The PLANETARY REPORT

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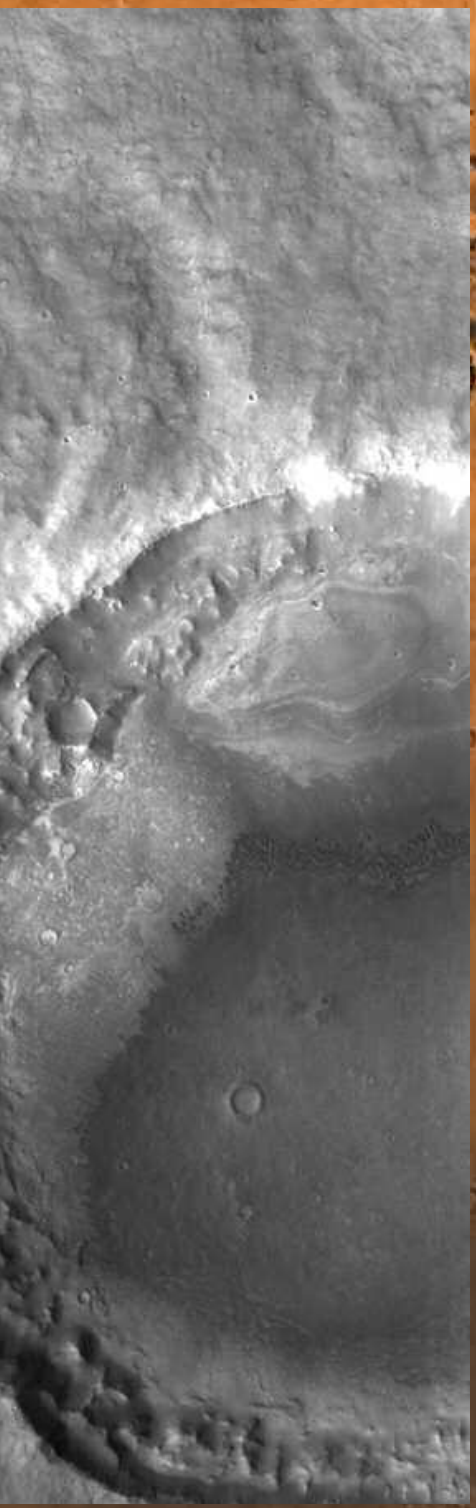

Reading the Rocks

A PUBLICATION OF THE PLANETARY SOCIETY

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From The Editor

"Space is unforgiving." Lou Friedman, Planetary Society executive director, reminded us of that when we received word that *Nozomi*, the Japanese mission to Mars, would fly past its target world and fail to achieve its mission. Instead of exploring the Red Planet's upper atmosphere, *Nozomi* will continue into an orbit about the Sun. Mission leaders are hopeful they will be able to squeeze another sort of science out of the spacecraft.

As I write this, four other spacecraft are closing on Mars. At The Planetary Society, we've lived through the losses of *Mars Observer*, *Mars Climate Orbiter,* and *Mars Polar Lander*. We had an instrument, the Mars Microphone, on the last mission in 1999 fall victim to the Great Galactic Ghoul, the Monster of Mars, or whatever imaginary beast people use to personify the extreme difficulty of exploring other worlds.

But it is just that difficulty—demanding the utmost effort of which we are capable—that makes planetary exploration so extraordinarily rewarding when we succeed. *Mars Express, Beagle 2*, *Spirit,* and *Opportunity* are still carrying our hope to Mars, and though there may well be more failures to come, it is still an extraordinarily worthwhile endeavor.

We won't stop. We can't. Humanity must explore.

—Charlene M. Anderson

On the Cover:

We study rocks to discover clues about a planet's geologic and climatic history. On Earth, gray hematite (center) is commonly formed in liquid water. When scientists detected gray hematite on Mars, they pondered whether it, too, formed in water—could it be evidence of a warmer, wetter past?

Gray hematite has been identified in three locations on Mars—Valles Marineris (background), Meridiani Planum (left), and Aram crater (bottom).

Images: Background: JPL/NASA; left: NASA/JPL/Arizona State University; center: John Betts Fine Minerals; bottom: Kees Veenenbos

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Members' **Dialogue**

In this issue, we'd like to share a few of the letters we received in response to our website, planetary.org

On "The Trials of Galileo" (September 16, 2003):
Galileo is truly an amazing story of a mission that beat insurmountable odds. I remember how let down I felt when I first heard that its main antenna wouldn't unfurl. It is extremely rewarding that the mission scientists and engineers were able to devise a "workaround" to what seemed to be the demise of the mission, and that it survived to capture such a fantastic collection of useful data.

My disappointment when a mission fails can nowhere near compare to that of the people whose heart went into creating the mission—as has happened many times. It is wonderful that there have been so many success stories that have enriched all of our lives with the enlightenment found through new discoveries. *Galileo* was one such mission that inspired tremendous hope and joy to people all over the world.

Keep up the good work, and may you always have the element of success on your side.
—GREG BROWNELL,
Notre Dame, Indiana

I remember when *Galileo* sent its first pictures of Jupiter. We had a new boss at the office and he called a special introductory meeting of upper managers. I skipped the meeting so I could follow the happenings on the Internet. Luckily the new boss didn't last long, otherwise my last few years before retirement could have been difficult.
—FRED MERCHANT,
Akron, Ohio

On Wesley Huntress' Testimony to Congress on the Future of Human Space Flight, October 2003:
For most of my life I have been interested in space exploration. Sometimes mildly interested, sometimes keenly interested and sometimes passionately interested. But reading this testimony has rekindled a spark in me that was missing for some time. I thank you for this.
—JOHN SHERIDAN,
Dublin, Ireland

On The Planetary Society's Nuclear Propulsion Space Initiative White Paper:
I fully concur with your position paper on the Nuclear Propulsion Space Initiative. We must continue to pursue a vigorous space exploration program and, at the same time, prepare for the future by developing high-power RTG's and nuclear electric propulsion systems.

Keep up the good work and keep the pressure on those politicians and bureaucrats! They will only listen if we keep on making noise.
—ED KUTZ,
Arlington, Texas

On SETI@home:
Like many others, I wanted to explore the world firsthand as an astronaut, but that didn't happen. I would have loved to have helped humanity by doing important medical research, but that didn't happen. I would have loved to be a great scientist, but that didn't happen.

Instead, I've spent my career as a tax assessor irritating most of humanity. Thank God SETI has opened the possibility for redemption.

By donating a few hours of computer time, I get to participate in one of the most unique projects in human history. I am lucky enough to have some deliciously tantalizing scientific data passing through my computer. And, there is a very small, but real possibility that I could be involved in truly momentous discovery.

Participating in SETI has been fun too. The "techno" look of the screen saver with its bold declaration that a search for intelligent extraterrestrial life forms is being conducted in my office has led to the greatest human reactions—total disbelief from my more staid acquaintances and envy from those less savvy than I. (HA!)

There is no question that other monumental computing tasks will be completed only because SETI's groundbreaking example will be followed.

Thank you for the opportunity to participate in this adventure.
—JOE TURNER,
Saginaw, Michigan

Please send your letters to
Members' Dialogue
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or e-mail:
tps.des@planetary.org

We Make It Happen!

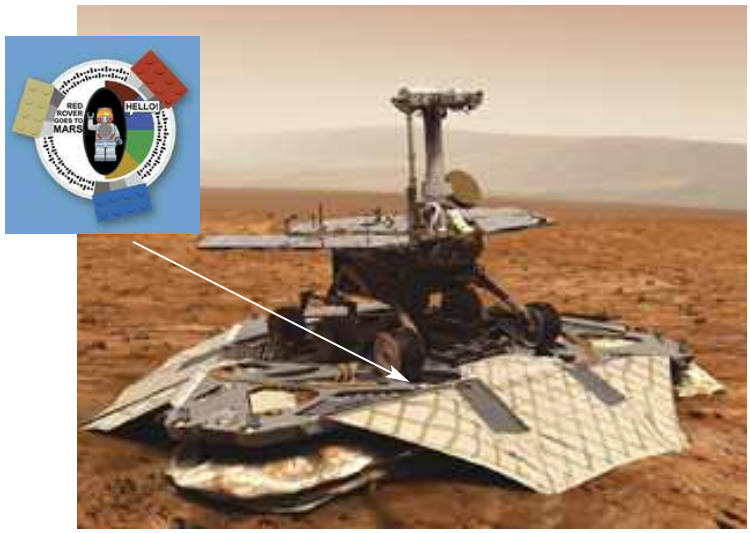
by Bruce Betts

This issue, I have extraterrestrial secret codes you can crack, sundials you can make, and a new feature you can use. The new "What's Up?" feature, adapted from our weekly Planetary Radio show, is for the whole family. It provides fun information about space, including things that are easy to see in the night sky and a trivia question.

Secret Messages from Mars: Decode Them!

For well over a hundred years, certain people have claimed that there are secret messages being beamed to us from Mars. I finally agree—because we're putting them there.

As part of The Planetary Society's Red Rover Goes to Mars project (see "We Make It Happen!" in the May/June 2003 issue of *The Planetary Report*), we have provided mini-DVDs to each NASA Mars Exploration Rover spacecraft.



The Red Rover Goes to Mars DVD, on board both spacecraft carrying the Mars Exploration Rovers* Spirit *and* Opportunity*, will land on Mars in January. Each DVD has a different secret code on its face (shown here without the real code).

Images: JPL/NASA; Mars Exploration Rover rendering by Daniel Maas/Mass Digital LLC

They carry almost 4 million names of Mars enthusiasts to the surface of Mars. They also carry more: as part of a unique activity to engage students and the general public worldwide in space exploration, each also has, on its face, a different secret code.

After the spacecraft land on Mars, the Mars Exploration Rover project will image the mini-DVD within two to four days. You, your family, your relatives—even your pets, if they're so inclined—can come to the Exploring Mars section of our website at *planetary.org/mars* to view the image and attempt to decode the secret passwords. We'll release clues every day or two to make the job a little easier.

The first to decode the messages will win spiffy prizes. All who succeed in decoding each of the two passwords can download certificates of accomplishment. In the process, you can learn about data transmission and the clever codes we've employed on the DVDs, both of which are used a lot on Earth (oops, was that a clue?). While you're on our website, you can also learn all about the mission, Mars, and our Red Rover Goes to Mars project. Have some fun, learn a lot, come play!

Sundials on Earth: Build Them!

For centuries, humanity used sundials to mark time by tracking the motion of the Sun across the sky. The EarthDials project will use a network of sundials around the world to show many facts about planetary motion that can be learned from these simple devices. This network of sundials is being created at the same time that sundials will be roving on Mars with the Mars Exploration Rovers (see "The MarsDial: A Sundial for the Red Planet" on page 6), a project that The Planetary Society is also deeply involved in with our Red Rover Goes to Mars Student Astronauts. This is a perfect time and tie-in for us. The EarthDial project is a partnership among The Planetary Society; Bill Nye, the Science Guy and Nye Labs; and Woody Sullivan at the University of Washington. Bill and Woody, both sundial fanatics involved in Mars exploration, brought the EarthDial concept to us.

You can get involved right now by building your own EarthDial. Instructions are on our website at *planetary.org/mars/earthdial.html*. They include automatic adjustment of the lines on the EarthDial based on your latitude. Individuals, schools, and clubs around the world are invited to participate, with each location creating its own unique EarthDial and embellishing it with designs representative of its region.

After building an EarthDial, you can send us just a single image of your EarthDial to post on our website, or you can set up a webcam that can provide regular images of your EarthDial for posting. Once we assemble a network of those willing to provide webcam images for our website, we will unveil part two of the project, where you will be able to see near-live images of a number of EarthDials around the world. You can use this to demonstrate to kids, neighbors, and, yes, pets, the variation in sun angle around the world at any given moment, or to ponder the passage of time.

Bruce Betts is director of projects at The Planetary Society.

What's Up?

In the Sky

Lots of planets are easy to see right now. Exact locations of planets will vary somewhat depending on your latitude, but this guide will get you close.

Venus: Looks like the brightest star in the Western sky for two to three hours after sunset.

Mars: Reddish-orange bright "star" high in the sky in the evening. Still easy to see, but fading.

Saturn: Rises around sunset in the East and sets around sunrise in the West. Yellowish and bright.

Jupiter: Very bright (only Venus is brighter right now), rising in the East in the late evening.

As we move into February, you'll be able to see all four planets at once, as Jupiter rises before Venus sets.

Random Space Fact

Approximately 1,000 Earths would fit in Jupiter, and 1,000 Jupiters would fit in the Sun (and thus 1 million Earths in the Sun).

Trivia Contest

Try to win a free year's Planetary Society membership and a Planetary Radio T-shirt by answering this question:

How many instruments are on the arm of each Mars Exploration Rover?

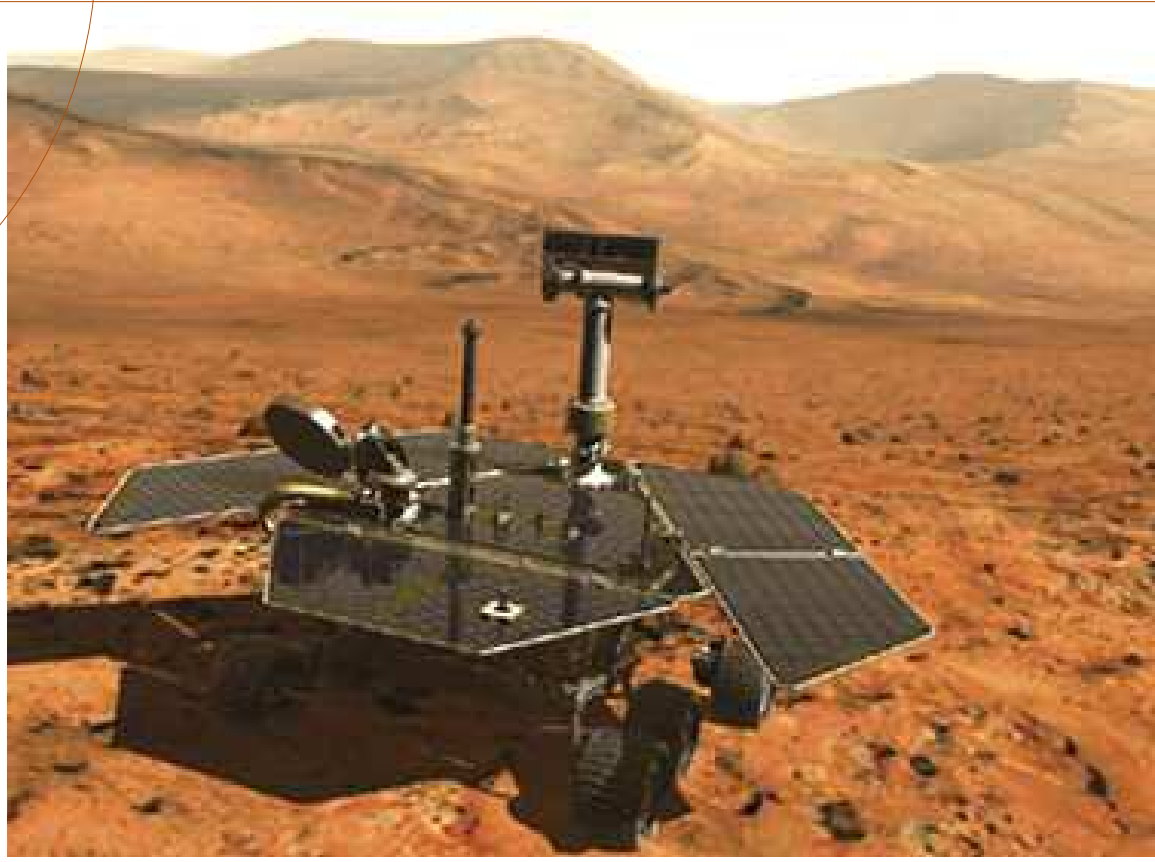
E-mail your answer to *planetaryreport@planetary.org* or mail your answer to *The Planetary Report*, 65 North Catalina Avenue, Pasadena, CA 91106. Make sure you include the answer, and your name, mailing address, and e-mail address (if you have one).

Submissions must be received by February 29, 2004. The winner will be chosen by a random drawing from among all the correct entries received. The winner will be notified in March 2004 and will have his or her name published in the May/June 2004 issue of *The Planetary Report*.

For a weekly dose of "What's Up?" complete with humor, a weekly trivia contest, and a range of significant space and science fiction guests, listen to Planetary Radio at *planetary.org/radio*.

The MarsDial: A Sundial for the Red Planet

by Woody Sullivan and Jim Bell



The Mars Exploration Rovers,* Spirit *and* Opportunity*, will carry the first-ever interplanetary sundials. These MarsDials will be used to calibrate the Pancam (panoramic camera) on each of the rovers. This simulated image of one of the rovers shows the MarsDial on the rear solar panel.
Image: Cornell/Maas Digital LLC

NASA's Mars Exploration Rover (MER) mission will soon land two highly mobile robotic scientists on the Red Planet. Named *Spirit* and *Opportunity*, the rovers will explore the geologic and climatic history of two landing sites, chosen to provide new insights into the history of water and climate on Mars. Each rover carries a suite of sophisticated science instruments known as the Athena payload, as well as high-tech navigation, mobility, and communications systems. Unbeknownst to many, each rover also carries one of the simplest but most elegant scientific instruments ever devised: a sundial. Just as with sundials on Earth, these MarsDials will use the shadow of the Sun to determine the time of day on Mars. Students and space enthusiasts around the world will be able to read the Martian time by viewing images of the MarsDials on the Web.

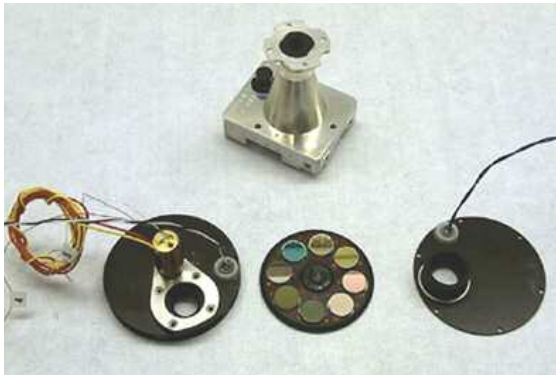
The MER mission and Athena science payload have a long and tortuous history, with Athena having first been proposed in the mid-1990s in response to NASA's early calls for "better, faster, cheaper" planetary exploration initiatives. At first, Athena was proposed for a rover mission, then it was selected by NASA for a stationary lander, then (after the *Mars Polar Lander* failure in 1999) it was reselected in 2000 for a rover mission and finally for two MER rover missions.

Pancam and Its Calibration Target

One of the key scientific instruments on the MER Athena payload is a multispectral panoramic stereo camera system known as Pancam. Pancam is a pair of charge-coupled device (CCD) cameras mounted atop the rover's mast, about 1.5 meters above the surface, that provide high-resolution views of the landing site. Each camera has the equivalent of 20/20 human vision (about three times better resolution than the camera on the *Mars Pathfinder* lander), and the mast can move to allow Pancam to view the full 360 degrees in azimuth and ±90 degrees in elevation around each rover. Each camera also uses a small eight-position filter wheel to allow imaging in specific colors of the spectrum.

Pancam has a number of important scientific objectives. These include obtaining stereo color images of the surroundings of each MER landing site to study its geology, especially the spectra and light-reflecting properties of the minerals making up nearby rocks. These

Above: This photo shows the Pancam's mast assembly with the camera bar in stowed position, ready for flight.
Photo: NASA/JPL/Cornell



Right: Pancam uses a filter wheel to take images at various wavelengths so that scientists can learn more about the mineralogical makeup of the Martian surface. This image shows the Pancam lens (top) and filter wheel assembly.
Photo: NASA/JPL/Cornell

Above: Pancam has a camera bar that contains Pancam and Navcam (navigation camera) heads. Designed to "see" the way human eyes do, the cameras are mounted atop a mast about 1.5 meters above the surface, which allows Pancam a full 360 degree view. Additionally, each camera has the equivalent of 20/20 vision and a "visor" that changes the elevation of the camera so the rover can look up or down.
Image: Cornell/Maas Digital LLC

images will be vital for making decisions as to which rocks should be examined "up close and personal." Pancam will also image the Martian sky to study its ever-present dust. Finally, Pancam has several important practical roles on MER, including helping the rover's navigation by mapping out possible routes, as well as finding the Sun (using specially designed filters) to determine rover orientation.

The Pancams are just two of the nine cameras carried by each rover. Pancam's filter wheels give these cameras a unique role on each rover, however, as they are the only cameras that can obtain color images. Having color imaging capability presents an additional problem to scientists working with Pancam images: How do we make sure the colors are correct? The MER team has taken a two-part approach to this problem. First, we calibrated the cameras before launch to determine how each filter will respond to sunlight reflected off Martian rocks and soils. Second, because we don't know how or if the cameras' response will change after the turmoil of launch and landing on Mars, we carry with us a calibration "target" that has known grayscale and color properties. By imaging the target and getting its color

This color Pancam image of the MarsDial on the **Opportunity** *rover during system thermal vacuum testing shows the size and orientation of the dial images expected to be returned from Mars. The multiple gnomon shadows are caused by multiple light sources in the vacuum chamber.* *Image: Cornell/JPL/NASA*

balance correct, we will be assured that subsequent images of the landing site will have their colors properly displayed.

This second approach is very much like the approach taken during the *Viking* and *Mars Pathfinder* missions, both of which also carried calibration targets. The MER target, in fact, was originally designed to be similar to the target for the imager used in 1997 on *Mars Pathfinder*. That target played a critical role in getting the colors right on *Pathfinder*'s marvelous pictures. The Pancam target initially also consisted of a small metal plate covered by silicone rubber materials pigmented to specific colors or shades of gray. We also placed a post in the center of the plate to cast a shadow across some of the materials; this allowed us to measure the contributions of direct sunlight and of the diffuse skylight that fills in the shadow region.

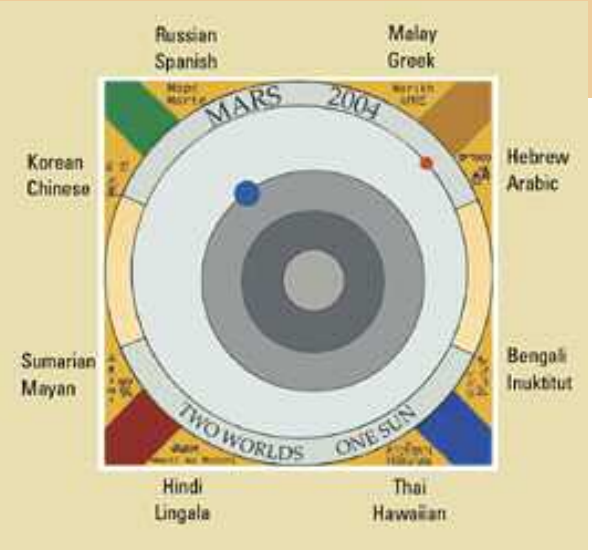
During a fateful airplane flight in 1998, one of us (Jim) noticed television writer and entertainer Bill Nye (the Science Guy) and struck up a conversation about Mars missions and Pancam in particular. Bill was intrigued by the mission and yearned for more details about the instruments themselves. When he learned about Pancam and its stick-casting-a-shadow calibration target, he had an epiphany: "It's a sundial!" Bill's eyes lit up as he foresaw an opportunity to merge science, education, his own personal interest in sundials (Bill's father wrote a book on the sundials of Maryland and Virginia), and space exploration into an exciting new project. We could make that mundane little object into the first sundial on another planet! Wouldn't it be great if we could tell time on Mars by reading the post's shadow? Bill joined our team, and thus was born the Mars sundial project. Now, more than 5 years later, the two rovers that are about to land on the Red Planet are each outfitted with a MarsDial.

Sundials come in many forms. Shown here is a wall-mounted dial, La Forteleza, San Juan (top); an analemmatic sundial in Highland Park, Illinois (center); and a Suncircle in Tucson, Arizona (bottom).
Photos: courtesy of the North American Sundial Society

Sundial Lore

For millennia, humans have appreciated that the shadow of a post (also known as a *gnomon*) could be used to tell time as the Sun travels westward across the sky. In ancient Greece, sundials were fashioned out of large blocks of marble, with an iron rod casting a shadow onto a hemispherical bowl having lines for the hours of the day. The date can also be read from a sundial, for the path of the Sun through the sky is much higher in summer than winter, causing generally shorter shadows in summer.

By the time of the Renaissance, an amazing variety of sundials had been designed and were in common use. Some were on walls, with the gnomon protruding from the wall, while others were aligned with the Earth's rotational axis and Equator (equatorial dials). Pocket



Above: On the face of each MarsDial is the motto "Two Worlds, One Sun" and the word "Mars" in 17 languages. *Image: Jon Lomberg/Jim Bell*

Left: A closeup of one of the flight MarsDials shows the gnomon in the center; it will cast shadows on the face. *Photo: Cornell/JPL/NASA*

sundials could be carried anywhere—some had built-in magnetic compasses, while others were self-aligning to north. Some dials were based on vertical gnomons, but these required the post to have a reference point (called a *nodus*) for reading the specific position of the shadow. There's even a type of dial whereby a person stands upright and reads the time as indicated by his or her own shadow falling on markers on the ground.

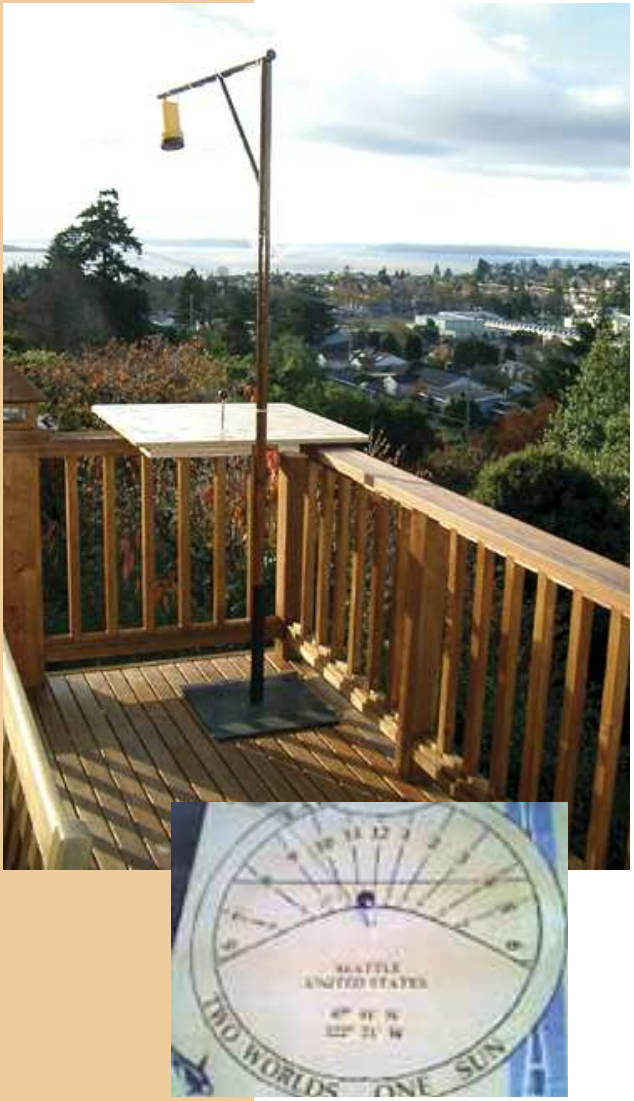
Sundials reached their peak in the 18th century but then rapidly declined as clocks and watches became affordable and accurate (and with the distinct advantage of being able to work under clouds or at night!). Today we have remarkably accurate timepieces (based on exquisitely machined gears and springs or fast vibrations of quartz crystals or on energy transitions in atomic nuclei), and the minutes of our lives are dictated by the clock. So why is it that sundials are currently enjoying a revival? They are no longer practical for timekeeping, of course, but they are nonetheless still marvelous devices for educational, philosophical, and artistic purposes. A sundial today, when well designed for its users and location, makes one pause from the bustle of modern life and contemplate our history and our position in the cosmos.

Turning a Calibration Target into a Sundial

Once the decision was made by the Pancam team to make a MarsDial, an informal design team was assembled that "met" via e-mail over a period of more than 6 months. On the team, in addition to the present authors and Bill Nye, were Steve Squyres (Cornell), principal investigator for the MER Athena science instruments; Jon Lomberg, a well-known artist specializing in astronomical subjects; Louis Friedman, executive director of The Planetary Society; and Tyler Nordgren, an astronomer and artist then at the U.S. Naval Observatory and now at the University of Redlands. Larry Stark, scientific instrument maker at the University of Washington, was the key person for turning the design ideas into the reality of metal and silicone rubber.

The first problem we encountered was that the dial had to be fabricated long before the landing sites on Mars were to be selected, but a sundial's hour lines very much depend on its latitude, whether you're on Earth or on Mars. Thus, we couldn't engrave hour and date lines onto the dial ahead of time. Instead, we decided to take advantage of the fact that everyone would be viewing images of the MarsDial and its shadow on the Web, so we could superimpose the needed lines later, by digital methods. Second, we realized that the dial's gnomon needed a nodus, so we put a 2-centimeter (nearly 1-inch) diameter sphere on the top and a petal-like "daisy wheel" structure lower down. The sphere acts as our nodus when the Sun is nearly overhead (as will happen midday for the near-equatorial latitudes where the rovers will land), but when the shadow of the sphere falls off the 8-centimeter-square face of the dial, then the petal will step in to act as the nodus.

In the process of turning our esoteric little (all of 65 grams) calibration target into a piece of interplanetary art, other features—sundial designers call them "furniture"—were added. For example, a motto is traditional on sundials. After much discussion, and inspired by



Top: The Seattle EarthDial has a beautiful view from its permanent home.

Inset: This is a view through the Webcam of the Seattle EarthDial at 9:30 a.m. (solar time).
Photos: Bill Nye

ideas from a number of schoolchildren (compiled by Sheri Klug of the Arizona State University Mars K-12 Education Program), we adopted "Two Worlds, One Sun" as ours. The name of Mars is written in 17 languages (more if you count all the other languages besides English for which the word for Mars is spelled "Mars") around the edge of the dial face, as well as the common era year of the landings (2004). Two mirrored surfaces on the plate are designed to reflect the color of the Martian sky. A careful look will reveal that the post is actually off-center and that not all the rings are centered on the post. This is because we decided to make the middle ring represent Earth's orbit (hence the blue dot) and the outer ring, Mars' (the smaller red dot). Earth's orbit is indeed close to a circle centered on the Sun, but Mars' orbit is much more elliptical, with the Sun noticeably "off-center." Finally, around all four sides of the plate we engraved a short text message and drawings, again inspired by those of schoolchildren, that tell the tale of the mission. How many years will it be before a human comes upon a half-buried rover, dusts it off, and first reads these words on Mars?

One final peculiar property of the MarsDial is that it sits on a moving vehicle, a strange fate indeed for a sundial, which always needs to know how it is aligned with respect to north. When originally designed, the calibration target was going to be on a fixed lander, but changes in the mission and spacecraft design meant first that the MarsDial was delayed by 2 years, then that it was riding along on a rover! Now we must figure out the orientation of the rover (and hence the MarsDial) before we can calculate the correct hour and date lines to superimpose on the Web image—and how does NASA determine the rover's orientation and tilt? In a sweet bit of interplanetary irony, it's by looking at the Sun with Pancam and knowing its position in the Martian sky for any given time!

Time and Calendars on Mars

As we contemplate the implications of reading a sundial on another planet, it is only natural to wonder what should be the units of time and the calendar system that would be natural for a denizen of Mars, whether robotic or human. Think like a Martian when considering the following facts: The Martian solar day, which has had the name *sol* since the *Viking* lander days in the 1970s, is 24 (Earth) hours, 39 minutes, 35.2 seconds long, or 1.02749 Earth days. But what should be the subunits of the sol? An unimaginative answer would be to decide that 24 Martian hours (perhaps called "mhours"?) make up a sol. The peculiar division of our day into 24 units goes back at least to the ancient Egyptians and has nothing to do with Mars, so why choose 24? Is 10

mhours in a sol better? As a Martian, you'd better first count the number of fingers on your hands! And how would you break the mhour up into smaller units?

A Martian calendar is even trickier. Mars' axis of rotation has a similar tilt to that of Earth (25.2 degrees versus 23.4 degrees), which means that it similarly goes through four seasons (which need characteristically Martian names, please). But because Mars is much farther from the Sun, its year is a good bit longer, at 668.60 sols (686.98 Earth days). What should be the name of the Martian year? And how should it be divided? Here on Terra, we have 12 months in our year basically because our Moon happens to go around us roughly 12 times every time we orbit the Sun once. But Mars has two moons, Phobos and Deimos, that zip around every 7.6 and 30.3 hours, respectively, as seen from outside (the sidereal periods). You're a Martian standing on a surface that is itself rotating once every 24.6 hours. The upshot is that speedy Phobos actually laps you about twice a day, rising in the west and setting in the east with an apparent period of 0.45 sols, while Deimos behaves more "normally" by rising in the east every 5.38 sols. Should there be a length of time called a *phobe* (or would a *milliphobe* be more useful?), or maybe a *conjie* for the interval of time between conjunctions of the two moons, when they pass each other in the sky and surely create an auspicious occasion for any Martian skygazer? Whatever the answers, Mars surely deserves a set of unique and distinctly Martian units of time!

Operations on Mars

When the two Rovers land on the 4th and 25th of January, Pancam and the other rover cameras will immediately start imaging the landscapes of Gusev Crater and Meridiani Planum, which of course means that the calibration target/MarsDial also will be imaged. The Pancam team plans to image the calibration target at least once per sol, and sometimes more frequently during times when additional calibration fidelity is required. Every sol, Student Astronauts sponsored by The Planetary Society will be in charge of getting these images onto a website where the public will be able to read the time and date on Mars, as well as view much more information about the mission's instruments, goals, and results. We also plan to initiate a related project called EarthDial, which will link up images of similar sundials constructed by people from longitudes all around the Earth, each under the gaze of its own Webcam. (See *www.planetary.org/mars/earthdial.html* for how you can participate in this exciting project.)

It has been challenging but exciting to turn a simple instrument needed for critical color and grayscale calibration of the rover cameras into a fun, artistic, and educational piece of space art that will, we hope, inspire people on both Earth and (eventually) Mars to think beyond their everyday experiences. More than 2,000 years ago, the Egyptian astronomer Eratosthenes used a simple gnomon—a stick stuck in the ground casting a shadow—to estimate the diameter of the Earth. Today, in our world of digital computers and atomic clocks, it is fitting that we recall the wisdom of the ancients and the simple power of sticks and shadows to reveal the beauty and harmony of the world around us, whether that world is Earth, Mars, or some other place in our imaginations.

Woody Sullivan, a professor of astronomy at the University of Washington in Seattle, works on astrobiology and the history of astronomy. He intends to make Seattle the sundial capital of North America. Jim Bell is a professor of astronomy at Cornell University in Ithaca, New York and is the lead scientist for the Pancam investigation. Most of his experience with sticks and shadows has been on a baseball diamond. Please send any fully worked out schemes for Martian calendars to woody@astro.washington.edu.

Jim Bell, one of the authors and Pancam Payload Element Lead, places the MarsDial on the rear solar panel deck of one of the Mars Exploration Rovers at the Kennedy Space Center. ***Photo: NASA/JPL/Cornell***

For more information:

MarsDial
http://athena.cornell.edu/kids/sundial.html

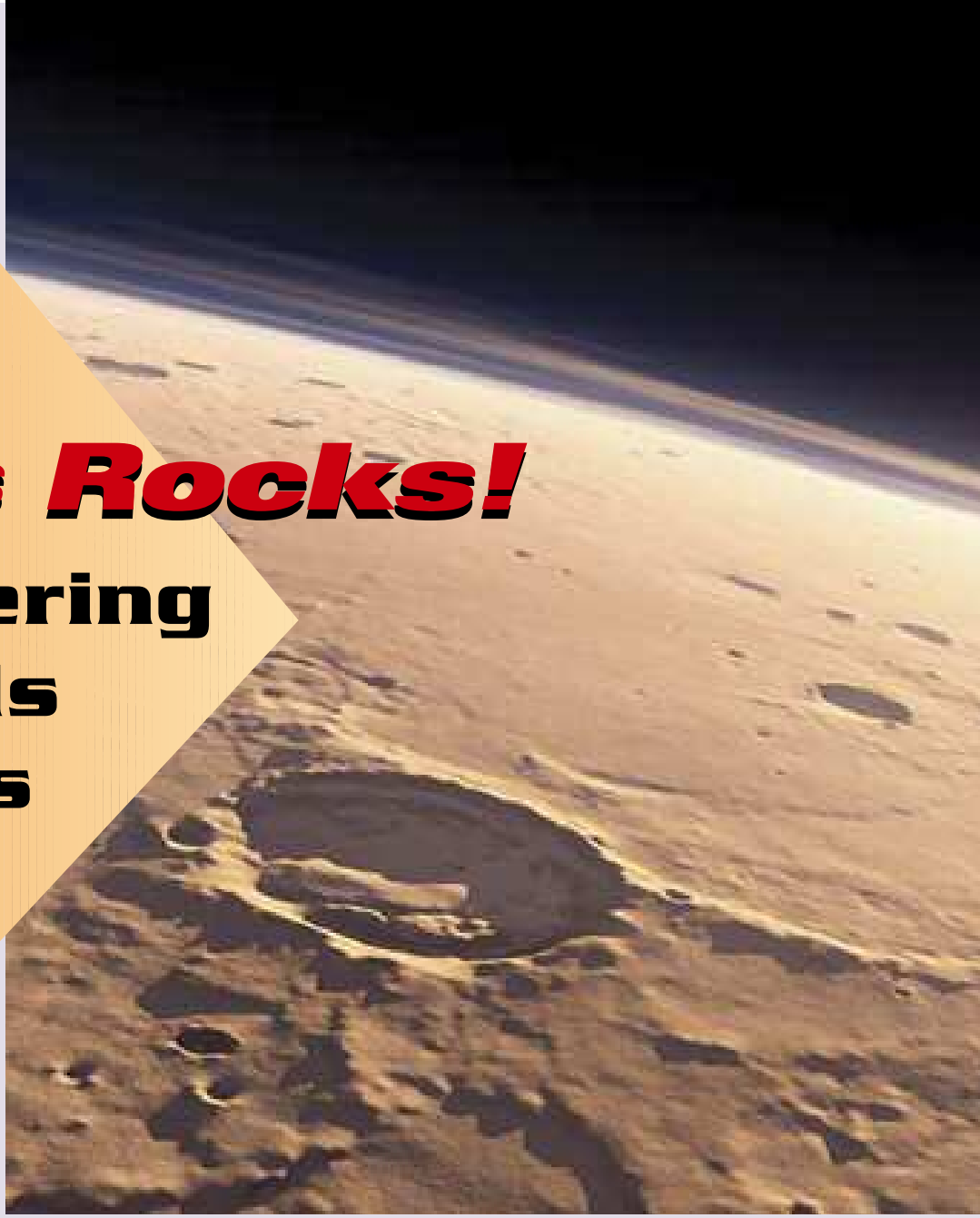
Build Your Own EarthDial
http://planetary.org/mars/earthdial.html

North American Sundial Society
http://www.sundials.org/

MER mission and Athena instruments
http://athena.cornell.edu

Mars Rocks!

Deciphering Minerals on Mars



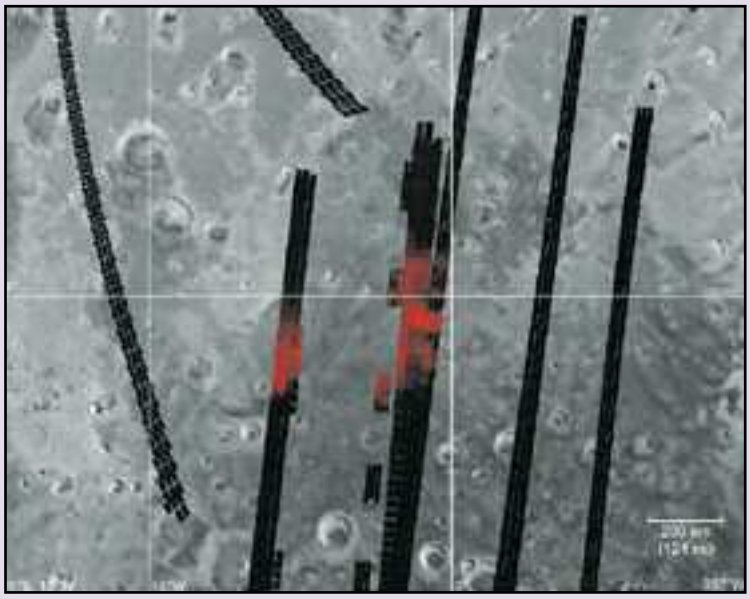
by Melissa D. Lane

Hematite: What Does It Tell Us?

The official NASA mantra for Mars exploration is "Follow the water." Because life as we know it depends on liquid water—and probably originated in an aqueous environment—finding water in its liquid form on another world would greatly increase the chances of finding life-forms or their fossil remains there.

In pursuit of water, instruments on robotic spacecraft have been tuned for its detection, and scientists have been combing data for any hint of its presence, past or present. Great interest was raised when the Thermal Emission Spectrometer (TES) on *Mars Global Surveyor* unequivocally identified gray hematite on the Red Planet. This iron oxide (Fe_2O_3) occurs on Earth as well as on Mars, and its chemistry resembles that of common rust. On Earth, it commonly forms in the presence of liquid water, spurring the great scientific interest in its discovery on Mars.

The hematite found on Mars occurs in both fine-grained and coarse-grained varieties. Fine-grained hematite (grain diameters less than 10 micrometers) gives Mars its red color and its nickname, the "Red Planet." The tiny hematite crystals absorb blue light and scatter the red light that falls upon them, giving that color to both rusty nails and Martian dust. Martian winds blow this fine-grained hematite entrained in the dust around the planet during the seasonal dust storms, dispersing it widely and coloring the lighter regions on Mars.



Above: The Thermal Emission Spectrometer (TES) instrument on* Mars Global Surveyor *discovered a remarkable accumulation of hematite covering an area approximately 500 square kilometers (180 square miles) in size. The TES results indicate that the hematite is coarse-grained (sand-sized or larger) and occurs within a localized region with very sharp boundaries. This image shows the hematite region, with the abundance of hematite shown in red. The location and size of the individual TES observations on the surface are indicated by the individual squares. Black squares indicate observations with no detectable hematite. The TES data are superimposed on a* Viking *image for context. ***Image: NASA/JPL/Arizona State University***

Left: On January 24, 2004, the Mars Exploration Rover* Opportunity *is set to land in the Meridiani Planum hematite region. The hematite lies in the middle of the Terra Meridiani (near the middle of this artist's rendering), west of the Schiaparelli Crater, which may have been filled with large quantities of water, forming a lake billions of years ago. ***Illustration: Kees Veenenbos***

Coarser-grained hematite (grains more than 10 micrometers in diameter) is a steely gray, not red like its finer-grained cousin, because light can't pass through these larger grains. On Earth, this form is often seen in jewelry, cut and polished to a silvery shine. This exposed gray hematite on Mars is attractive to scientists, for it most often forms in the presence of liquid water, and where there is—or was—liquid water, there is the possibility of life. Gray hematite may be evidence that there once were large quantities of liquid water on Mars.

How much gray hematite exists on Mars (because more still may be buried under the surface) and how it was formed remain to be determined.

The TES instrument identified only three main areas of gray hematite exposed at the surface of the entire planet. These deposits all occur in darker regions on Mars near the equator: in an area called Meridiani Planum, in a large impact crater called Aram, and within the Valles Marineris canyon system. Areas such as these may be the sources for the fine-grained, red hematite. The weathering effects of wind and time on the gray hematite may have worn down the original deposits and allowed the finest grains of hematite to be caught by the wind and mixed with the dust.

Now that scientists have identified hematite on Mars, we can begin to interpret its origin. To do this, we use a strategy called *comparative planetology*, whereby the geologic processes that form hematite on Earth are assumed to be the same processes that might form the hematite on Mars. Hematite on Earth usually forms in oxidizing environments. Oxidizing environments on Earth are anywhere there is water (H_2O), which readily gives up its oxygen to form other chemical compounds. Water in contact with iron-bearing materials can form hematite through such a chemical reaction.

Mars holds large quantities of basaltic rock (similar in

Gray hematite has also been found in the giant canyon system Valles Marineris, suggesting that liquid water may have been present there early in Mars' history. This artist's rendering of Valles Marineris is an east-to-west view of the Candor Chasma, with liquid water flowing through the canyon. *Image: Kees Veenenbos*

Hematite on Earth has a brilliant iridescence and is often cut, polished, and made into jewelry.
Photo: Magnets To Go

Shown above and at left are hematite beads and a hematite pendant.
Photos: Alaska Guide Store (above) and The Crystal Ball Inc. (left)

composition to the volcanic rock in Hawaii) in regions where we find the gray hematite. Basalts contain iron within the pyroxene minerals, along with non-iron-bearing feldspars, that make up the rock. In the presence of water, the iron is removed from these minerals and used to form hematite.

On Earth, hematite forms in several types of geologic settings. In an ocean or lake whose water contains iron, the iron combines with oxygen to form hematite that settles out onto the floor as a sedimentary deposit. In a hydrothermal setting, where hot water flows through rocks, the water strips minerals of iron, which is later deposited as hematite. Another oxide mineral, magnetite (Fe_3O_4), occurs in volcanic rocks. It can react with oxygen in the atmosphere or in water and be converted to hematite.

On the surface of Mars today, liquid water is not stable because the atmosphere is too thin and the surface temperatures are too cold. If a bucket of water were placed on Mars, it would quickly evaporate or freeze, then sublimate. How is it possible, then, that liquid water helped to form the Martian hematite?

Scientists are actively debating the gray hematite issue, and we may soon have the answer. The Mars Exploration Rover *Opportunity* will land in the Meridiani Planum hematite region. It and the other rover, *Spirit*, may each roam up to 100 meters a day (for about 90 days), carrying a payload of instruments designed to photograph and measure the chemistry of the rocks and soils of Mars. We will be able to interpret the data received from their instruments to learn more about the past and current geologic and climatic environments—and maybe solve the mystery of the gray hematite on Mars.

Hunting for Clues to Ancient and Recent Water on Mars

The early orbiting explorers of Mars, *Mariner 9* in 1971 and *Viking 1* and *Viking 2* in 1976, startled scientists when they revealed clear and detailed evidence of what appeared to be the scars left by running water on Mars. The now-dry channels, craters with inflow and outflow channels, and other data suggest that early in Mars' history, liquid water flowed on the surface. But were all these features carved nearly instantaneously in catastrophic floods, or were some carved slowly? We do not know for how long liquid water was on the surface, but we are interested in finding out because long-standing water is more likely to have harbored life than water that appeared in catastrophic floods.

On Earth, where oceans and lakes are common, certain rocks and minerals are formed when certain cations (positively charged ions) and anions (negatively charged ions) within the water reach their saturation points. These ions then combine to form minerals that sink to the ocean floor, such as carbonates, sulfates, chlorides, and other salts.

If a beaker of seawater were dehydrated, a residue of salt minerals would remain. The salts in seawater precipitate in a specific order, the first being calcium carbonate (aragonite and calcite) and calcium sulfate (gypsum and anhydrite). The next salt that precipitates is halite (sodium chloride, common table salt). After the halite is removed, other less common chlorides and sulfates of magnesium and potassium will precipitate. Carbonates, sulfates, and chlorides, similar in chemistry to terrestrial sea salts, may have formed on Mars—but we don't know how extensive these deposits might be.

Scientists would like to understand what the chemistry of water on Mars was in the past, so we are looking to identify salt minerals on Mars that would have precipitated from the water. One place scientists have been able to look for clues about the chemistry of Martian water is within the meteorites from Mars that have fallen to Earth. Some have been collected and studied, and these have been found to contain minor amounts of evaporite minerals such as gypsum and anhydrite (both sulfates), calcite and siderite (both carbonates), and halite (a chloride). We don't yet know for certain the regions on Mars that meteorites came from, nor do we know if the processes that formed the salt minerals in the meteorites were global or limited to small regions.

Once we have identified salt minerals on Mars using data from orbiting spacecraft or rovers, we will be able to determine how long water may have interacted with

Above: The large, circular feature in the upper left is Aram Chaos, an ancient impact crater filled with layered sedimentary rock that was later disrupted and eroded to form a blocky, "chaotic" appearance. Gray hematite has been detected in the crater—one of just three known locations on Mars where this mineral exists.
Image: NASA/JPL/Malin Space Science Systems

Left: This* Mars Odyssey *THEMIS image shows a stack of eroding sediments roughly 200 meters high that contains the northeastern-most occurrence of the hematite layer that covers much of Meridiani Planum. The origin of the hematite layer is still a mystery, one that may be solved when* Opportunity *arrives in January.
Image: NASA/JPL/Arizona State University

the rocks on the planet. That will give us a better idea of whether the water flowed on the surface for a short time, geologically speaking, or existed in long-lived cycles with episodes of evaporation. Identifying sequences of salts on Mars will allow us to interpret what the water chemistry was and perhaps even its temperature.

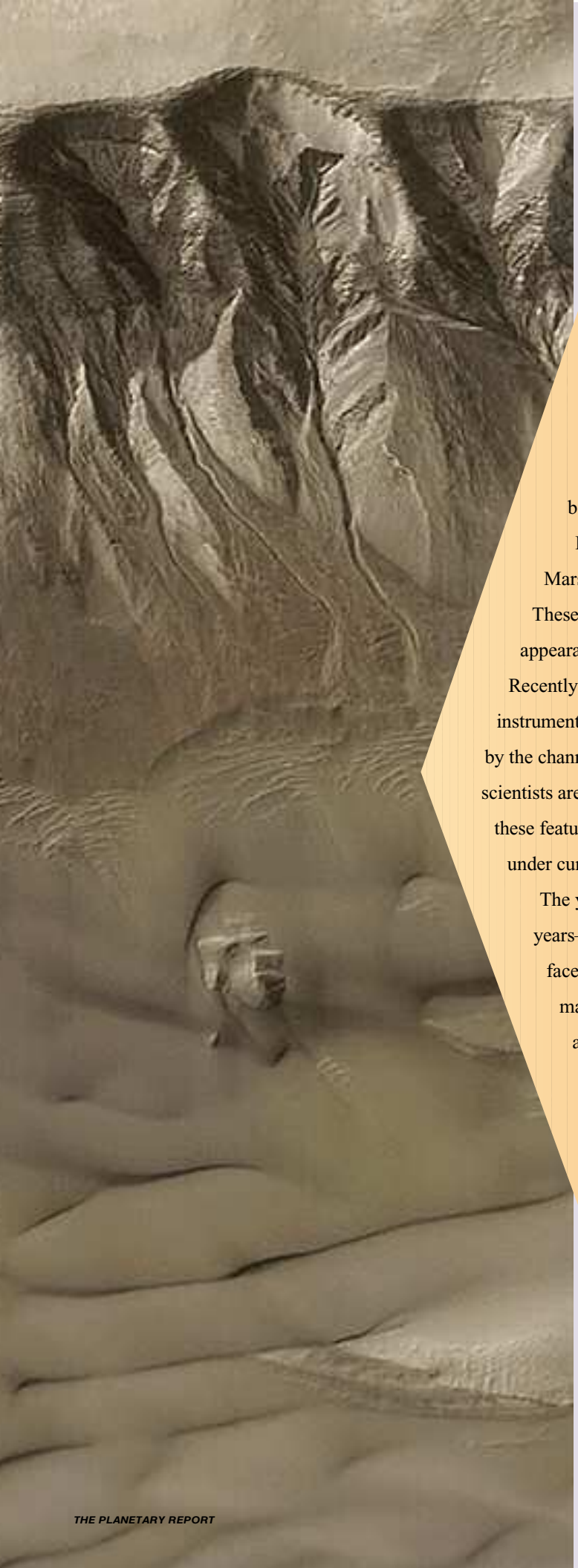
Finding minerals on Mars that precipitate from seawater and brines may be the first step toward understanding the complex role that water played on the planet's surface. Although it has been thought that Mars had liquid water on the surface during its early history, the recently revealed "young" gully evidence brings to light an intriguing possibility that water may have played a critical role in the evolution of Mars throughout its entire history. More fascinating is the idea that a long history of water on Mars may have allowed a biosphere to develop. All we can do now is keep looking for answers.

Melissa Lane is a research scientist at the Planetary Science Institute in Tucson, Arizona and a participating scientist on the Mars Odyssey *mission. She specializes in remote-sensing studies of Mars using the thermal infrared wavelengths of energy (the "heat" region of the electromagnetic spectrum).*

Above left: Meteorites deliver crucial information about Mars. More than a dozen unusual meteorites that have reached Earth are almost certainly pieces of Mars blasted off the planet by meteoroid impact. ALH84001 was found in Antarctica in 1993 and became known as the "Mars Rock" after scientists detected bacteria-like shapes inside it, raising questions about past microbial life on Mars. ***Photo: JSC/NASA***

Above right: The EETA 79001 meteorite was found in Elephant Morraine in the Antarctic and is classified as a shergotite, the most common subgroup of the Mars meteorites. Weighing 7,900 grams (17.4 pounds), it is the second largest Mars meteorite ever found. EETA 79001 is only 180 million years old—very young on the solar system scale—and was launched into space from Mars 600,000 years ago. ***Photo: JSC/NASA***

Right: Gullies in a crater near Newton Basin in Sirenum Terra exhibit patches of wintertime frost on the crater wall and dark-toned sand dunes on the floor. The gullies in these craters may have formed by release of groundwater to the Martian surface in geologically recent times. The image was captured by* Mars Global Surveyor*'s high-resolution Mars Orbiter Camera and was colorized using data from the wide-angle cameras.
Image: NASA/JPL/Malin Space Science Systems



Is There Liquid Water on Mars Today?

Based on data collected over the past 30 years, many scientists have hypothesized that, if Mars ever had liquid water, it existed only in the early history of the planet's evolution. Recent images taken by *Mars Global Surveyor*'s Mars Orbiter Camera, however, are beginning to change that view.

In 2000, Mike Malin and Ken Edgett noticed features on Mars that look an awful lot like water-carved gullies on Earth. These gullies appear on some crater and canyon walls and have the appearance of being formed by seepage or spring deposits.

Recently, Phil Christensen, using data from *Mars Odyssey*'s THEMIS instrument, proposed that these gullies may have formed by the channeled flow of water beneath a melting snowpack. Although scientists are now debating how these gullies formed, they agree that these features are geologically young—and may even be forming under current Martian climatic conditions.

The young age of these features—within the past few million years—suggests that the flow of liquid water on the Martian surface may not have been restricted to the planet's early history: it may be occurring even now. This notion of liquid water being available today, albeit intermittently, implies that water may still flow either at or not too far beneath the planet's surface, where it could support an active biosphere. For any astronauts who might visit the Red Planet, the availability of water near the surface may provide a critical staple to sustain them on this alien world.

—MDL

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Questions and Answers

Why can't we see gravity? This is a question my second-grade science students asked me. How would you explain it to them?
—MAGGIE OWENS,
El Sobrante, California

Great question! Gravity is a force in the universe, but there doesn't seem to be any rule that says we should be able to see it. That's just the way nature is sometimes. We can measure and understand gravity, but it's invisible.

Now, that's not that weird. We can't see the tiny beam of heat—of infrared—that comes out of our television's remote control. We can't see the sound of our voices or of a musical instrument. We can't see pressure at the bottom of a pool of water. We can't see air, and it's all around us all the time. Oh, sure, we can see dust in the air, but not the air itself. Well, gravity is the same way. We can see balls fall, raindrops fall, apples fall off trees, and dust settle on bookshelves, but we can't see the gravity that makes these things happen.

Light plays a part in this gravity thing, too. There's an old saying, "We don't see things; we see light bouncing off of things." You know that's true. Just walk around your house in the dark. Where there's no light, nothing can be seen. (Be careful of your shin bones!) Light and gravity have a tricky and hard-to-measure connection. If there is enough gravity, it affects the path of light enough for us to notice. Giant groups of stars (also known as galaxies) in deep space have been shown to ever-so-slightly bend the path of light beams from other stars behind them. It's the huge amount of gravity from the stars in the galaxies that's doing it. The light's not bouncing off, it's bending just a little. For everything else in our lives, from

Factinos

Scientists have discovered new clues in the mystery surrounding the greatest extinction in Earth's history. "An ancient meteorite body—one from the days when the solar system was still forming—struck the Earth 251 million years ago," reports the University of Rochester's Asish Basu in the November 20, 2003 issue of *Science*. This catastrophic event likely triggered climate change and unprecedented volcanic activity, wiping out 90 percent of life on the young Earth. That one-two punch so affected the composition of the atmosphere that it took thousands of years to recover—leaving only a relative handful of plants and animals alive.

While a meteorite has been largely accepted as the source of the dinosaurs' demise 65 million years ago, the cause of what is often called "The Great Dying" has been unknown. In 1991, however, Basu published a study in *Science* that showed a massive and ancient lava flow that occurred in Siberia precisely 251 million years ago. The lava did not shoot out of the Earth like a giant volcano but oozed molten rock for thousands of years. Further testing by Basu and colleague Robert Poreda determined that this lava came from as deep as 3,000 kilometers (1,800 miles) below the surface. "Something brought this lava all the way up from near the Earth's core," explained Poreda.

Basu and Poreda recently studied rock samples from Graphite Peak in Antarctica and from sources of P/T strata in Meishan, China, and Japan. They discovered a variety of meteorite samples and metallic grains, all indicative of a major, ancient impact. Some scientists question the validity of these results, arguing that meteoritic deposits would have dissolved into the Earth millions of years ago.
—from the University of Rochester.

We now know what a solar flare "sounds" like. Don Gurnett of the University of Iowa recently used the *Cassini* spacecraft to record the sound of one of the largest solar flares seen in decades as it moved outward from the Sun.

The radio wave burst, resembling the clicking of an old-fashioned telegraph machine followed by the rush of a jet engine, was recorded October 28, 2003. Gurnett noted that the radio waves—moving at the speed of light—took just 69 minutes to reach the spacecraft, which is currently about 8.7 Astronomical Units (AU) from Earth. (One AU is the distance between Earth and the Sun—about 150 million kilometers, or 93 million miles.)

"This is one of the biggest events of its kind ever seen," said Gurnett. The event, described as a "type III" radio burst, was detected using *Cassini* 's 86-pound radio and plasma wave instrument, for which Gurnett serves as principal investigator.

The sound can be heard by visiting Gurnett's website at *http://www-pw.physics.uiowa.edu/space-audio/*
—from the University of Iowa

Newly seen details in a fan-shaped apron of debris on Mars may help settle a decades-long debate about whether the planet had long-lasting

reflecting pools to eyeglasses, light goes pretty much in straight lines.

Maybe you'll be the scientist who uses light bent by gravity to help us imagine and understand what gravity would look like, if we could see it. If so, you could change the world.
—BILL NYE The Science Guy,
Planetary Society Board of Directors

As I examined the photos on the cover of the July/August 2003 issue of* The Planetary Report, *I noticed the clean white nose cones on the booster rockets in frames 1 and 2, but in frames 3 and 4, the tips of the cones appeared to be burnt. What caused this?
**—LEONARD JORGENSEN,
Edmonton, Alberta, Canada**

To establish Earth orbit, a rocket's speed must be increased from zero to 28,200 kilometers (about 17,500 miles) per hour. This typically takes about 15 minutes. Less than a minute after liftoff, the rocket reaches supersonic speed, and it quickly accelerates all the way up to a hypersonic speed of about Mach 25 (25 times the speed of sound) at about 100 kilometers (about 60 miles) altitude. These super- and hypersonic flight regimes create a complex system of shock waves and related air-friction effects that continue until the rocket passes through Earth's sensible atmosphere—about 8 to 10 minutes after launch.

Any exposed surfaces, especially the conical noses of the solid rocket boosters, are subject to this extreme environment. The darkened cones you see in these images are simply evidence that the white paint got so hot that it cooked, much like a marshmallow does when placed close to an open campfire.
—REX RIDENOURE,
Ecliptic Enterprises

In 1974,* Mariner 10 *was placed in a solar orbit, visiting Mercury every second Mercury year. Contact with* Mariner 10 *was lost, however, after its third rendezvous in 1975. Does this mute spacecraft still visit the planet every second Mercury year?
**—LARS LUNDSTROM ANDERSEN,
Frederiksberg, Denmark**

Mariner 10's last flyby of Mercury took place on March 16, 1974, and the last of the attitude control gas was depleted eight days later, ending the mission. *Mariner 10* is no longer tracked, so we do not know its location, but presumably it continues along its orbit of roughly two Mercury years, reaching perihelion at Mercury's distance from the Sun.

However, perturbations in the spacecraft's orbit caused by its last encounter with Mercury, as well as by the gravitational effects of Venus, would have caused *Mariner 10*'s orbit to have changed so that it no longer comes close to Mercury at each perihelion.
—DAVE WILLIAMS,
Goddard Space Flight Center

rivers instead of just brief, intense floods (see image at right).

Pictures taken by the Mars Orbiter Camera (MOC) on *Mars Global Surveyor* show eroded ancient deposits of transported sediment long since hardened into interweaving, curved ridges of layered rock. Scientists interpret some of the curves as traces of ancient meanders made in a sedimentary fan as flowing water changed its course over time.

"Meanders are key, unequivocal evidence that some valleys on early Mars held persistent flows of water over considerable periods of time," said Michael Malin of Malin Space Science Systems.

"The shape of the fan and the pattern of inverted channels in it suggest it may have been a real delta, a deposit made where a river enters a body of water," he said. "If so, it would be the strongest indicator yet Mars once had lakes."

Malin and colleague Ken Edgett published pictures and analysis of the landform in the November 13, 2003 online edition of *Science Express.*

More images with captions are available online from the MOC team at *http://www.msss.com/mars_images/moc/2003/11/13/*
—from NASA and Malin Space Science Systems

This mosaic of Mars Orbiter Camera (MOC) images taken between August 2000 and September 2003 shows the fossilized remains of a distributary fan, the "smoking gun" for persistent water flow and sediment deposition on ancient Mars. The physical characteristics of this feature indicate that it was probably a delta, a deposit made when a river or stream enters a body of water. Although hundreds of other places on Mars where valleys enter craters and basins have been imaged by MOC, this is the first to show a landform like this. The area covered is 14 kilometers (about 9 miles) by 19 kilometers (12 miles), and it is located in a crater about 24 degrees south and 33.5 degrees west.

Image: NASA/JPL/MSSS

Society News

Thanks for MarsWatch 2003

Thank you to all of our volunteers, event coordinators, and Society members who supported the more than 300 MarsWatch events around the world surrounding the Mars opposition on August 27. The events were extremely well attended and heightened awareness worldwide about Mars and the current missions to the Red Planet.

We are fortunate to work with such dedicated people, helping to turn the world's eyes toward the Red Planet in this exciting season of Mars.
—Vilia Zmuidzinas,
Events and Project Coordinator

You Make It Happen!

Thank you, members, for helping shape the future of space exploration. We very much appreciate your support—in our advocacy campaigns, at events in your communities, and for special projects and daily operations.

This is a crucial and exciting year for exploration. This year you will help us take the debate about the future of human space exploration to communities around the world; bring in new members, especially the students who are key to our future; expand our fleet of Mars Stations; further the Search for Extraterrestrial Intelligence; provide grants to amateurs who will detect potentially devastating Near Earth Objects; take Planetary Radio to the world's airwaves; and much more.

Check in regularly at our website, *planetary.org*, to find out about the projects that you make happen, and join our e-mail list so we can keep you up to date on Society initiatives.
—Andrea Carroll,
Director of Development

Annual Audit Completed

The firm of Hensiek & Caron has completed its yearly audit of The Planetary Society. The firm determined that the Society's 2003 financial statement was in conformity with generally accepted accounting principles.

Copies of the financial statement are available upon request.
—Lu Coffing, Financial Manager

Special Thanks

We thank the following companies for their support through matching gift programs:

AES Duck Creek, Avon Products Foundation, Inc., Bank of America, BP Foundation, Chubb, Compaq, Computer Association, Deutsche Bank Americas Foundation, Elser Enterprises, ExxonMobil, Fannie Mae, Federal Insurance Co., FM Global Foundation, Fortis, ITG, John Hancock, JP Morgan Chase Foundation, Kimberly Clark Foundation, *Los Angeles Times*, The May Department Stores Co., Microsoft Matching Gifts Program, Philip Morris, Prudential Foundation, Research Systems, Reuters, Square D Foundation, St. Paul Companies, Inc. Foundation, Sun Microsystems, Tektronix Foundation, Towers Perrin, United Technologies, UPS Foundation, Verizon, Woodmen, and Xcel Energy. *—LC*

Two Scholarship Opportunities

ISU Summer Session

The Planetary Society, with major support from New Millennium Committee member Eric Tilenius, is again pleased to provide scholarship support for the International Space University (ISU) summer session.

In 2004, the James and Lin Burke Scholarship covers half tuition at the ISU session in Adelaide, Australia, June 27–August 28, 2004. Jim Burke is a longtime contributor to The Planetary Society, including serving as technical editor for *The Planetary Report*, and is a member of the Society's New Millennium Committee.

The summer session is divided into two parts: one month of comprehensive interdisciplinary coursework along with interactive workshops and presentations by international experts, and a second month devoted to student team projects (intense research efforts conducted by students working in international teams).

All students accepted to the program are eligible. The scholarship will be awarded from among a pool of candidates determined by ISU. Further information on ISU and the summer session program is available at *www.isunet.edu*.

Planetary Society Scholarship

The Planetary Society is offering university scholarships for space-related studies at either the undergraduate or graduate level. We will award two $1,000 scholarships for the 2004–2005 academic year.

Members or persons nominated by members (one nomination per member) must submit their applications to The Planetary Society by April 30, 2004. For an application, call Linda Wong at (626) 793-5100, e-mail her at tps@planetary.org, or write to Planetary Scholarships, The Planetary Society, 65 North Catalina Avenue, Pasadena, CA 91106.
—Linda Wong,
Program Development Administrative Assistant

A New Year of Exploration!

Last Chance on 2004 Calendars!

Deep Space Mysteries: 2004 Wall Calendar
Each month, enjoy awe-inspiring full-color images from deep space. This 2004 wall calendar is produced by the creators of *Astronomy* magazine. 2 lb. **#520 $12.00**

The Year in Space: 2004 Desk Calendar
A dazzling photograph awaits you each week as you plan your daily appointments. This planner includes 52 weekly calendars, 12 monthly calendars, a full-year planning calendar, and a four-year, long-range calendar. 1 lb. **#523 $12.00**

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Britain's *Beagle 2* lander has touched down on Mars and is setting up shop in this computer-generated illustration. Transported to the Red Planet by the European Space Agency's *Mars Express* spacecraft, the 30-kilogram (66-pound) *Beagle 2* lander packs a powerful set of instruments that it will use to study the geology and climate of its landing site in the quest for answers to one of space science's burning questions: Was there once, or is there now, life on Mars?

Mirage3D, based in the Netherlands, produces scientific computer-generated animations for full-dome planetarium productions, as well as images for science publications. This picture is a still from a planetarium show called *Origins of Life*, scheduled for a Christmas 2004 release.

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