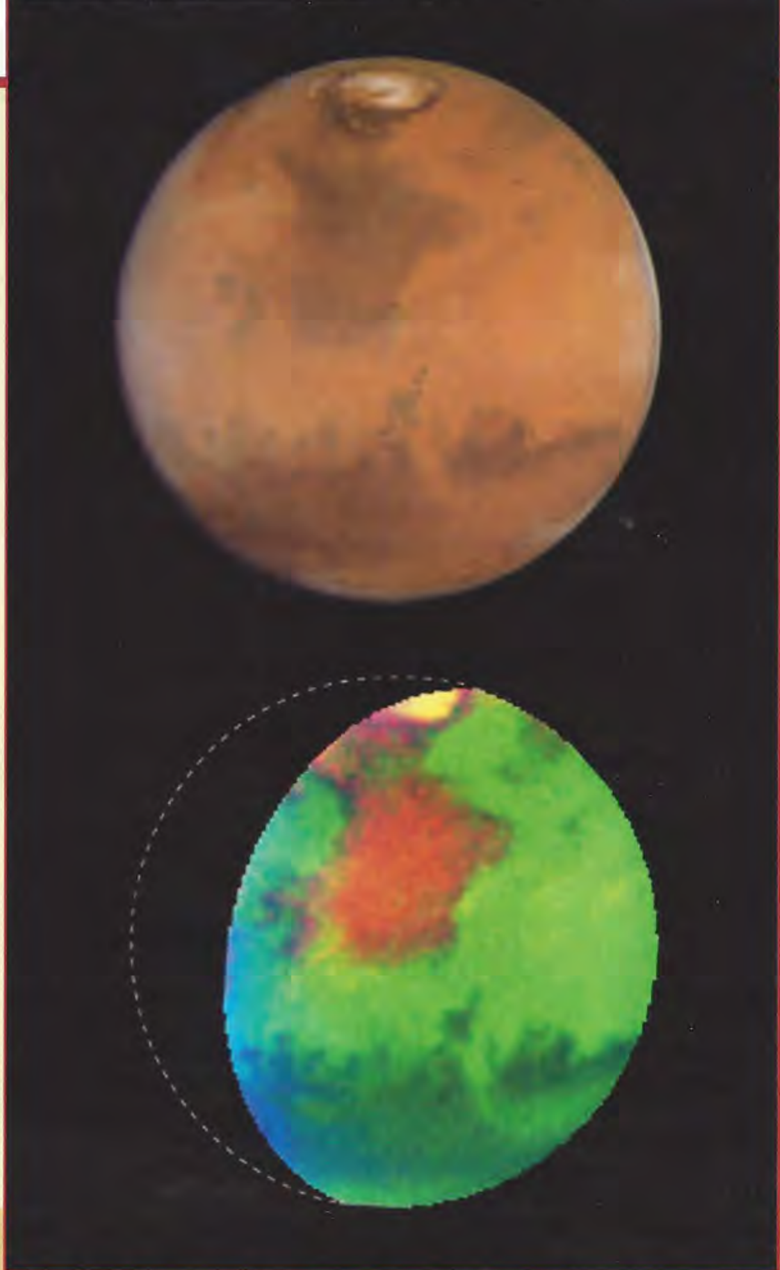
(continued from page 11)
May/June 1999 *Planetary Report*).

Trained Student Scientists will be placed with various mission teams during Mars Surveyor 2001 operations. For one week, Student Scientists will work right alongside mission scientists, experiencing the thrill of planetary exploration firsthand. Since the 2001 science teams operate in a number of institutions in the United States, there is no telling where a particular Student Scientist might end up working—possibly Arizona State University, the University of Washington, or the Jet Propulsion Laboratory in Pasadena, California. Wherever she or he ends up, it's a guaranteed experience of a lifetime.

Selecting Student Astronauts

The winners of the second contest, the Student Astronaut Selection Journal Contest, will have the opportunity to live and work in a simulated Mars base here on Earth, while participating in the teleoperation of the *Marie Curie* rover and robotic arm on another world. This unprecedented opportunity requires bright, dedicated students who understand rover mechanics and command sequencing as well as the Martian environment. To help us find these exceptional kids, we developed the journal contest, which will allow students to log specific information about their work with Red Rover, Red Rover or similar programs, such as LEGO Mindstorm Robotics Invention System, LEGO Robolab, or LEGO Dacta Control Lab.

Students participating in the journal contest will need to answer specific questions using their experience operating a robotic vehicle in a terrain similar to the rocky Martian landscape. Completed journals must be 1,500 words or less and must include general information about Mars and the Mars Surveyor 2001 mission as well as an answer to this question: "How would you resolve a conflict between two mission scientists who want to give the *Marie Curie* rover two opposite commands?"



***Top:** This true-color image of Mars, captured by Hubble Space Telescope, shows the planet as it would look to human eyes. It is clearly more earth-toned than depicted in other astronomical images, including earlier Hubble pictures. We need accurate colors to determine the composition and mineralogy of Mars. This information can tell how water has influenced the formation of rocks and minerals found on Mars today. It can also provide clues to the distribution and abundance of ice and subsurface liquid water. The slightly bluer shade along the edges of the disk is due to atmospheric hazes and wispy water-ice clouds (like cirrus clouds). The yellowish-pink color of the northern polar cap indicates the presence of small iron-bearing dust particles. These particles are covering or are suspended in the air above the blue-white water ice and carbon dioxide ice that make up the polar cap.*

***Bottom:** A false-color picture taken in infrared light reveals features that cannot be seen in visible light. Hubble's unique infrared view pinpoints variations in the abundance and distribution of water-bearing minerals on the planet. While it has been known for decades that small amounts of water-bearing minerals exist on the surface, the reddish regions in this image indicate areas of enhanced concentrations of these as-yet-unidentified deposits. The large reddish region known as Mare Acidalium was the site of massive flooding early in Martian history—*Mars Pathfinder *landed at the southern edge of this region in 1997.* *Images: Space Telescope Science Institute/NASA*

As in the essay contest, completed journals are submitted first to a Regional Center, where winners are chosen representing each of the three age categories. These quarterfinal winners will then be forwarded to the National Center for semifinal judging, with winners being sent to The Planetary Society for the selection of the final Student Astronaut Candidate Team.

Student Astronaut Candidates will be divided into the Student Astronaut Team and the Student Astronaut Backup Team, in case a Student Astronaut is unable to perform his or her duties. Both teams will receive nine months of intensive training via the Internet. During mission operations, the Student Astronauts will take shifts living and working in the simulated Mars base,

(continued on page 16)

Science Instruments Aboard Mars Surveyor 2001

On April 10, 2001, the Mars Surveyor 2001 mission is scheduled to begin its journey to the Red Planet. The lander is equipped with a robotic arm to scoop and sample Martian soil and with a rover, named *Marie Curie*, similar to *Mars Pathfinder*'s *Sojourner* rover.

"Red Rover Goes to Mars will provide an incredible opportunity for students to experience, first hand, the inner workings of a complex scientific endeavor—the Mars 2001 lander and rover integrated science experiments." — R. Stephen Saunders, Mars Surveyor 2001 Project Scientist

This artist's conception depicts Mars Surveyor 2001 after landing and the* Maria Curie *rover exploring the nearby terrain. *Illustration: JPL/NASA*

Set to touch down in January 2002, the '01 lander mission has two primary goals: to study geologic terrain on Mars and to gather information for eventual human exploration. The first of these two goals is the job of the APEX experiment. Led by Cornell University and run by a team of scientists from around the world, the APEX experiment will prepare Mars researchers for the 2005 Mars Sample Return mission —the first space expedition designed to return rock samples from another planet.

APEX carries a payload of four tools. The tall mast of the lander houses two of them—Pancam at the top and Mini-TES at the base. Pancam uses two high-resolution, digital cameras, with resolution almost four times that of the cameras on the *Pathfinder* and *Mars Polar Lander* missions, to provide a panoramic 3-D view of the Martian surface. Mini-TES, or the Mini-Thermal Emission Spectrometer, observes the infrared (or thermal) radiation emitted by rocks and soils. Detecting and imaging thermal radiation allows scientists to see what is under thin layers of dust that cover Martian rocks. Both Pancam and Mini-TES will be used to identify which rocks and landscape features the rover team wants to study in more detail.

A Mössbauer spectrometer, the third of the lander's APEX instruments, is mounted on the robotic arm. Designed to determine with great accuracy the composition and abundance of iron-bearing minerals, the Mössbauer spectrometer will analyze dust samples from the air collected on a magnet. Identifying these minerals may provide information about early environmental conditions on Mars and could yield clues to the likelihood of past Martian life.

The fourth tool, called the Alpha-Proton-X-Ray Spectrometer (APXS), is located on the *Marie Curie* rover. APXS can sample and determine the chemical make-up of rocks and patches of soil that are out of the lander's reach. This information is valuable in understanding Martian weathering processes, water activity, and the formation of the Martian crust.

Learning all we can about what Mars is like today not only provides clues to how it might have been millions of years ago, it also provides basic knowledge necessary to plan for the future. In the next 20 years, NASA hopes to send astronauts to Mars. These astronauts may be living on the surface of Mars for 500 days or more. How will they protect themselves from the hostile Martian environment? How can they use Martian elements to grow food and generate power for long-term living?

The Mars Radiation Environment Experiment (MARIE) will measure how much protection the atmosphere of Mars provides against cosmic radiation. A pair of spectrometers—one on the orbiter, the other on the lander—will take readings above the atmosphere and at the surface, giving us vital insight on hazards from constant, low-dose radiation and sporadic radiation from solar flares. The Mars Environmental Compatibility Assessment (MECA) project is a set of instruments on the Mars Surveyor '01 lander that will investigate surface hazards that could affect human exploration. The MECA payload includes a Wet Chemistry Lab to evaluate samples of Martian soil in water, looking for hazardous chemical components, including peroxides, strong acids/bases, and heavy metals. The Microscopy Station, combining an optical microscope, an atomic-force microscope, and an abrasion tool, will study particle morphology, hardness, adhesion, and abrasion. On the robotic arm's scoop, an electrometer will measure atmospheric radiation to answer the question "How much electricity builds up when the robot arm is digging?" Also, the lander's Robotic Arm Camera will observe a number of material "patches," such as Plexiglas and various spacesuit fabrics, to record the effects of the harsh Martian environment.

Additionally, the Mars Surveyor 2001 lander will be a platform for new technology, including the Mars In-Situ Propellant Production Precursor (MIP), which will acquire and compress Martian atmospheric carbon dioxide and produce pure oxygen for rocket propellant —a necessity for cost-effective human missions to Mars.

And for the first time in history, a sundial will be sent to another planet. Initially, the sundial's black, gray, and white rings will serve as a calibration target for the lander's Pancam. But over time, pictures of the sundial will reveal the passage of the hours and seasons as the Sun moves across the Martian sky. Inscribed with the motto "Two Worlds, One Sun," the sundial carries a message for future Martian explorers. —*JV*

Detailed information about the Mars Surveyor 2001 mission is available on the Internet at:
http://mars.jpl.nasa.gov/2001/index.html

Because Mars is a desert world, winds often pick up dust as they blow across the Martian plains. **Mars Global Surveyor***'s Mars Orbiter Camera (MOC) captured this view of a dust storm advancing southward across the northern plains toward Tempe Terra on August 22, 1998, which is early northern spring on Mars. The storm front is delineated across the bottom quarter of the image by a sharp boundary between clear atmosphere, where craters are visible on the surface, and cloudy atmosphere, where the surface can barely be seen.* Image: MSSS/NASA

(continued from page 14)

and the Student Astronaut Backup Team will serve as media representatives, keeping major networks and newspapers as well as local media groups informed about the daily activities and progress of the Red Rover Goes to Mars Student Astronauts and Scientists.

There are still a few months before the start of the Student Astronaut Selection Journal Contest, which begins March 1, 2000, but this contest will undoubtedly be very competitive, so it's certainly not too early to start preparing.

Growing the Red Rover Network

Since participation in the Student Astronaut Selection Journal Contest requires students to have hands-on experience using Red Rover, Red Rover or similar products, we had to find a way to expand our Red Rover, Red Rover network to new places. Through a random drawing in April 2000, The Planetary Society will donate a number of Red Rover, Red Rover systems to institutions, schools, clubs, science centers, or other places where children gather.

To participate in this drawing, interested institutions must write a letter to The Planetary Society during the month of March 2000, explaining approximately how many children will be able to use the Red Rover, Red Rover system to participate in the astronaut contest, should that particular institution receive a donation.

Check the Red Rover Goes to Mars Web site for detailed information on how to enter the drawing.

Global Volunteers Needed

Although part one of the selection process is just beginning, we have been working for months to find and aid the development of National and Regional Centers around the world. A Regional Center is completely based on volunteer efforts. We are thrilled to report that Regional Centers are emerging across the US and worldwide, in places such as the UK, Korea, Kenya, Austria, New Zealand, Romania, Jordan, Nepal, and Japan. We have tried to make this opportunity as accessible as possible so that any community, anywhere, can build its own Regional Center for no more than the cost of some photocopies and the time of a few dedicated volunteers. In many cases, the initial spark of enthusiasm in one person was all it took to get the ball rolling, and teams of teachers, parents, scientists, and other professionals emerged to ensure their own community's involvement in Red Rover Goes to Mars.

Of course, Regional Centers have the important task of choosing the quarterfinalists for both the essay and the journal contests, but they will also be the place for local children to get specific information about the contests and to get general advice about how to find resources for their research. Regional Centers become one of the most important factors in facilitating this global effort.

Get Involved

It is of utmost importance to remember that Red Rover Goes to Mars is child-centered and child-driven. Both the essay and the journal contests are open only to children born on or between January 31, 1984 and January 31, 1991. Interested adults can help in many ways—by contacting local schools and community centers to get the word out, helping establish a Regional Center, or volunteering to become a mentor for a contestant. But once the word is out and the resources are available, it's up to the students themselves to take it to the next step. With the hard work of student participants, dedicated adult volunteers, and The Planetary Society, we will make this dream come true, and, through the eyes of a child, we will share the wonder and achievement of planetary exploration with the world.

Jennifer Vaughn is Assistant Editor of The Planetary Report.

Watch this project, as it evolves, on The Planetary Society Web site:
http://planetary.org

World Watch

by Louis D. Friedman

Washington, DC—We have been inundating Planetary Society members with news from Washington, DC about the threatened deep cuts to NASA's budget. Our urgent calls for action came to you in the mail and by e-mail, if you are one of the 10,000 who have signed up on our e-mail list. We reached tens of thousands of others who visit our World Wide Web site.

And our efforts paid off: before Congress recessed for its summer break, the House of Representatives' Appropriations Committee changed the proposed cut to NASA from $1.4 billion to "only" $1 billion.

As I write this column, Congress is still in recess and that $1 billion cut is still hanging over NASA's head. We continue to fight, but, as one congressional insider told me the day before Congress recessed, there are still as many amendments to cut NASA's budget being proposed as there are to put money back.

The attack on space exploration is not an attack on its merits. There is little opposition to missions to Mars, comets, Titan, and other solar system objects or to searching for planets around other stars or to probing the nature of the universe. Most politicians see space exploration as a good thing—but not as something important. This mindset has been confirmed in many polls, even in polls we take among our own members.

Personally, I don't understand this. To me, space exploration is the search for knowledge and an attempt to understand ourselves in relation to the cosmos. Exploration is as important for society as teaching children to read is for a family.

In the political realm, we run into a second objection—that planetary exploration isn't big enough! Politicians tend to vote for things that have big impacts on their constituents: jobs, taxes, health care, welfare, and exotic weapons. The minor government expenditures for planetary exploration don't get as much attention as building expensive (high-employment) systems like missile defense—no matter what the merits.

To overcome these two factors, unrecognized importance and lack of bigness, we have to do some work. We have to raise consciousness with better arguments, more activism, and increased intensity. Although NASA is the world's largest space agency, planetary exploration is not just an American issue. We must make ourselves heard in every country around the world. In spacefaring countries such as France, Germany, and Japan, we must press the same arguments. In non-spacefaring countries, we must make the case for supporting science and technology at all levels of society—especially for education. Our international members can call for action in their own countries and even write the US ambassadors in their capitals to tell them of their support of US space missions. Our American members should be just as aware of international ventures and write in support of them.

We don't know what will happen when Congress returns. NASA's situation is part of a partisan battle over budget surpluses. We do know, sadly, the battle of budget priorities has to be fought with tactics of noise as much as with reason. As another congressional representative said, "We know that not all of these cuts will stand; we just have to see who yells the loudest."

At The Planetary Society, we like to think of ourselves as a public interest group, not as a special interest group. We are not funded by governments or the aerospace industry. But we do depend on governments in the pursuit of our goals—exploration of the solar system and the search for extraterrestrial life. We can and do secure private funding for clever initiatives such as SETI@home, the Mars Microphone, and so on. But make no mistake: for many, many years to come, missions to other worlds are not going to be accomplished by anyone other than governments.

Commercialization and private initiatives in space are good and welcome developments. In fact, The Planetary Society is leading the way with relationships we are building in private industry. But it is still true that societies organize great achievements of science and exploration through governments. If we don't support government programs for science, technology, and exploration, they will not happen.

To keep up with the latest news relating to the NASA budget, visit our Web site (**http://planetary.org**).

Great Britain—The British government has announced its financial support for the development of the *Beagle 2* lander to fly on the European Space Agency's *Mars Express*. This rare expression of British government support for space science is most welcome. The *Beagle 2* team, led by Colin Pillinger of the Open University, deserves great credit for their effort. The lander, which includes first-rate experiments relevant to life detection on Mars, is still not fully funded, but the expression of government support should help convince backers in private industry that the venture is very worthwhile.

Louis D. Friedman is Executive Director of The Planetary Society.

News and Reviews

by Clark R. Chapman

Late one evening in mid-August, I experienced an exciting "Internet moment." An e-mail message arrived from radar astronomer Steve Ostro of the Jet Propulsion Laboratory (JPL), encouraging me to enjoy some new radar images of an Earth-approaching asteroid, called 1999 JM8. For years, NASA and the National Science Foundation have been upgrading the capabilities of American radar observatories, especially the giant, non-steerable dish at Arecibo, Puerto Rico, which was featured in the movie *Contact*. These efforts are bearing fruit.

I pasted the URL address into Netscape and was soon marvelling at the best-ever images of a small body (an asteroid or comet), except for *Galileo*'s early-1990s close-ups of Gaspra and Ida. The images of this 4-kilometer-wide body (about 2 1/2 miles wide), which passed just 20 times as far from the Earth as the Moon, are better than comet Halley portraits by European and Russian spacecraft or the sequence taken during last December's premature flyby of Eros by the Near Earth Asteroid Rendezvous spacecraft.

The most telling contrast, however, is with *Deep Space 1* (*DS1*), the first New Millennium mission. Its failed-but-hyped encounter with a Mars-crossing asteroid happened while JM8 was being scrutinized by the Goldstone radar in California.

The several hundred planetary scientists attending the international Asteroids Comets Meteors (ACM) meeting at Cornell University were disappointed by reports that *DS1*'s automated pointing technology (AutoNav) failed to locate the asteroid, so pictures were taken of blank sky. Its target was the diminutive object 1992 KD, renamed Braille in a Planetary Society-sponsored contest. (Sardonic journalists derided NASA for "flying blind" past an asteroid named to honor the inventor of the raised alphabet used by the visually handicapped.)

The disappointment of some scientists turned to vocal disdain, however, when they then saw the JPL Press Office's "spin" on *DS1*'s failure. In a press release entitled "NASA's *Deep Space 1* Succeeds in Close Asteroid Flyby," the deputy mission manager is quoted as extolling "AutoNav's successful piloting of the spacecraft" and declaring the encounter with Braille to be "a dramatic finale to an amazingly successful mission." JPL even claimed, absurdly, that it "exceed[ed] 100 percent of [its] objectives."

A few days later, while Arecibo was receiving echoes from JM8, NASA staged a press conference to tout *DS1*'s alleged success. Presenters exclaimed over *DS1*'s infrared spectrum of Braille, which they said essentially proved that it was composed of rock, like the third-largest asteroid, Vesta. (This didn't surprise scientists returning from ACM, where ground-based spectra suggesting Braille's possible affinity with Vesta had been presented several days before *DS1*'s flyby.) So little real news emerged from the press conference that the *New York Times* irrelevantly headlined its brief report "Baby Asteroid Poses Threat Years Hence." *DS1*'s fuzzy, virtually meaningless pictures of Braille, taken a full 15 minutes after encounter, were released two days later.

For decades, spacecraft missions have gotten the hype, and even undue credit, while solid results of ground-based telescopic research remained unsung. A big discovery attributed to *Mariner 4* in 1965 was that Mars has a very low atmospheric pressure at the surface—less than 1 percent of sea-level pressure on Earth. Yet that had been derived and published in 1964 by Gerard Kuiper and Tobias Owen, among others, from analyzing telescopic spectra of Mars (they calculated 1.7 percent).

Many things can be researched only by sending spacecraft out to remote locations. But spacecraft results aren't always better than those obtained by methods costing a hundred times less. *DS1*'s designers would hasten to point out, correctly, that the mission's primary goal was to demonstrate new technology and that scientific goals were secondary. But engineering goals should never be sole ends in themselves (although they often seem so in NASA), and scientists and the public properly expected to be rewarded with truly new knowledge about Braille. When those goals were not met, JPL's New Millennium Project could fairly point with pride to some of *DS1*'s technology demonstrations, but it was disingenuous for them to pretend that the Braille flyby was "successful" and that serious scientific goals were met.

Real scientific results were being presented at Cornell but receiving much less press attention. While Lance Benner was observing JM8 at Goldstone, his colleagues at ACM, including Ostro, were showing spectacular radar pictures of other asteroids. Dramatic advances were being reported about how asteroids are cleared out from the inner part of the asteroid belt and how dormant comets are removed from the Kuiper Belt (by Pluto!). Ninety-three-year-old Fred Whipple reported his new insights about comets. And the discovery of new moons of Uranus was announced.

Creative research using ingenious ground-based instruments is in full flower. And yet, even as the ACM meeting was going on, Congress was threatening to cut 60 percent of the funding of such research. Given that each year the *entire* NASA Planetary Astronomy research program costs less than 10 percent of the *DS1* mission, it is unfortunate that *DS1*'s failure should be so glibly touted to the taxpayers as a success. The budget cutters might be perplexed, and all researchers could suffer.

Clark R. Chapman is part of a team, led by Bill Merline, that reported at the ACM meeting the discovery, using the Canada-France-Hawaii ground-based telescope, of a satellite orbiting the main-belt asteroid 45 Eugenia.

Society News

Your Directory, Your Choice

As most of our members know, we are producing a membership directory for the Society. Many members have asked for such a listing as a way to bond more closely with the organization. Others object, feeling that a directory is a potential invasion of privacy or that the offer to purchase the directory is too pushy.

Having yourself listed and deciding to purchase a directory are completely voluntary. Becoming part of the listing should not be intrusive—phone numbers and addresses will not be included, and the information will not be exchanged or sold. The directory company does use mass-marketing techniques; that, unfortunately, is how such businesses exist. However, a simple "no" should be sufficient if you decide not to be listed or not to purchase the directory.

The Planetary Society will realize a donation to our projects based on the sales of the directories, and since it is a voluntary activity with some Society benefits, we decided to try it for our members.
—Louis D. Friedman,
Executive Director

Asteroid Braille Named in Society Contest

The target of NASA's *Deep Space 1* mission now has an official name: 9969 Braille, after Louis Braille, the inventor of the language system for the blind. The asteroid, formerly known as 1992 KD, was discovered by Eleanor Helin and Ken Lawrence of the Jet Propulsion Laboratory in 1992. Helin and The Planetary Society chose the theme Inventors for the worldwide contest. Kerry Babcock of Port Orange, Florida submitted the winning name, which Helin and Lawrence chose out of hundreds of entries. *Deep Space 1* flew past asteroid Braille on July 28, 1999.
—Donna Stevens, Associate Editor

Planetcast a Success

Thanks to all who participated in the first-ever Planetcast, a live broadcast from our Web site. Louis Friedman, Society Executive Director, and Bob Nelson, *Deep Space 1* Project Scientist, discussed that mission's results, as well as threats to NASA's budget.

Watch for the beginning of the official Planetcast series on September 23, the kickoff date for Planetfest '99. Be sure to have Real Player (**www.realaudio.com**) installed on your computer so you can join in the discussion.
—Cynthia Kumagawa,
Manager of Electronic Publications

More News

Mars Underground News: Mars Polar Lander gets closer to landing on and listening to the Red Planet.

Bioastronomy News: Scientists across the globe are now exploring the origins and development of life in the universe.

The NEO News: Asteroid and comet discoverers have a new tool that can help them inform the public about the potential hazards of an object's collision with Earth.

For more information on The Planetary Society's special-interest newsletters, phone (626) 793-5100.

Also, visit our home page at *http://planetary.org*

Questions and Answers

How are the distances to deep space objects calculated?
—Jeanette Howard,
Halifax, Canada

Scientists have devised a number of methods for measuring astronomical distances. The oldest is based on an effect called parallax.

Hold out your thumb in front of you; then close your left eye. Now, keeping your thumb still, open your left eye and close your right eye. Notice how your thumb appears to shift position relative to whatever you can see beyond it? This "parallax effect" occurs because your left and right eyes look at your thumb from slightly different angles.

Now imagine drawing lines from your thumb to each eye plus a line between your eyes. These lines form a triangle. The line between your eyes is called the baseline. If you measure the length of the baseline and the apparent shift of your thumb as you look at it with each eye, you can calculate the distance to your thumb. A little basic geometry is all you need.

Suppose you want to determine the distance to a tall tree on the other side of a wide river. How could you do it without crossing the river? You can create a baseline as long as you want simply by moving from one place on the riverbank to another. When you change positions, you'll see the tree appear to move relative to more distant objects, such as a range of mountains far beyond the tree. The parallax effect gets bigger as your baseline gets longer.

Centuries ago astronomers were able to roughly calculate the distances to the Moon, the Sun, and the other planets by observing how they appeared to shift relative to much more distant background stars over the course of a night. As Earth rotates from dusk to dawn, the scientist, in effect, moves from one "side" of our planet to the other, giving a baseline of about 12,800 kilometers (8,000 miles). This is enough to determine distances to objects within our solar system. But to measure the distances to stars, we need an even longer baseline.

If a nearby star is observed in June and then again in December, it will shift slightly relative to more distant background stars because the Earth has moved through half of its orbit during this six-month period. Since the Earth is 150 million kilometers (93 million miles) from the Sun, the baseline is 300 million kilometers (about 190 million miles). Given this baseline, we can calculate the distances to nearby stars.

This works well for stars that lie within a few dozen light-years of the Earth, but the parallax effect becomes very small and hard to measure for more distant stars, not to mention other galaxies, which are millions of light-years away. Astronomers have discovered a number of "standard candles" that allow them to determine these immense distances. For example, certain kinds of novas (exploding stars) peak at about the same absolute brightness. By comparing the apparent brightness of a nova at its peak to its known, true brightness, we can calculate its distance. A nova in distant galaxies can therefore be used to determine the distance to that galaxy.

—ANDRE BORMANIS,
Planetary Society Program Development

In the May/June 1999 issue of* The Planetary Report, *David Stevenson writes that it was possible to determine the moment of inertia of Callisto from studying the motion of* Galileo. *[See "How Gravity Reveals Inner Structure" on page 10.] I have often seen this mentioned (there was a similar statement about determining the moment of inertia of Mars from the motion of the* Mars Global Surveyor*), but I'm not sure that I understand it.

If a heavenly body is spherically symmetric, its gravity cannot be distinguished from that of a point source, and the most that an orbiting spacecraft could measure would be the body's mass. If the body is not spherically symmetric, the orbit of a spacecraft will precess (wobble). I do not see how it is possible to determine the moments of inertia separately without some additional assumption independent of the motion of the orbiting spacecraft.
—Jeremy Tatum,
Victoria, Canada

This is a good question because it illustrates how scientists sometimes make "hidden" assumptions whose validity should always be carefully evaluated. Rotating bodies are not spheres, and the gravity field external to all rotating bodies is accordingly not just that of a point mass—it has a piece that tells you about the mass distribution inside that planet (and especially its equatorial bulge due to rotation).

However, this is not sufficient to determine the moment of inertia* of a planet or satellite. Fortunately, it is usually true that the planet or satellite is very close to hydrostatic equilibrium, which means that it deforms as though it were a fluid. This seems astonishing until you realize that the insides of all planets are "soft" (can flow like a fluid on very long timescales) even though they are mostly solid in the everyday sense of the word. For example, water ice is solid but flows (as in glaciers). In the case of Earth, this softness allows us to have plate tectonics, but Mars, large icy satellites, and even the Moon also have this property (despite having no plate tectonics).

Small bodies such as asteroids do not have this property. The combination of the assumption of hydrostatic equilibrium and that part of the measured gravity field due to rotation of the planet or large satellite enables us to get the moment of inertia. The theory is quite complicated but was worked out (at least approximately) about a century ago.

Is the assumption true or verifiable? In a few special cases, we can assess the truth of it by determining the moment of

* The moment of inertia is a property of rotating bodies. For example, a hollow spherical shell has a higher moment of inertia (that is, it takes more effort to set it rotating) than a solid sphere of the same mass and radius. And a uniformly solid ball has a higher moment of inertia than one with a denser central core (but still the same total mass and radius).

inertia in a different "exact" way. In the case of Earth and Mars, it can be done by measuring what is called the precession constant (the rate at which the rotation axis changes due to torques exerted by other bodies; for example, the Sun). This measurement together with gravity yields two simultaneous equations from which one can solve for the moments of inertia. The result agrees quite well, though not exactly, with that from the method outlined earlier. The disagreement tells us about small but important deviations away from hydrostatic behavior. In the case of an icy moon such as Callisto, one can, in principle, compare the relative amplitudes of the distortions due to tides and rotation with the predicted behavior for a fluid. But one should always be aware of the uncertainties introduced by the assumptions made.

—DAVID J. STEVENSON,
California Institute of Technology

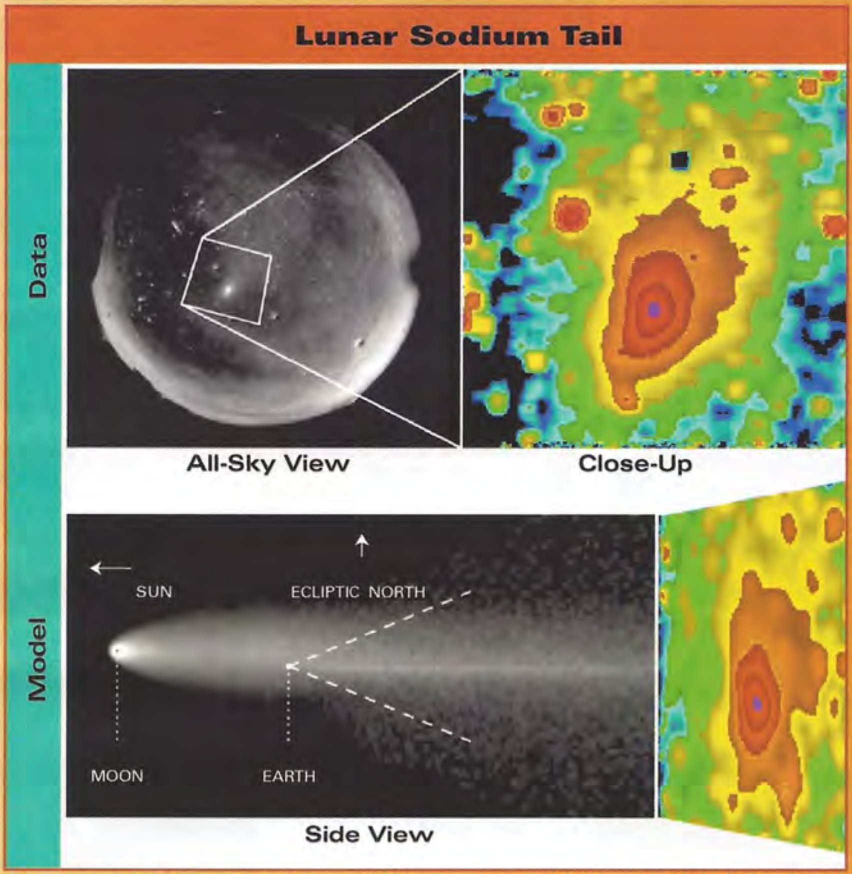
Factinos

The Moon has an enormous tail of sodium gas that stretches out to a distance of at least 500,000 kilometers (about 310,000 miles), reports a team of scientists from Boston University's Center for Space Physics (see image at right). The researchers made their observations at the McDonald Observatory in Fort Davis, Texas on the nights following the Leonid meteor shower in November 1998—when the Moon was in its "new" phase.

The team recorded, just by chance, images of the sodium tail in an otherwise moonless sky over three nights and, one by one, ruled out possible causes of the mysterious gas. Jody Wilson, a research associate with the space physics group, suggested that the sodium emanated from the Moon. "We found out that when the Moon is new, it takes two days or so for sodium atoms leaving the surface to reach the vicinity of Earth. They are pushed away from the Moon by the pressure of sunlight, and, as they sweep past us, Earth's gravity pulls on them, focusing them into a long, narrow tail," Wilson said.

"The pieces of the puzzle fit together rather well," added Michael Mendillo, professor of astronomy at BU. "While some of the Leonid meteors burned up in their streaks through Earth's atmosphere . . . others crashed into the Moon's dusty soil, liberating sodium gas. These atoms, speeding away from the Earth-Moon system, were then captured in photographs . . . several days later, looking down the length of the tail."

—from Boston University



These images of sodium gas emissions from the Moon were captured in November 1998, after the Leonid meteor shower. Scientists from Boston University (BU) discovered that the sodium atoms were liberated when some of the meteors struck the lunar surface. The gas then streamed away from the Moon, creating a long "tail." The color close-ups display sodium concentrations, with purple and red representing the highest concentrations and dark blue the lowest. "If it [the tail] were bright enough for the human eye to see, perhaps a thousand times brighter," said BU researcher Jeffrey Baumgardner, "it would be a glowing orange cloud dominating the nighttime moonless sky." Images: Boston University Center for Space Physics

Jupiter's moon Io could be a salty world, according to two scientists from the University of Colorado at Boulder. Nick Schneider and Michael Kueppers of the university's Laboratory for Atmospheric and Space Physics believe the recent discovery of chlorine (an ingedient in sodium chloride, or common table salt) is related to all the violent volcanic activity on that satellite. "In fact, Io seems to have a higher proportion of chlorine in its atmosphere than any other object in the solar system," said Schneider. Kueppers and Schneider used a telescope at the Kitt Peak National Observatory in Arizona to make their findings, including the discovery of chloride emissions in the ring of charged particles around Jupiter known as the Io torus.

"Chemical reactions may actually produce salt in the atmosphere," said Schneider. "The study of chloride on Io is sure to benefit from the extensive research on Earth's ozone hole, which in turn benefited from the study of chlorine in the atmospheres of other planets." On Earth, small amounts of chlorine from human-made pollutants go far in breaking down ozone in the atmosphere.

The pair presented a paper detailing their findings at a meeting of the American Geophysical Union held in Boston this past June.

—from the University of Colorado

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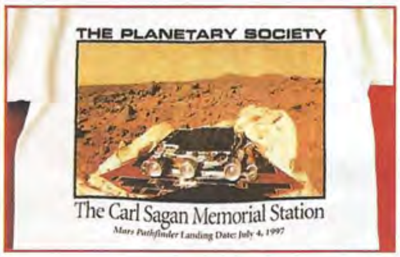

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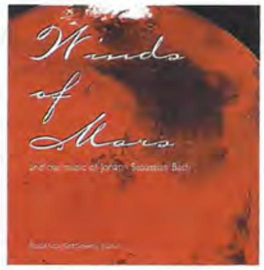

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MAX ERNST (1891–1976) was a pioneer of 20th century art. In 1946, he moved to Sedona, Arizona, where he painted *Moon and Mars*. Enigmatic astronomical signs and mysterious fields of energy between the Sun, Moon, Earth, and stars were a characteristic of Ernst's work since the beginning of his career.

A poet and self-taught artist, Ernst and other members of the avant-garde formed a Dada group in Cologne, Germany. In 1925, he displayed his work at the first Surrealist painting exhibition in Paris. Ernst developed a technique called *frottage*, in which a sheet of paper is placed over an object and rubbed with a pencil until the texture of the surface is transferred. He also produced some of the earliest "drip" paintings.

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