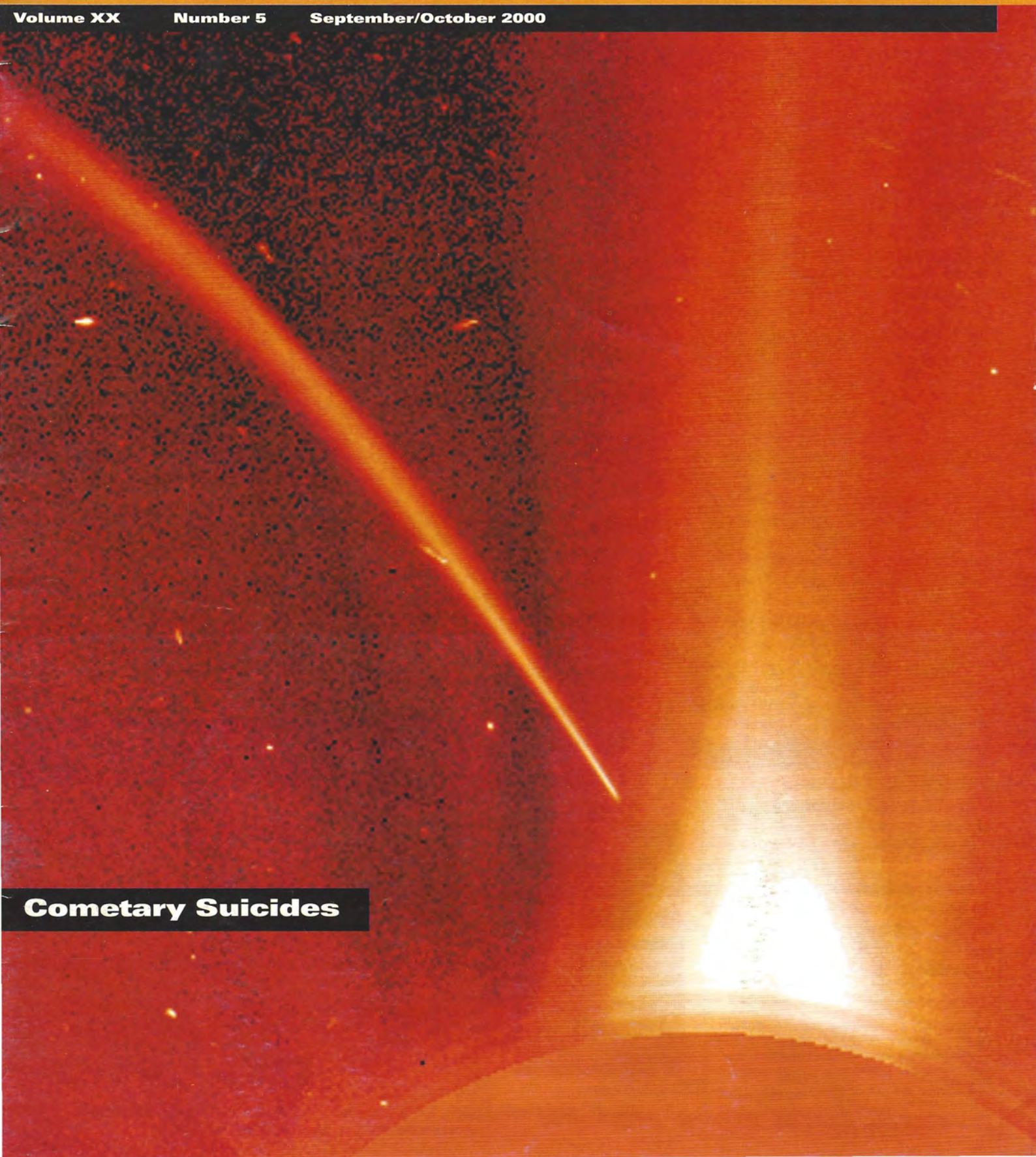
The PLANETARY REPORT

Volume XX Number 5 September/October 2000



Cometary Suicides

On the Cover:

An orbiting telescope designed to study the Sun has also proved effective at finding comets. Professional and amateur comet-hunters alike are detecting comet after comet in data returned by the Solar and Heliospheric Observatory (SOHO). This image of a comet plunging into the Sun's corona was taken on December 23, 1996 by the Large Angle Spectrometric Coronagraph (LASCO) on SOHO. Better known as the "Christmas Comet," SOHO-6 was, as its name suggests, the sixth comet found by the spacecraft. The solid orange area at bottom is a mask to block out the brilliant disk of the Sun.

Image: NASA/European Space Agency (ESA)

From The Editor

Well, we knew we might ignite a firestorm with the Opinion piece "Contamination From Mars: No Threat" by Robert Zubrin in the July/August issue of *The Planetary Report*. The volume of mail received and the strength of opinions expressed confirmed that prediction.

We are actually very pleased with the reaction to Robert's essay. One of the reasons The Planetary Society exists is to foster exchanges between the scientific and engineering communities and the general public. On one level, such an exchange is important because people pay for space exploration through taxes. But there is a deeper and even more important level.

The exploration of other worlds and the search for other life-forms is an endeavor of the entire population of Earth. It is such a great and difficult undertaking that no one person or one company or one nation can do it all.

Not only scientists and engineers do the work. The farmers growing the food, the miners uncovering the raw materials, the secretaries typing the reports, all contribute to the effort. All should have a say. Some proposals are controversial, and they should be discussed openly and broadly. Our Opinion essays are just one means of dialogue.

And this dialogue will continue. We print the first wave of reaction here in Members' Dialogue. You'll see more responses in the next issue. Enjoy the fun!

—Charlene M. Anderson

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Members' Dialogue

Contamination Concerns

I was shocked at the nonscientific nature of "Contamination From Mars: No Threat" in the July/August issue of *The Planetary Report*.

So we don't catch Dutch Elm disease. There have been numerous past examples where pathogens have crossed the species barrier. I expect that some lessons would be learned from this.

Mr. Zubrin's argument is no different than a 17th-century scholar's in support of introducing species—foxes, rabbits, and rats, to name a few—into other parts of the world. These have devastated countries they have been introduced to without a compatible predator.

Maybe there are no pathogens on Mars that can infect us. But that does not guarantee that Mars lacks organisms that would attack or replace organisms on Earth in similar harsh environments. We may discover something that loves feeding on plastics, for instance.

Please, there is no room in your journal for such nonscientific mumbo jumbo.

—ROHIT GUPTA,
Auckland, New Zealand

It was somewhat embarrassing in 1996, when pictures of bacteria-like fossils in meteorite ALH84001 went around the world, to hear the arguments by microbiologists and others debating the unusually small size of the fossils [and to witness] the general ignorance in judging the finds.

What did we expect? Will we be able to identify what we do not yet know? There has to be more focused research on the issue of nanobacteria, on the potential longevity and space-duration of microorganisms, on improved detection methods for microbes (or their molecules) in order to form clearer ideas on possible discoveries when sample return (non-sterilized, please, as Zubrin emphasizes) is a reality.

It may also be advisable to think of an outer-space laboratory (space station or moon) for performing some of the research, staffed with volunteer researchers.

HELGA STAN-LOTTER,
Salzburg, Austria

While I can appreciate Robert Zubrin's zeal and gung-ho humans-to-Mars philosophy, he is out of his field with his comments on forward and back contamination. I find it incredibly amusing that he does not mention the recent Space Studies Board report entitled "Preventing the Forward Contamination of Europa" [posted on the Web] at **http://www.nationalacademies.org/ssb/europamenu.htm.**

—BARRY E. GREGORIO,
Lockport, New York

Robert Zubrin is too optimistic in his dismissal of worry about contamination from a Mars sample return. The human genome and human proteins have millions of sites to which foreign molecules can attach.

The insurance industry shut down the nuclear power industry in this country. Let them decide this issue too. The contractors who will benefit financially from building a Mars sample return mission should be required to demonstrate insurance coverage for all possible negative impacts. The rocket used to launch the mission might blow up. An upper stage might land on a cow. A virus from Mars might infect and exterminate the entire human race—or maybe only all dogs.

How much would the premium be for such coverage? Perhaps it would be cheaper to examine the rocks on the International Space Station.

—FRANK WEIGERT,
Wilmington, Delaware

I was disappointed to read the disclaimer "The views expressed in this article are those of the author and do not necessarily represent those of The Planetary Society." Perhaps a large-print disclaimer warning people of a dangerous ideologue would have been more appropriate. I'm surprised that such a reputable publication would publish an ideological treatise lacking in the scientific method, or, if forced by the writer because of reputation, would not warn readers of the dire consequences that could occur should the author's untested conclusions prove wrong.

I shudder to think that his article can now be referenced by policy makers, decision makers, and the general public in deciding whether and how Earth and Mars are exposed to each other's biospheres.

The Planetary Report should publish a response to the article from reputable scientists that addresses Zubrin's accusations and conclusions.

—OTTIS FOSTER,
McGregor, Texas

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Flowers for Mars

by Christopher P. McKay

Life is the reason that Mars is interesting to us: we search for the possibility of life early in that planet's history and try to determine the potential of Mars as a home for life in the future. Ultimately perhaps the Martian surface could support a planetary-scale biosphere.

The near-term robotic exploration of Mars is the first step toward realizing this vision. Robotic probes provide us with background information about Mars: where to search for evidence of past and present life and how to assess the future biological potential of the planet.

One important way to assess the biological potential of Mars is to send life there. Thus, a goal for the near-term robotic program ought to be to send a seed to Mars and to grow it into a plant—ideally a flowering plant—using to the extent possible the sunlight, soil, and nutrients available in the Martian environment.

Why do such an experiment if the laws of physics and chemistry are the same on another planet? Isn't testing on Earth adequate? Certainly testing on Earth is important, but we gain technical as well as psychological reassurance by demonstrating viability on Mars.

NASA has a long tradition of flying technology demonstration missions. *Mars Pathfinder* was such a mission. On a future lander mission, NASA plans to fly a unit to test oxygen production from atmospheric carbon dioxide on Mars. A module capable of growing a single plant from seed would also be a demonstration mission.

The best design for a plant growth module for Mars would make use of the Martian soil, with nutrients added as necessary. Carbon dioxide and water would be obtained from the Martian atmosphere, and the natural sunlight on Mars would provide for photosynthesis. Because of the lower pressure on Mars, the plant would need to be in a small pressure vessel—its own little spacesuit. The design of this miniature greenhouse would allow light to enter and, true to its name, provide greenhouse warmth during the day. At night the growth module may need to draw on heat generated by the main spacecraft to keep the plant warm. The plant's growth and flowering would be monitored using the lander camera. Initial designs by groups at the University of Colorado and the Jet Propulsion Laboratory have shown that such a unit can be constructed. We could therefore send life to Mars on the next lander.

There are many reasons for sending a flower to Mars. First, it would be highly symbolic. This plant would be the first organism from Earth to play out its existence on another world. It would be a true biological pioneer, an important step for life on Earth expanding to other planets. More practically, a plant growth module would directly test the toxicity of the Martian soil. It would also demonstrate the effectiveness of Martian carbon dioxide and water for a Martian greenhouse. These are essential steps toward a full-scale greenhouse to support a human base. Moreover, the growth of a plant in the Martian environment would help alleviate concerns about the danger of contaminating the Earth by the return of Martian samples.

In all these respects a plant growth model would serve as a biological precursor to human exploration. Indeed, when humans go to Mars, it would make sense for them to arrive at a site that has already established a biologically based life support system, tested and fully operating—robotically. As on Earth, we humans function best when surrounded by other life-forms.

A simple plant growth module would not be in violation of the planetary protection policy. NASA abides by the policy established in 1967 to prevent the inadvertent contamination of Mars by terrestrial microorganisms. For the *Viking* missions this involved the complete sterilization of the spacecraft. However, these missions showed that environmental conditions on the surface of Mars were hostile to life. No organism known could grow or reproduce under Martian conditions. As a result the requirement for sterilization was replaced with a limitation on the number of microorganisms on spacecraft surfaces to less than 300 per square meter.

The original purpose of the planetary protection policy was to preserve extraterrestrial environments as objects of scientific study. We appreciate that the accidental contamination of an alien ecosystem has ethical implications that extend beyond scientific exploration. Sending life beyond

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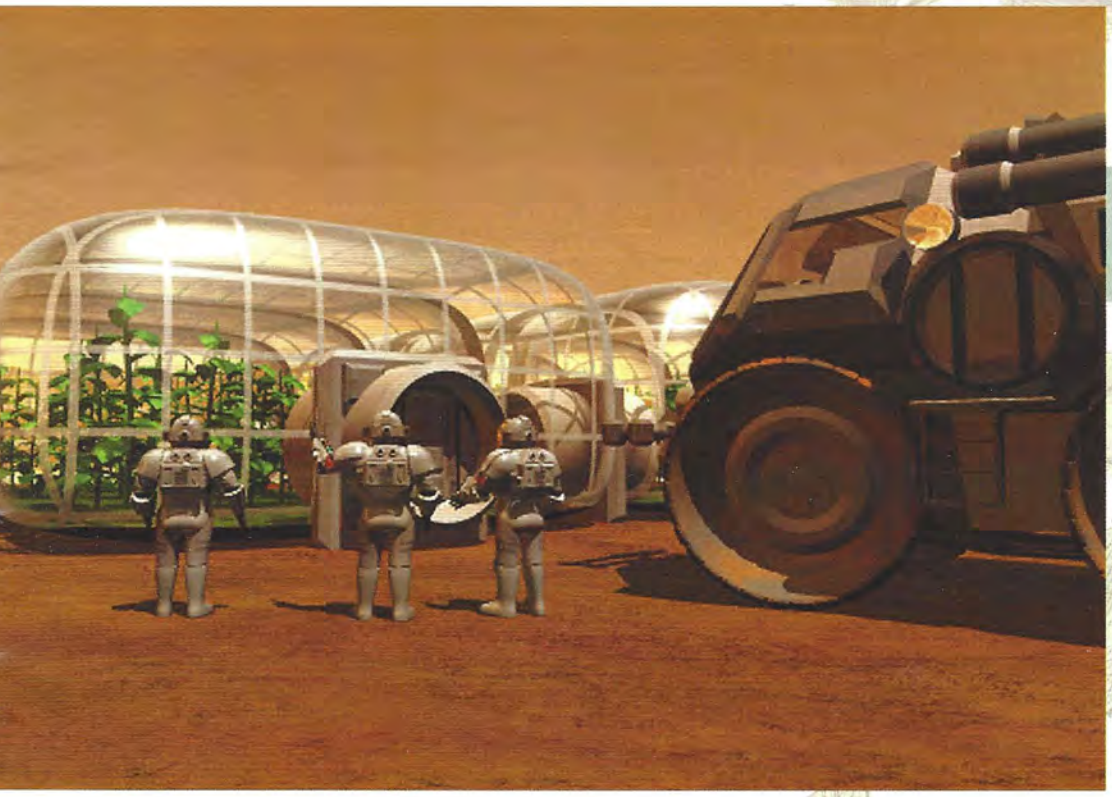
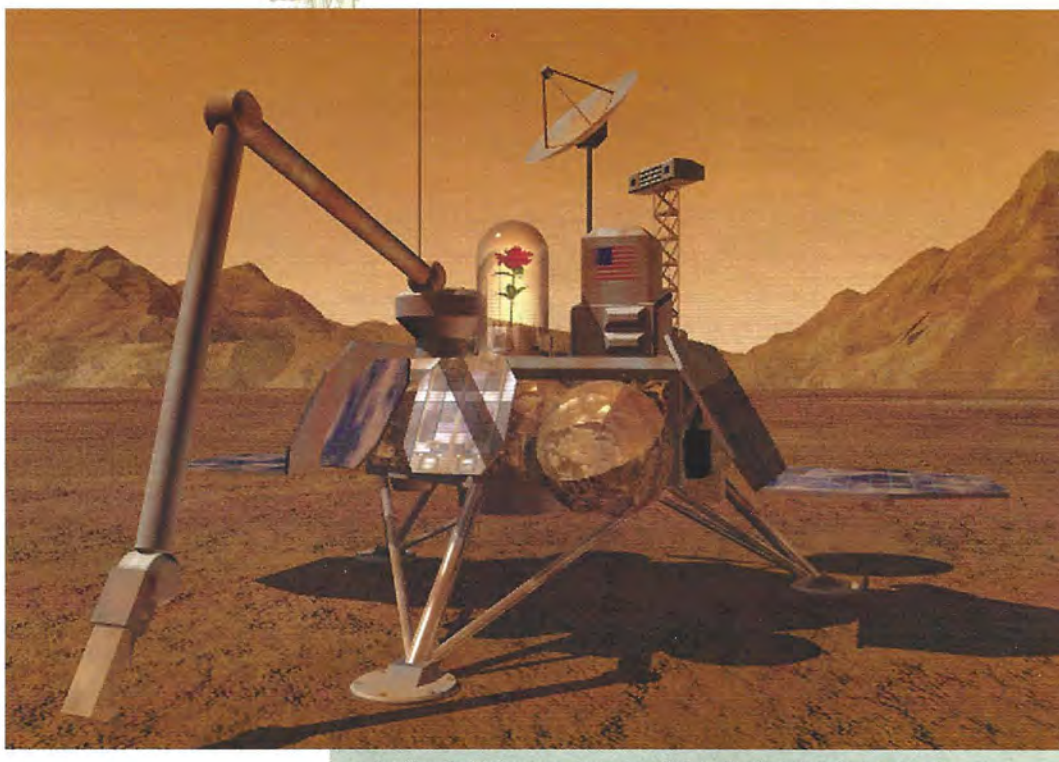


Once the toxicity of Martian soil and the effectiveness of local carbon dioxide and water are determined, the next step toward a full-scale greenhouse might be a small inflatable model.

the Earth is an important step and not one we would want to take without consideration of consequences.

The planetary protection guidelines do not explicitly prevent the controlled transport of biological materials to Mars or the use of biological materials in controlled experiments aboard spacecraft. A plant growth unit could be constructed in accordance with the bioload limits of the present planetary protection policy. In fact, to be sure it functions as intended, the system might well exceed these limits and even be treated to eliminate nearly all bacteria.

By developing ways to send life to Mars consistent with the goals of the planetary protection policy, a near-term plant experiment would pave the way for future research and study on the planet. Most important, the growth of a single flower on Mars would be a powerful symbol of the long-term goal of expanding life beyond the Earth, first to Mars and then elsewhere. It would rival the image of the Earth from space—the pale blue dot—as a symbol of our place and future in the universe.



It will probably happen—humans will take the first steps to terraforming Mars. A good way to test the planet's biological friendliness is to export life there. An experiment as close as the next lander could grow a single flowering plant from seed in Martian soil. *Illustrations: Douglas Shrock*

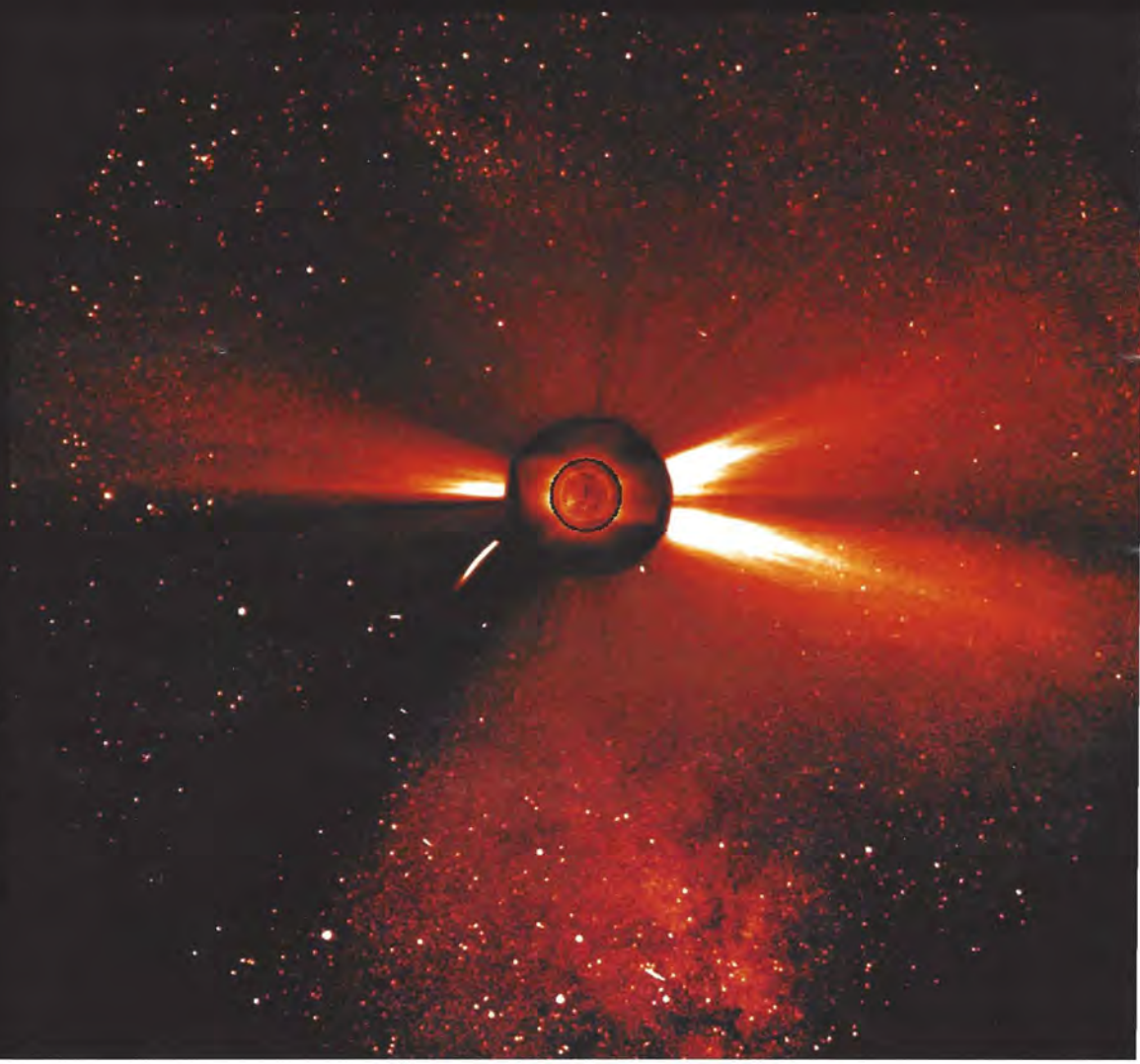
Background illustration: Rosa Micrantha *by Carolus Linnaeus (1707–1778), the Swedish naturalist considered the founder of modern plant taxonomy.*

Christopher P. McKay is an astrobiologist conducting research at NASA Ames Research Center on life in extreme cold and dry environments. He is a member of The Planetary Society's Board of Directors.

Hunting Snowballs in Hell

Most amateur comet-hunters use backyard telescopes in the traditional way. But a few are using a solar observatory satellite to nab comets making a last, fatal dive into the Sun.

by
Robert
Burnham



Comets that cozy up to the Sun have been seen from Earth for hundreds of years. Called sungrazers, they rarely survive their close encounters with our star. This composite image was created by using three different instruments on the Solar and Heliospheric Observatory. The comet shown is SOHO-6. The Milky Way provides the sparkling background. *Image: NASA/ESA*

Discovering a comet has a lot in common with how you're supposed to get to Carnegie Hall—you know, practice, practice, practice. You take a telescope or binoculars and, night after night, for months or even years, you scan the skies between sunset and sunrise. You look for a patch of fuzz that's not part of the sky's fixed population of nebulae, clusters, or galaxies; if it moves, you've got a comet.

That system still works. But now there's another way to find comets—by checking the images relayed each day from a satellite telescope monitoring the Sun. This new approach has certainly worked for Michael Oates. He's a British amateur astronomer who's found more than 50 comets exactly this way.

But Oates isn't the only amateur astronomer searching the solar picture database, just the most successful. On his heels are about a dozen other amateurs from several countries, all using much the same method. And encouraged by these amateurs' success, some professional solar astronomers as well are digging through the photo files.

Staring at the Sun

A solar telescope is about the last instrument anyone would choose as a comet finder. But the Solar and Heliospheric Observatory (SOHO) is different. "We knew it was going to see comets," says Douglas Biesecker, a solar physicist at

NASA's Goddard Space Flight Center. He coordinates comet discoveries for the project. "Our experience with earlier solar observatory satellites told us to expect them."

Between 1979 and 1984, an instrument named Solwind aboard a US Air Force test satellite in Earth orbit discovered six comets passing very close to the Sun. The comets were not found through any deliberate search; they appeared by chance as Solwind was imaging the Sun's corona. By 1989 a different solar-monitoring satellite named Solar Max had caught 10 more comets that either struck the Sun or passed too close to survive.

When SOHO was launched in December 1995, it was not put into Earth orbit as the other two satellites had been. Instead, mission controllers placed it out at the L1 Lagrangian point, about 1.5 million kilometers (about a million miles) sunward from Earth, where it can watch the Sun 24 hours a day. L1 is one of five Lagrangian points where a spacecraft can remain floating, delicately balanced between the gravitational pulls of the Earth and Sun.

SOHO, a joint project of NASA and the European Space Agency, carries a dozen instruments built and operated by research groups in the United States, Germany, France, Britain, and Switzerland. As befits its name—the Solar and Heliospheric Observatory—SOHO's mission is to study the Sun and its immediate surroundings.

But SOHO's amateur comet-hunters have little interest in the nearest star. They are using only one spacecraft instrument, the Large Angle and Spectrometric Coronagraph, or LASCO for short. LASCO has three coronagraphic cameras—designated C1, C2, and C3—which photograph the relatively dim solar corona by blocking the light from the Sun's brilliant surface. This lets the cameras record faint details almost to the edge of the Sun. The three cameras are aligned, and their fields of view nest within one another, overlapping slightly.

LASCO's gaze doesn't take in much sky. The camera with the widest field of view, the C3 coronagraph, covers from 3.7 solar radii out to 32 solar radii. This means that C3's frame covers a circle of sky some 15 to 16 degrees across—less than a handspan held at arm's length. The C2 instrument's field reaches from 2.0 to 6.0 solar radii, and C1 covers from 1.1 to 3.0 solar radii. (The C1 instrument, however, is now set to wavelengths "blind" to comets, so it is not being used by the comet searchers.)

On a typical day, SOHO sends back to Earth 65 to 70 images from the C2 coronagraph plus 45 to 50 from the C3 instrument. The SOHO mission website (see sidebar on page 11) posts these images in several formats in real time and provides reduced-resolution MPEG movies of them. The photos are then stored at full resolution in an archive where they are accessible over the Web.

Snowballs in a Furnace

What kind of comet is likely to pass close to the Sun? The answer is a sungrazer. These are comets that sail to within a few radii of the Sun's surface. Since the Sun's radius is 696,000 kilometers (433,000 miles)—less than twice the distance to the Moon—this is close indeed. Sungrazing comets have been seen from Earth for centuries, often during solar eclipses. The first such comet on record may be one from 371 BC noted by Artistotle and Ephorus.

But sungrazers were long believed to be rare; as of 1979, fewer than a dozen had been seen. Still, they were intriguing enough that in the 1880s and 1890s, German astronomer Heinrich Kreutz (1854–1907) showed that several sungrazers were probably related since they followed similar orbits. He suggested they were fragments of a large comet that broke apart on one of its close solar passages. Comets from this group are now called Kreutz family sungrazers in his honor.

More recently, Brian Marsden of the Harvard/Smithsonian Center for Astrophysics reconstructed a history for this remarkable comet family. The original parent comet, which may have had a nucleus about 120 kilometers (75 miles) in diameter, seems to have arrived in the inner solar system between 10,000 and 20,000 years ago. This mega-comet wound up in an orbit that skimmed the Sun every 1,000 years or so. As Marsden figures it, perhaps 10,000 years ago the Kreutz parent comet broke apart on one of its sungrazing passages. The rupture spawned two major fragments traveling on similar though not identical orbits.

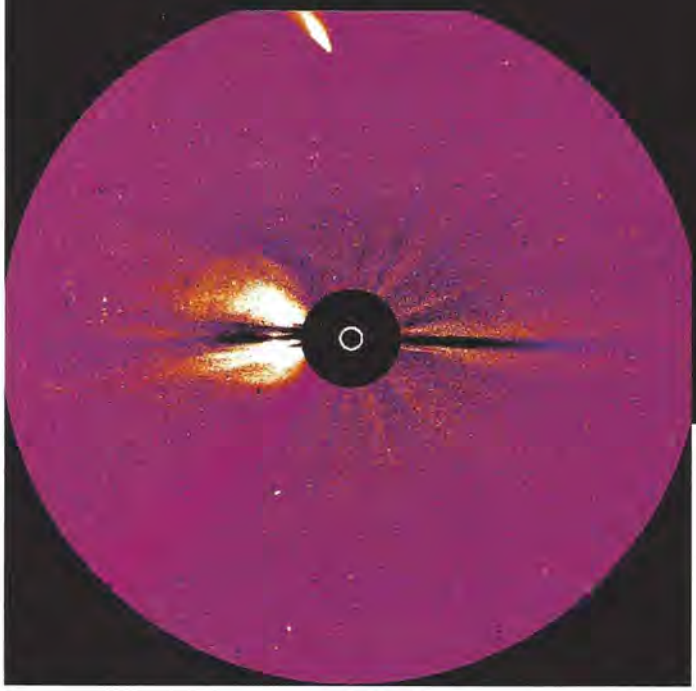
The first Kreutz fragment held together until 371 BC, when it broke into at least three large pieces, one of which became the Great Comet of 1843. The second Kreutz fragment remained intact until AD 1106, when it split into three or more comets. Its descendants include the Great Comet of 1882 and comet Ikeya-Seki of 1965. Many more Kreutz member comets, including Solwind's first comet, are now known or suspected.

Marsden explains, "When you trace the good orbits back on the sky, they all come from a spot only about half a degree across—as wide as the Moon." And, he continues, "more than 90 percent of SOHO's comets are Kreutz family members."

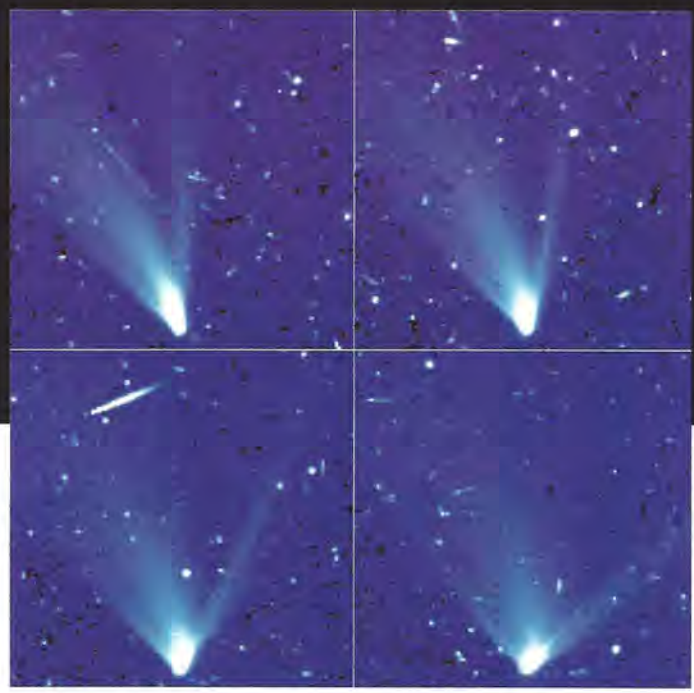
Whether a sungrazer hits the Sun or is simply vaporized as it passes very close is unclear, since no SOHO comet has been caught in the act of vanishing. This is because comets

Imaged on July 28, 1984, this comet was the fifth of six found in pictures taken by the Solwind instrument aboard a US Air Force test satellite. The fact that these comets appeared by chance as Solwind imaged the Sun's corona alerted solar scientists to expect them in SOHO data also.

Image: © 1985 the High Altitude Observatory and NASA



Comet Hyakutake was picked up by LASCO's C3 coronagraph on May 2, 1996. This picture shows the comet to the north of the Sun. Image: NASA/ESA



These LASCO close-ups of Hyakutake at perihelion were taken over four days from May 2 through 5, 1996 (left to right, top to bottom). Image: NASA/ESA

disappear behind the optical shield about 2 solar radii above the surface. Yet whatever happens to them at closest approach, the attrition is brutal—virtually none survives, probably because most SOHO comets are small, less than a few dozen meters in diameter.

Bigger sungrazers stand a better chance. For example, comet Ikeya-Seki passed less than 2 solar radii above the Sun's surface at perihelion in 1965. The comet grew so hot that astronomers at the time detected emission from atoms of vaporized iron and other metals in the comet's dust. Immediately after perihelion the comet's nucleus broke into three pieces, one of which quickly vanished as it evaporated. The two remaining nuclei departed on slightly different orbits and will return in periods of 880 years and 1,056 years, respectively.

But not all comets that zoom in close to the Sun belong to the Kreutz family. One outstanding nonmember was the bright comet Hyakutake, caught by SOHO's C3 camera as it rounded perihelion on May 1, 1996. Hyakutake is part of a background rate of ordinary sungrazers that Marsden thinks is probably not part of another, unidentified Kreutz family, much dispersed.

"You've got things coming from the Oort cloud, and some will go very close to the Sun," he explains. "The most famous non-Kreutz sungrazer is the Great Comet of 1680." This comet was much studied by Isaac Newton, Edmond Halley, and others.

Yet Marsden points out that the observational record of accurate comet positions is still very short, roughly three centuries or so in length. This is long in human terms, yet the orbital period of the 1680 comet is some 8,000 years. It could have sibling comets for which no accurate observations exist.

Beyond questions of family membership, the SOHO discoveries have given scientists a real jolt. "A big surprise was how many there have turned out to be," says Douglas Biesecker. "We thought we'd find only a couple a year." Instead, in the images from 1996, 16 comets have been detected, whereas from 1997's the tally is 23. The images from 1998 show 34 comets and 1999's reveal 50. In the period from January to early July 2000, 33 sungrazers have been found. And nearly half of all SOHO's comets are discoveries by amateur astronomers.

Meet Some Comet-Hunters

Jonathan Shanklin straddles the pro-amateur divide since his main work is in atmospheric science for the British Antarctic Survey. (He was one of three scientists who discovered the Antarctic ozone hole in 1985.) Based at England's Cambridge University, he's also head of the comets section of the British Astronomical Association, the UK organization for amateur astronomers.

"I've done some conventional comet-hunting from the Antarctic," he says, "idly scanning fairly close to the Sun, but I'm not particularly systematic about it." The advent of SOHO's images made many changes, however. "It used to be that it took 300 hours of real-time searching to find one. With SOHO, you can compress that by scanning rapidly through perhaps 24 hours' worth of images in several minutes.

"Most of the comets don't look particularly cometary," he adds. "One may appear slightly more diffuse than a star, but essentially they're difficult to distinguish, especially in the low-resolution images. The clear thing is that they are moving in a systematic way."

Which part of a SOHO image to study changes from season to season. The Kreutz sungrazers slant in from the south, at 35 degrees to the plane where Earth and the other planets orbit. As SOHO moves around the Sun along with Earth, it sees the comets approaching from the east (the left side of

This photo of comet Ikeya-Seki was taken by Roger Lynds at Kitt Peak, Arizona, on October 29, 1965. The comet, quickly recognized as a sungrazer, became visible in broad daylight to anyone who blocked the Sun with a hand. Ikeya-Seki, a Kreutz family comet, may possibly be a return of the great comet of 1106, visible in broad daylight in Europe. Photo: Roger Lynds/AURA/NOAO/NSF

In the 1880s and 1890s, German astronomer Heinrich Kreutz demonstrated that several sungrazers with similar orbits were probably relatives—pieces of a larger body that broke up during a brush with the Sun. This image of SOHO-48, a member of the Kreutz clan, was taken by the LASCO C2 telescope on April 30, 1998. Image: NASA/ESA

the image) in February and from the west (right) in August. In June and November the sungrazers seem to head straight up toward the Sun.

Discoverer Michael Boschat of Halifax, Nova Scotia, is a photo technician who enjoys looking for the comets in real time and has found 13 of them. Boschat downloads GIF-format images (which appear on the SOHO website about every half hour or so) and, after some image processing, puts them into animation software. He then studies the resulting images, running them back and forth, seeking telltale patterns in the flickering pixels. He says, "I usually loop the images at four frames per second. I'm looking for an object moving toward the Sun in a steady manner."

Maik Meyer, of Frauenstein, Germany, is a scientist at the Technische Universität in Chemnitz. Unlike some other SOHO comet-hunters, he has made many observations of comets with backyard telescopes, including a 10-inch Dobsonian reflector and a pair of 20 x 100 binoculars. He collects full-resolution images and, using software, rapidly compares them, sandwiching work between his downloads and searches. His score, as of mid-July, is 13.

Terry Lovejoy, who has found 10 comets in SOHO images, lives in a suburb of Brisbane, Australia, and is a third-generation comet watcher—"I've got comets in my blood, I guess!" His routine: "I download the images in the evenings and spend about half an hour a day on this. Sometimes I'll grab two or three low-resolution frames quickly to see if there's anything obvious."

He adds, "I've also been trying different techniques. One is to adjust the frames so the star field is fixed. If you just animate the frames directly, you have the moving stars confusing the picture and making comets harder to see."

The top-scoring amateur at the moment is Michael Oates, with a tally approaching 60. He runs an electroplating company in Manchester, England, and by his own acknowledgment is a pretty low-key

Comet SWAN: The Comet No One Saw

The Large Angle and Spectrometric Coronagraphs are not the only comet-discovering instruments on board the Solar and Heliospheric Observatory (SOHO) satellite. Another instrument aboard SOHO, dubbed SWAN (for Solar Wind Anisotropies), discovered a comet that slipped through the sky undetected in May through July 1997. The comet turned up years after the fact in SWAN's data as astronomers were studying the atomic hydrogen surrounding the Sun.

"The discovery was a surprise," says Teemu Mäkinen, a Finnish member of the SWAN instrument team. SWAN was designed to measure and map the atomic hydrogen around the Sun. Much of this material comes from cometary water molecules broken apart by solar ultraviolet light. SWAN thus provides a useful way to measure the amount of water given off by comets as they warm under the Sun's radiation.

SWAN's comet, designated comet C/1997 K2, was not seen by anyone on Earth. Astronomers estimate that the comet, which was best visible from the Southern Hemisphere, was still only 11th magnitude at brightest. This is within reach of 15-centimeter (6-inch) amateur telescopes but well below what the naked eye can see.

—RB

The next comet to enter the LASCO C2's field of view was not a Kreutz sungrazer. Shortly after SOHO-49 (near the top of the frame) was discovered, comet hunters realized it could eventually be observed from the ground. Image: NASA/ESA

This ground-based photograph of SOHO-49 passing by the Horse Head and Flame nebulae was taken by Michael Horn on May 23, 1998, from Wandibindle in Queensland, Australia. (South is at the top of the image.) Photo: Michael Horn © 1998

amateur astronomer in the traditional sense. "I don't even have a telescope," he admits. Yet once Oates saw how to use SOHO images to hunt comets, he was off and running, aided by high-speed Internet connections at home and at work.

"I would estimate I'm online at home about 12 hours a day," he says. "Now that doesn't mean I'm stuck at the computer all that time. Before I go to work in the morning, I'll set the computer to downloading 100 megabytes of archive images, which takes three or four hours. When I go to bed, I'll do the same. That extends the work day, if you like."

Searching the downloaded images at the computer takes Oates an hour or two each day, and he's building his own image archive as well. "I put them all onto CD-ROMs, and I now have a couple hundred CDs full."

"Early in the mission," says Douglas Biesecker, "we thought it would be great public relations to have amateurs involved." At that point, amateurs had made few discoveries, so project scientists saw the amateurs' role mainly as a kind of early warning system. Then the number of amateur discoveries started to mount, and even the professionals began to take a more than casual interest.

One result is that the tally of comet SOHOs is steadily growing, even for years gone by. For example, if you check the discoveries for any period of several weeks in 1998, you'll find that the number has ratcheted up in the meantime. What's happening is that comet hunters, amateur and pro, are digging through SOHO's archives, probing for comets that were photographed but overlooked amid the daily flood of new images.

"I got into the archives," explains Michael Oates, "because there were more people looking [at the real-time images]. I thought to have a go at the old material to see if any comets were missed." His starting point was one that anyone might choose. "I began with the C3 camera's images because it has a wider field of view, and I thought it would be easier to spot comets using it."

Yet results were disappointing. In about six months' data he'd found only two comets, which seemed like pretty slim pickings. So he switched tactics.

"While working with the C3 images, I'd also been looking at the C2 ones in real time, and I learned what to look for," he says. "I then decided to look at the archived C2 data. That was a really good move, because that's where all the comets are."

Racing to Publish

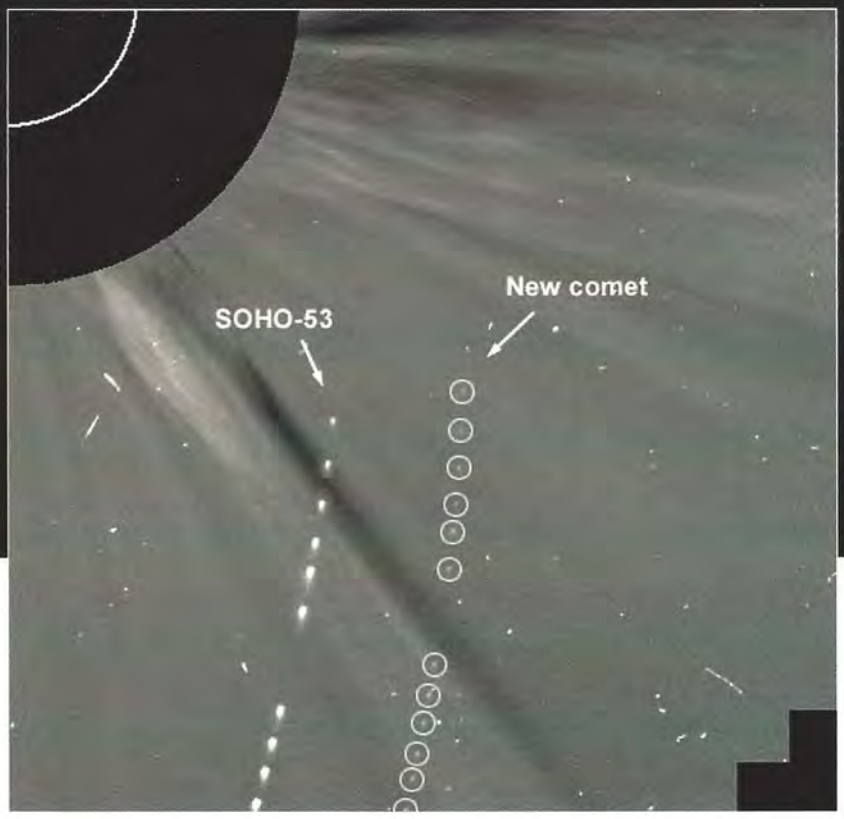
As regards future discoveries, Michael Oates is philosophical. "It's a bit of a race, really, and I'm getting what I can before everybody else joins in."

"It's very competitive, I must say," agrees Terry Lovejoy. Despite the pressure, he's optimistic: "I would say there are lots and lots that haven't yet been picked up in the data." Oates adds, "To come across a day's data without a comet in it is unusual. Sometimes there are two comets a day."

The idea that there is still room for discoveries is echoed by other amateurs. "Very often you take a quick glance and don't see anything," says Jon Shanklin. "And then somebody comes along and reports one in frames you've scanned. You go back and look again—and there it is. That's happened a couple of times to me."

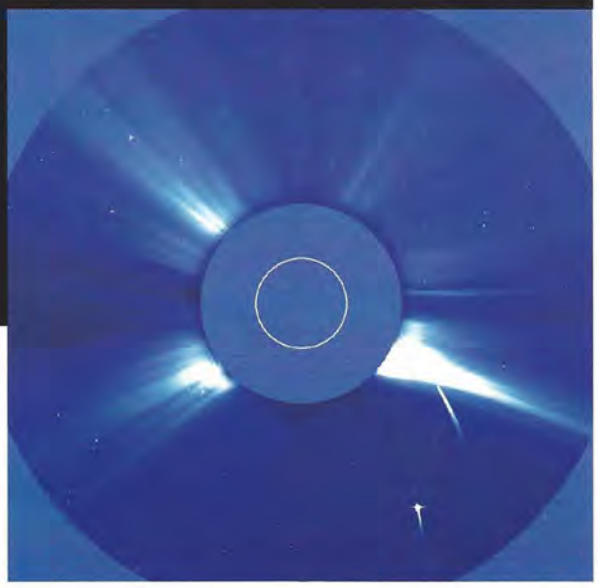
And timing is important with the real-time images, he says. "If you just happen to be looking in the hour and a half, say, when no one else is, then you'll probably get something. That, I think, is what it really boils down to."

As comet-discovery coordinator, Douglas Biesecker has had to institute some rules to keep the game fair for all. For instance, don't bother reporting a comet unless you have it on at least four successive frames moving in a physically



Left: Michael Oates, a British amateur astronomer, has a real talent for ferreting out comets in SOHO data. This year on June 17 he detected comet number 143 running alongside previously discovered SOHO-53.

Below: Observers got a real treat on June 1 and 2, 1998, when two comets, SOHO-54 and SOHO-55, were seen plunging into the Sun in close succession. Images: NASA/ESA



plausible manner. Cosmic rays produce random bright pixels that come and go in the images, and many searchers have been fooled by these spurious "comets."

Reporting also has a protocol. Says Biesecker, "Whoever is first to e-mail me with a finding that checks out is the person who gets named in the report. Remember, these comets are not named for individuals—they're all comet SOHOs. But the finders are mentioned by name in the IAU circulars and on the mission webpage." Many of the discoveries, in fact, are joint ones, shared because they were independently made.

Watch This Space

Between June and September 1998, SOHO looked like a lost mission. The spacecraft had spun out of control during a routine maneuver, and it took mission controllers several months to get back in radio contact, regain command, check out systems, and restore the spacecraft to operation.

"It's now in good shape," remarks Biesecker. "There's enough maneuvering fuel left for 50 years. We hope that NASA and the international agencies will keep it going at least until 2001, when the next coronagraph mission is launched." That mission, called Solar Mass Ejection Imager, or SMEI, will have cameras that record images over six times fainter than LASCO's can, and the pace of comet discoveries should step up even more.

When asked to guess how many comet SOHOs will be known by then, Biesecker says, "We'll have easily 200 more than now."

Robert Burnham is a former editor of Astronomy *magazine and the author or editor of several books on astronomy and Earth science. His latest book is* Great Comets *(Cambridge University Press, 2000).*

Do It Yourself!

Why should others have all the fun? Below are websites for the SOHO project, the LASCO coronagraph, and Douglas Biesecker's sungrazing comet page. Also, several comet-hunting amateurs have their own websites. (For brevity, "http://" has been omitted.)

Solar and Heliospheric Observatory spacecraft
sohowww.nascom.nasa.gov

•

LASCO (coronagraph instrument)
lasco-www.nrl.navy.mil/lasco.html

•

Douglas Biesecker
sungrazer.nascom.nasa.gov

•

Terry Lovejoy
www.ozemail.com.au/~lovejoyt/southern.htm

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Maik Meyer
www.comethunter.de

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Michael Oates
www.ph.u-net.com/comets

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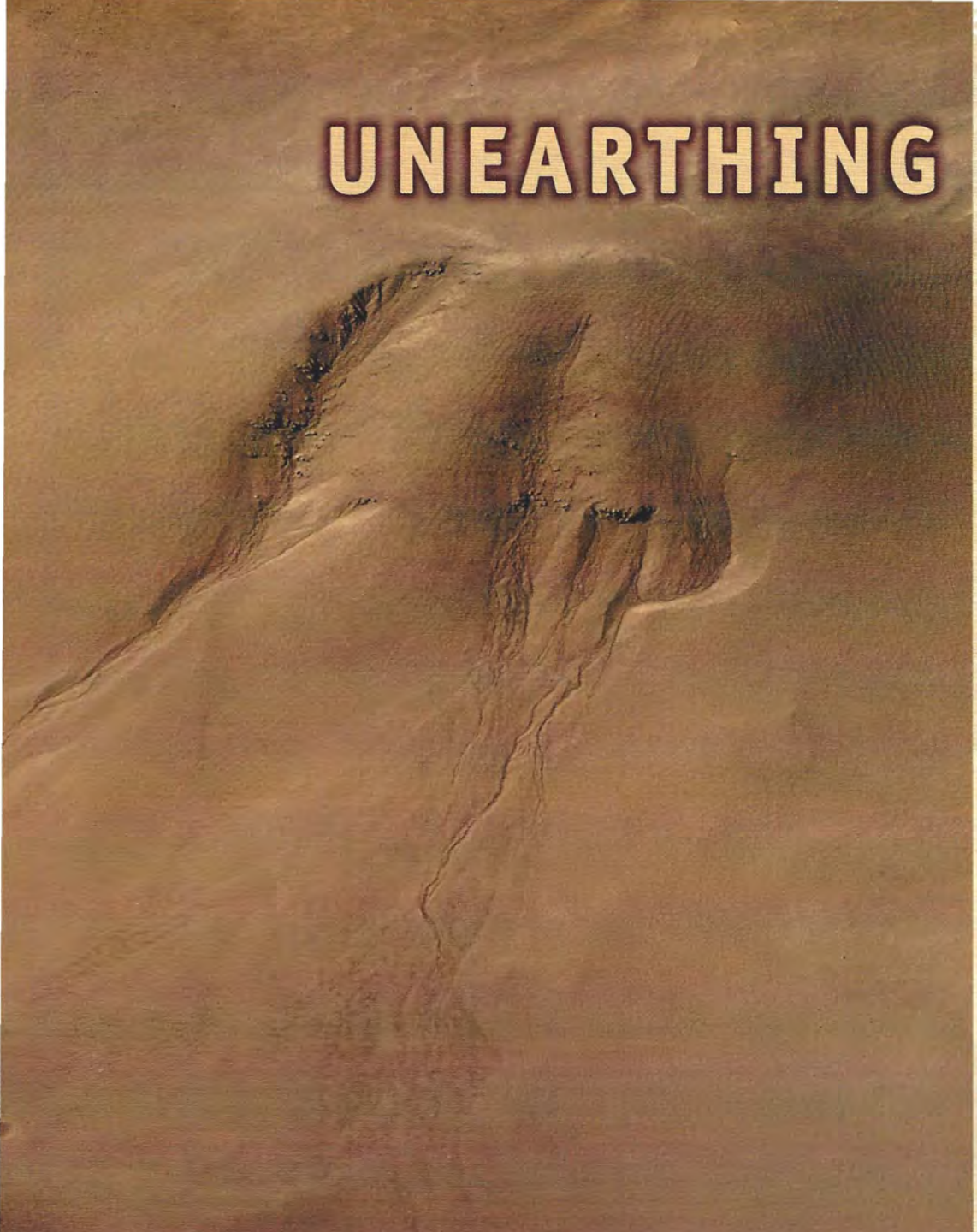
Jonathan Shanklin
www.nbs.ac.uk/public/icd/jds

UNEARTHING SEEPS A



Left: What chiseled out these gully landforms captured by the Mars Orbiter Camera (MOC)? On Earth, alcoves with clear channels and aprons of debris—like the Martian features shown here along the wall of a meteor impact crater in Noachis Terra —are formed by flowing water. On Mars, with its thin atmosphere and frigid temperatures, each outburst of liquid sets off a competition between evaporation, freezing, and gravity. Still, as on Earth, the Martian gullies appear to have been carved by groundwater seepage, surface runoff, and debris flow. Moreover, the lack of small craters superimposed on the channels and apron deposits suggests that these features are geologically young. In fact, it is possible that liquid water is seeping from the Martian subsurface today.

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Until recently, I thought I understood Mars and the likely distribution of water on the planet: water vapor in the atmosphere, ice at the poles and within the crust, and liquid water at great depth below the surface. However, when results from the *Mars Global Surveyor* camera (the Mars Orbiter Camera, or MOC) suggested the impossible—liquid water near Mars' surface—I found myself caught up in a new Martian mystery.

At a NASA press conference held June 22, Michael Malin and Kenneth Edgett from Malin Space Science Systems (the company that built and operates MOC) unveiled evidence that liquid water may exist near, or even on, the Martian surface. NASA had originally scheduled the media event for June 29, but leaks to the press precipitated its move forward a week.

Sensing that something big was up, reporters just two days earlier had called around to Mars researchers for someone who would talk. On Wednesday, June 21, a pieced-together version of Malin and Edgett's discovery made headlines.

NASA officials realized that they could no longer sit on the story. Plus, the news media, by jumping the gun on the story, got most of the major facts wrong. In an effort to get the truth out, officials spent Wednesday morning negotiating a release of Malin and Edgett's write-up of their discovery prior to its publication in *Science* magazine. They also arranged an earlier date for the press conference. By lunchtime Wednesday the press conference had been pushed ahead—to the following morning. Malin, Edgett, the US Geological Survey's Michael Carr, and I all booked flights to Washington, DC, for that

ND SPRINGS ON MARS

BY BRUCE JAKOSKY

llis, an ancient valley thought to have been carved in part by running water sometime in stant past, is the one location where Martian gullies have been found closer to the equator legrees latitude. Shown above is a mosaic of Viking orbiter images capturing a larger area Vallis. The small white box (arrow) indicates the location shown in the MOC high-resolution right, revealing more than 14 channels nearly 1 kilometer (0.6 mile) long running down the cing slope. Each narrow channel starts at about the same position near the top of the wall; a liquid—most likely water—percolated from a layer of Martian crust, then flowed down he channels as well as fan-shaped aprons at the bottom of the slope. Some of the apron seem to cover the dunes on the valley floor (lower third of the image), suggesting that the and aprons formed more recently than the dunes. None of these features shows evidence t craters, which indicates that they are geologically young. Interestingly, one of the first returned to Earth from MOC exhibited similar channels and aprons along the walls of Nirgal t at the time their significance went unrecognized. Images: MSSS/NASA

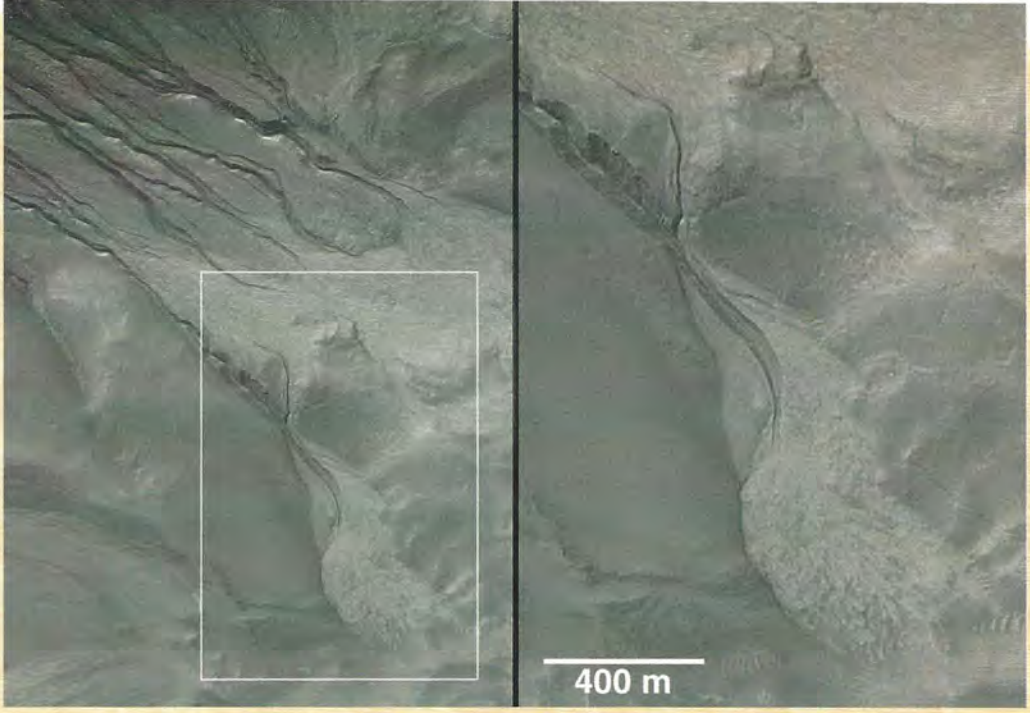
evening, arrived at our hotel rooms between 1 and 2 a.m., and showed up at NASA at 8:30 a.m. By 11 a.m., everything was set. That evening the network news broadcast the story, and the next morning, daily newspapers made it front-page news.

COMPELLING EVIDENCE

"The story" concerns evidence that liquid water may be accessible on Mars. The evidence appears on about 250 of the nearly 65,000 MOC images to date. These images reveal erosional gullies and depositional fans resembling features produced on Earth from the seepage of water in the form of springs. Perhaps most remarkably, the Martian features appear to be young—geologically speaking. The implication is the presence of liquid water within the Martian crust either currently or very recently on the geologic timescale. Liquid water may therefore be available much closer to the surface than we had suspected (hundreds of meters rather than thousands) and consequently be more accessible to future spacecraft missions.

While not proving conclusively that the erosional channels visible on the MOC images were formed by water, the evidence is compelling. The channels apparently display characteristics indicating the seepage of water. To varying degrees they all show an eroded alcove at the top, a discrete channel flowing downward from the alcove, and a depositional apron at the bottom.

The alcoves are typically "theater"-shaped depressions. Each contains debris and boulders that evidently slumped or rolled down onto the floor of the alcove. As Malin and



This telltale MOC image reveals channels that are deeply entrenched and cut into lighter-toned deposits. The numerous channels and apron deposits indicate that many tens to hundreds of individual events involving the flow of water and debris have occurred here. First the flow of debris creates the depositional aprons; then additional debris and water flow cut the trenches into the apron. These features—found in the northern wall of a 12-kilometer-(7.4-miles-)wide impact crater east of the Gorgonum Chaos region—are extremely young. The sharp relief of the channels and aprons and the absence of small meteorite impact craters suggest that these landforms may still be in the process of creation. Image: MSSS/NASA

Edgett describe in their paper, published in the June 30, 2000 issue of *Science*: "The overall impression of the uppermost zone of these landforms is that a headland has experienced undermining and collapse across a confined zone."

At the bottom of each alcove, the walls narrow into a V-shaped trench cut deeply into the surface and continuing downslope. Faint lines shadowing the paths of some trenches hint at the presence of earlier channels. A few of the trenches appear discontinuous, suggesting that subsurface flow and erosion ("piping") contributed to their formation.

Below the trench lies a depositional apron comprising debris carried down from above. This feature appears much like debris fans or aprons formed on Earth by running water emerging from mountains into a valley or onto surrounding plains. In some cases the trench cuts into the apron, indicating at least two episodes of activity: one in which the apron was deposited and another in which it was cut by the trench.

In general such features—alcove, trench, and depositional apron—form on the sides of impact craters or valley walls. A number of them appear on the walls of Nirgal Vallis, a sinuous channel thought to have been formed by liquid water. Overall their resemblance to terrestrial features resulting from erosion by liquid water is striking.

Indeed the simplest explanation for the available evidence is the action of liquid water. That is, water within the crust seeps out of cliff walls in the form of a spring, which cascades down the slope and carves channels; as material is wrenched from the walls, the alcoves form by collapse. Once the channels level out, the flow of water slackens (or possibly evaporates) and the debris it packs is deposited. If this scenario is correct, the source region for the seepage could lie within one hundred to several hundred meters of the surface; liquid water would therefore be present fairly close to the surface of Mars.

AN UNUSUAL SUSPECT

How can liquid water exist so close to the Martian surface, where temperatures are evidently cold enough to freeze it to ice? The scientific community holds that the planet's surface, with average daily temperatures around 220 kelvins (–53 degrees Celsius, or –63 degrees Fahrenheit), is too cold for liquid water to remain stable. Liquid water might perhaps exist at depths of 1 to 3 kilometers (0.6 to 1.9 miles), where geothermal heating would raise temperatures above the melting point of ice. At shallower depths, temperatures would be too cold unless volcanic magma were nearby or sufficient dissolved salts were present to lower the melting temperature. Yet evidently volcanic activity on Mars has been rare of late, and a brine with enough dissolved salts to remain liquid at such low temperatures would thicken to sludge and therefore not flow readily.

Most mystifying is the geographic distribution of the telltale gullies. They are noticeably absent where surface temperatures are warmest and liquid water would most likely be found: near the equator or on slopes pointing toward it and therefore warmed by sunlight. Instead they have been spotted at colder

Sites evidencing recent seepage and runoff of liquid water on Mars turn up in the most unlikely places. That is, they typically occur where temperatures are well below freezing all year round. The MOC image shown here was acquired July 14, 1999, near 70.7 degrees South, 355.7 degrees West—if you were at this same latitude on Earth, you would be in Antarctica. Nevertheless, gullies with deep, V-shaped channels are visible on the pit walls. About a third of the way down from the top of the image, the channels start wide and taper downslope. Avalanching of dry debris has formed a pattern of chutes and ridges on the upper slope of the pit wall. The top layer shows many boulders—each about the size of a small house—left behind at the removal of debris.

Image: MSSS/NASA

middle and high latitudes and on slopes pointing toward the poles!

Malin and Edgett are ready with an explanation. At the equator or on equator-facing slopes, water that seeped out slowly would presumably evaporate quickly and therefore fail to flow very far down the slope. By contrast, in colder regions, seeping water might freeze quickly and plug up the spring. Pressure building up behind the "ice plug" would eventually break through to the surface, causing water to burst forth all at once and plunge down the slope. In this way the channels would be carved by episodic seepage rather than by a steady trickle.

Another possible explanation may not have occurred to Malin and Edgett, residents of Southern California currently and of Arizona before that. In colder climates, water pipes tend to freeze during the winter—that is, unless faucets are left running at a trickle. The water then flows through the pipes faster than it can freeze. On Mars, water could circulate from depths of several kilometers to near the surface. As long as it moved toward the surface more rapidly than it froze, it could stay in a liquid state. At a hundred meters' depth, a layer of water a centimeter (0.39 inch) thick would freeze in the soil each day. The water might remain liquid as long as it were resupplied at this rate; flow rates of centimeters per day are common on Earth.

A competing scenario is presented by Paul Knauth (Arizona State University). Knauth suggests that dissolved salts could lower the freezing point of water sufficiently for liquid water to exist at Martian temperatures. However, it takes a lot of dissolved salt to lower the melting temperature from 0 degrees Celsius (32 degrees Fahrenheit) to –50 or –60 degrees Celsius (–58 to –76 degrees Fahrenheit). Imagine brine saltier than the Earth's oceans. In fact, such a brine would be up to 40 percent denser than pure water—literally thick as molasses.

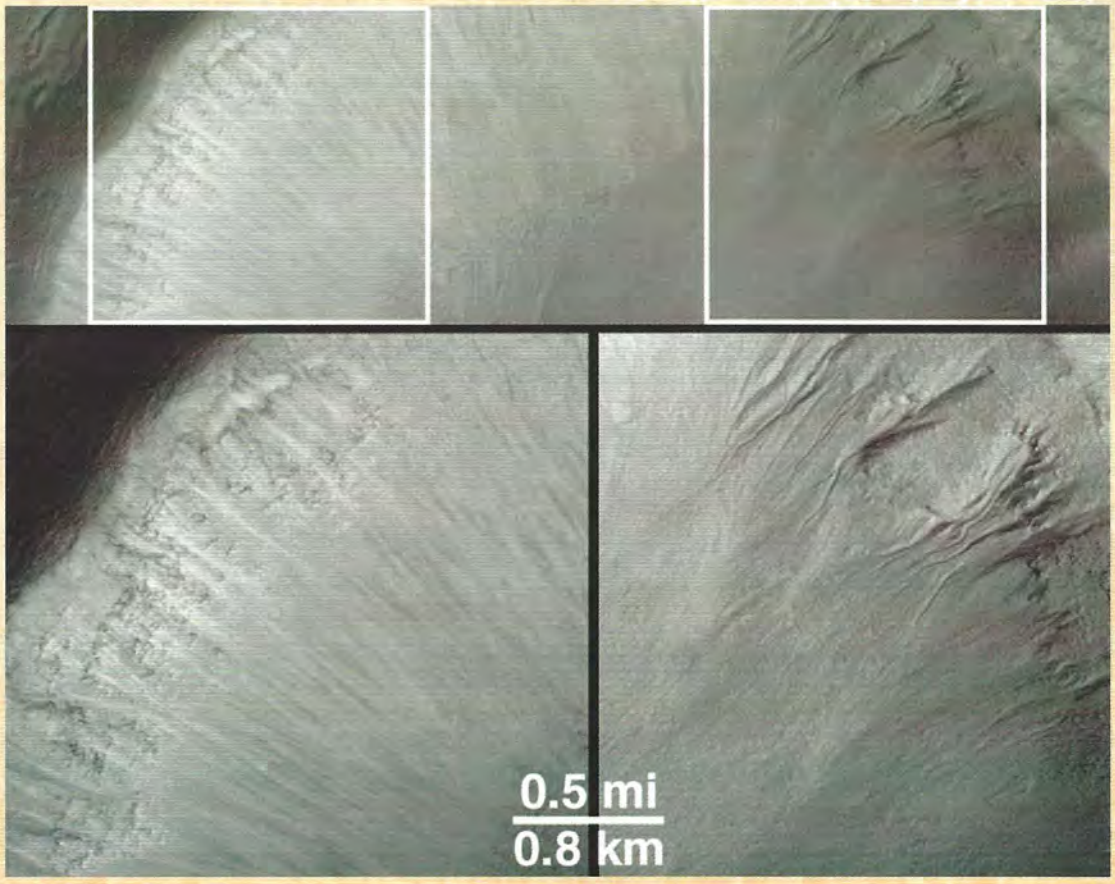
Alternatively, the features in question could have formed at a time when the tilt of Mars' polar axis was greater than it is today. The surface and near-surface temperatures might then have been high enough to melt ice. We know that the planet's polar tilt changes from its current value of 25 degrees on hundred-thousand- and million-year timescales. It may have been as much as 60 degrees as recently as 10 million years ago. Ken Tanaka (US Geological Survey in Flagstaff, Arizona), James Kasting (Pennsylvania State University), and Steven Squyres (Cornell University) have independently suggested that increased surface temperatures at upper latitudes during these periods conceivably penetrated the subsurface; ice then melted within the crust, and water seeped out and carved the gullies.

In contrast, a mechanism other than liquid

Newton crater is a large basin formed by an asteroid impact, evidently more than 3 billion years ago. It spans approximately 287 kilometers (178 miles). Shown here is a portion of a smaller impact crater located in the southwestern quarter of Newton crater. This smaller crater measures about 7 kilometers (4.4 miles) across. Eroded into its north wall are many narrow gullies, apparently formed by flowing water and debris. Debris transported with the water created the lobe- and fingerlike deposits at the base of the crater wall. Many of the fingerlike deposits display small channels, indicating the flow of liquid. Hundreds of individual water and debris flow events possibly created the scene shown here.

Analysis of the deposits visible at channel ends in the MOC image allows scientists to estimate the minimum amount of water involved in a flow event. First, scientists assume that the deposits are like debris flows on Earth (meaning that between 10 and 30 percent of their volume is water). Second, they estimate the volume of an apron deposit by measuring the area covered in the MOC image and multiplying the result by an approximation of thickness (2 meters or 6.5 feet). A conservative estimate is that a flow event containing only 10 percent water involves about 2.5 million liters (660,000 gallons)—enough to fill about seven community-size swimming pools or to supply water for 20 people for a year.

Image: MSSS/NASA



How can Martian gullies—thought to be caused in part by seepage and runoff of liquid water—be distinguished from the more typical "dry" slope erosion processes that occur on Mars? First, notice position; most gully landforms occur on slopes that face away from the Martian equator. Conversely, slopes that face toward the equator display features commonly seen on nearly every non-gullied slope on Mars. This picture, with boxed areas enlarged below, lets us compare equator-facing slopes (near right) with pole-facing slopes (far right) in a crater of northwestern Elysium Planitia. The shadowed poleward slope exhibits a series of Martian gullies—defined by their erosional alcoves, deep channels, and apron deposits. The sunlit equatorward slope shows a scene more typical of Martian impact craters: the upper slopes reveal layered bedrock; the lower, light-toned streaks of dry debris slid down the slope to form talus deposits, visibly different from the lobe-like gully aprons.

Image: MSSS/NASA

water might be responsible for the features seen on the MOC images. At the NASA press conference, Mike Carr suggested that debris entrained in carbon dioxide (CO_2) gas produced the flows. The gas, posits Carr, was released by subsurface clathrates. (A clathrate is a structure of ice in which water molecules form a "cage" with a CO_2 molecule inside.) Carr proposes an avalanche suddenly exposing some clathrate on the sides of a cliff, causing the clathrate "cages" to break apart and release CO_2; the CO_2 would then entrain debris, and the resulting mass would rush down the slope and carve a channel. Such gas- and debris-laden slides commonly occur on Earth in volcanic eruptions; for example, the 1980 eruption of Mount St. Helens. Carr suggests that this mechanism more naturally explains the geographical distribution of the channels than does the "ice plug" scenario offered by Malin and Edgett.

While considering alternatives, let us recall that the MOC-recorded features clearly share morphological characteristics with water-driven seeps and springs, erosional channels, and depositional fans on Earth. Indeed, liquid water still would seem the prime suspect in the production of these features.

A CASE FOR LIFE

Water is in many ways the key to life. On Earth, life occurs just about everywhere that liquid water is present (as long as temperatures are not too far above the boiling point). We have known for some time that Mars in the past harbored liquid water. However, finding current evidence for liquid water is significant, as it means that if life did in fact arise on Mars, it might exist there still.

The possible discovery of liquid water so near the planet's surface will no doubt influence our Mars exploration program. An emphasis of the program has been to "follow the water": to understand the stability and distribution of liquid water through time, as well as to determine the role played by water in the planet's geologic history. Implications for the presence of life on Mars are, not surprisingly, a prime consideration.

Indeed, thanks to these implications, the public's interest in Malin and Edgett's announcement has been tremendous. A week after the NASA press conference, I hailed a cab in Washington, DC, and asked the driver to take me to NASA. Without any prompting from me, the driver commented how exciting this recent discovery was in terms of what it meant for the possible existence of life on Mars.

What is my response to the discovery? I consider it very likely (though not absolutely proven) that the features identified on the MOC images were carved by water supplied by seepage from the exposed walls of canyons, impact craters, and escarpments. If this supposition turns out to be true, then Mars does not behave as we might expect. That is, Mars is not the "simpler than Earth planet" that we have always assumed. As Ken Edgett put it at the press briefing, "This is not your mother's Mars." Rather, this Mars seems to have all the complexities of a geologically active planet.

Bruce Jakosky is a professor of geological sciences and director of the Center for Astrobiology at the University of Colorado in Boulder. He participated as an outside commentator in the press conference announcing the discovery of the Martian seeps.

Check out the MOC images at the Malin Space Science Systems website, **www.msss.com**, and the details of the paper by Malin and Edgett in *Science* magazine at its website, **www.sciencemag.org**.

World Watch

by Louis D. Friedman

Washington, DC—The last week of July presented us with hope and disappointment simultaneously. First, NASA announced that instead of just one Mars lander for 2003, it planned to launch two identical rover missions. The hope generated by this stunning piece of good news was followed by disappointment when we learned that the *Pluto-Kuiper Express* mission was threatened with cancellation.

The rovers, called Mars Exploration Rovers, are to be larger descendants of *Sojourner*, the 1997 micro-rover of the *Pathfinder* mission. Unlike *Pathfinder*, the 2003 mission will have no lander spacecraft—the rovers themselves will handle the landing control. For a landing system, the Mars Exploration Rovers will employ an exact copy of the *Pathfinder*'s air bag system; the 150-kilogram (330-pound) rovers will drive right off the entry structure, over the air bags. With a range of perhaps a hundred meters per day, the rovers are expected to cover many kilometers over the course of the mission.

Announcing a rover mission was a courageous move by NASA, since the agency (and its contractors) took so much criticism for the Mars mission failures in 1999. The safer choice of an orbiter was considered. However, with the *Mars Global Surveyor* performing so well now, and orbiters planned by the United States in 2001 and Europe in 2003, and another in the works from Japan, one more orbiter was deemed less profitable than a return to the surface.

The mission will be managed and the rovers built at JPL. Steve Squyres of Cornell University is slated to lead the experiment team. His Athena rover team includes an international crew of scientists who will carry out six experiments with the payload. Instruments include a panoramic imaging camera, a Mini-TES (Thermal Emission Spectrometer) to view the scene around the rover in the infrared, a microscopic camera, a Mössbauer spectrometer to identify iron-bearing minerals, and an alpha-proton-X-ray spectrometer—that is, an improved version of the instrument used by *Pathfinder*'s *Sojourner* rover—that will measure concentrations of most major elements. The package also includes a rock abrasion tool, or RAT, to expose fresh rock surfaces for study.

The joy of the prospect of returning to the Martian surface is nevertheless tempered by the threat of cancellation of the *Pluto-Kuiper Express* mission. As we go to press, NASA maintains that no decision has yet been made, but budgetary forces inside the agency and within the Clinton administration make the threat very real.

The *Pluto-Kuiper Express* was expected to launch in 2004 to fly by Jupiter, pass through the Kuiper belt of comets (beyond Neptune's orbit), and then fly by Pluto—the only planet in our solar system not yet visited by spacecraft. The year 2004 will be the last for more than a decade when a Jupiter flyby can supply a gravity assist for a fast trajectory to Pluto. And the trajectory will not be all that fast because the hoped-for Evolved Expendable Launch Vehicles will not be ready. Therefore, even with a gravity assist, the mission would take 13 or 14 years to reach Pluto—a far cry from the goal of 7- to 8-year flight times set by initial studies.

The Pluto mission is one of three missions in the NASA Outer Planets Exploration program. The others are a Europa Orbiter and a Solar Probe. Although the latter may not seem like an outer planet mission, the spacecraft in fact first flies to Jupiter; it then counts on a gravity assist to turn it around and head it directly for the Sun. These missions, too, suffer from delays and a lack of capability in the Expendable Launch Vehicle fleet.

Faced with delays and increased costs to combat perceived technical risks and challenges, NASA and the Office of Management and Budget feel they must cancel missions rather than request increased funds. So NASA is considering including only the Europa mission in the Outer Planets program. The final decision awaits the new US president's submission of the 2002 budget, which will reach Congress in January 2001.

The Planetary Society took a strong stand in support of the Pluto mission, and indeed the Society was instrumental in incorporating the mission into the NASA plan. We are urging Congress to consider increasing funds to carry out a balanced program of solar system exploration: Mars, Pluto, Europa, the Solar Probe, and other missions of discovery.

Planetary exploration amounts to about 10 percent of NASA's overall budget, yet its value is far greater. We feel that it is at the core of the rationale for a government space program. At a time when all federal budgets are increasing and surpluses are growing, NASA should not be forced to cancel good missions.

You can join the Society's campaign to save the Pluto mission. Find out how by visiting our website, **planetary.org**.

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

Will Red Rover Go to Mars?

The Planetary Society's joint education experiment with LEGO, Red Rover Goes to Mars, was part of the now canceled *Mars Surveyor 2001* lander mission. The experiment would provide students with an opportunity to participate in the control of a rover on Mars and to conduct experiments on the surface. Among the experiments would be imaging a sundial developed as the image calibration target by the Athena team, imaging a LEGO figure and CD placed on the spacecraft for experiments created by the Society, and sending activity requests to the rover. Student scientists and astronauts would be selected to work on the project, while others around the world would follow the exploration via the Internet.

NASA and the 2003 mission team are now considering the feasibility of partnering the project with the newly announced Mars Exploration Rovers. Also being considered: a reflight of our Mars Microphone, which was part of the unsuccessful *Mars Polar Lander* mission. Watch our website, **planetary.org**, for updates.

Questions and Answers

Would someone with orbital mechanics experience please clarify whether the K-T impact could have sent earthly debris out into the solar system? This seems probable given the slingshot effect the Moon would have had on a great deal of the near-Earth debris. Shouldn't the K-T impact have splashed everything from soil microbes to dinosaur guts throughout most of our planetary system? The question of life on other planets (and moons) may not be whether it exists, but rather what has evolved from Cretaceous-era terrestrial contamination.
—Lawrence Ring,
Laguna Beach, California

The K-T impact blasted debris all over Earth, throwing it as far as the antipode of the impact site. Most of this debris was in the form of sand-size melt droplets and individual mineral crystals, but a few rock fragments and even pieces of the impactor have been found tens of thousands of kilometers from ground zero. Given this distribution of impact debris all over the planet, it is quite plausible that some material was also blasted entirely free of Earth.

The existence of Martian and lunar meteorites makes it clear that impacts can eject material from planet-size bodies. Although no Earth ejecta have been found on either the Moon or Mars, and no meteorites have been discovered that once were part of Earth, it's still possible that at least some material is ejected into interplanetary space by big impacts.

The main impediments to ejection into space are Earth's dense atmosphere and the sheer velocity needed to escape our planet's gravity. However, impact craters as small as 6 kilometers (almost 4 miles) in diameter have apparently succeeded in breaching the atmosphere and throwing molten material (tektites) briefly into space. The vapor plume created by the impact evidently clears the atmosphere out of the path of accelerated ejecta.

Furthermore, the escape velocity of Mars, 5 kilometers (3 miles) per second, is only about half of Earth's escape velocity of 11.2 kilometers (about 7 miles) per second. An extra factor of 2 in speed does not seem prohibitive. The velocity needed to get to the Moon is only a little short of this (11.1 kilometers per second), and so our satellite probably does not play much of a role in throwing material from Earth into interplanetary space—direct escape is nearly as easy in terms of velocity and is also much more probable than a lunar encounter.

The mechanism by which solid rock material is ejected at high speed but with little shock damage is a process called spallation. In spallation the strong shock wave created by the collision reflects from the open surface near the impact site. Thus, only near-surface material is ejected at the necessary speed while staying intact. It seems very probable that microbes, at least, could survive this process. (I recently contributed to a long paper on this subject, "Natural Transfer of Viable Microbes in Space, Part 1: From Mars to Earth and Earth to Mars," published in *Icarus*, Volume 145, pages 391–427.)

As for dinosaur guts, they might indeed have graced the moons of the solar system if the K-T impact had occurred on land. However, the actual strike appears to have been into a shallow sea (50 to 100 meters deep). Since spallation would have caused only the near-surface layers to be ejected intact, the K-T impact probably blasted out mostly seawater and whatever was living in the upper ocean. So instead of vacuum-dried dinosaur body parts, future astronauts should probably be looking for broken ammonite shells in space.
—JAY MELSOSH,
University of Arizona

Is it possible that other planets in our solar system were contaminated by Earth life—from soil microbes to pureed dinosaurs—due to the K-T impact? Bacteria may have survived this process but, because the impact occurred offshore, fossil seashells rather than dinosaur chunks may have ended up on other worlds.

Painting: Don Davis

If a planetary satellite is a captured asteroid, I would expect the satellite's orbit to be large and to display a lot of eccentricity. I would not expect the plane of the orbit to be close to the plane of the planet's equator; I would, however, expect a roughly equal chance of the orbital motion being prograde or retrograde. Such a description applies admirably to many of the outermost satellites of the four giant planets.

Why, then, is it so widely assumed that the satellites of Mars are captured asteroids, given that both satellites are in small, almost circular, prograde orbits, nearly in the plane of the Martian equator—that is, having every possible characteristic that I'd expect a captured asteroid would not have?

—Jeremy Tatum,
Victoria, British Columbia, Canada

It's a good question. An unsatisfying answer, and only part of the truth, is that it is hard to find a better explanation!

It seems unlikely that Phobos and Deimos are debris left over from Mars' formation, or even that they formed in the same solar-distance zone as Mars, because they appear to have spectral properties of a type of dark-colored asteroid (called type "D" or "P") found only in the outer part of the asteroid belt. There is some suggestion that Phobos may have contained water ice in its interior, as is possible in a body from the outer asteroid belt.

I have published a suggestion that Jupiter scattered thousands of these black asteroids around the solar system at the time it grew to its present mass and had enough gravity to begin clearing out the outer edges and Kirkwood gaps of the asteroid belt, some 4.5 billion years ago.

The usual capture model is that all the planets were then in their final formative stages and Mars may have had a very extended atmosphere (partly degassed from inside and partly captured from the solar nebula). A tiny percentage of the black, Jupiter-scattered asteroids may have passed so close to Mars that they were captured by drag, looping into the atmosphere as *Mars Global Surveyor* did when placed in orbit around the Red Planet.

Extended interaction would gradually lessen the apoapsis (most distant point) of a captured asteroid and circularize the orbit, as well as bring it more toward the planet's equatorial plane. If this process continued indefinitely, the satellites would crash into Mars because of drag. Therefore the model further assumes that the extended atmosphere dissipated quickly at the end of planet formation, leaving two captured moonlets stranded in orbit.

Not everyone is happy with this model, for some of the reasons you suggest, but no one has thought of a good alternative. It's frustrating that Phobos and Deimos are the closest satellites beyond our own moon and yet they remain so mysterious!

—WILLIAM K. HARTMANN,
Planetary Science Institute

Factinos

Magnetic readings from *Galileo* are giving scientists the strongest evidence yet that Jupiter's moon Europa harbors an ocean of water underneath its icy coat. The new data reveal that the Jovian moon's magnetic field flip-flops (unlike Earth's, which is relatively stable).

"The direction that a magnetic compass on Europa would point to flips around in a way that's best explained by the presence of a layer of electrically conducting liquid, such as saltwater, beneath the ice," Margaret Kivelson of the University of California, Los Angeles explained.

Kivelson presented this conclusion after receiving telltale readings from *Galileo*'s magnetometer following the spacecraft's flyby of Europa in January. Her team details its theory about the liquid layer in the August 25, 2000 issue of *Science*. "We have good reason to believe the surface layers of Europa are made up of water that is either frozen or liquid," she said, noting that earlier gravity measurements show a low density, such as water's, for the moon's outer portions. "But ice is not a good conductor, and therefore we infer that the conductor may be a liquid ocean."

However, those measurements could be explained by a past ocean that has subsequently frozen solid, pointed out *Galileo*'s project scientist, Torrence Johnson of the Jet Propulsion Laboratory. "This magnetometer data is the only indication we have that there's an ocean there now, rather than in the geological past," he said.

Johnson added that the case for liquid water on Europa is still not clinched. "The evidence is still indirect and requires several steps of inference to get to the conclusion there is really a salty ocean," he said.

"A definitive answer could come from precise measurements of gravity and altitude to check for effects of tides."

—from the Jet Propulsion Laboratory

Ten new planets have been discovered around stars relatively close to Earth! That's the hot news from the recent meeting of the International Astronomical Union in Manchester, England. Five of the new planets were detected by scientists in Geneva, Switzerland, using data gathered from the European Observatory's La Silla Observatory in Chile. Included in this group is the second multiplanetary system ever found, which brings the total of known extrasolar planets to 50.

The new planetary system consists of two Saturn-size planets, one found in May and the other just recently discovered. These planets circle the star HD 83443, 141 light-years away in the Vela constellation. Planet HD 190228 was also detected by the Geneva team using data gathered at the Observatory Haute-Provence in France.

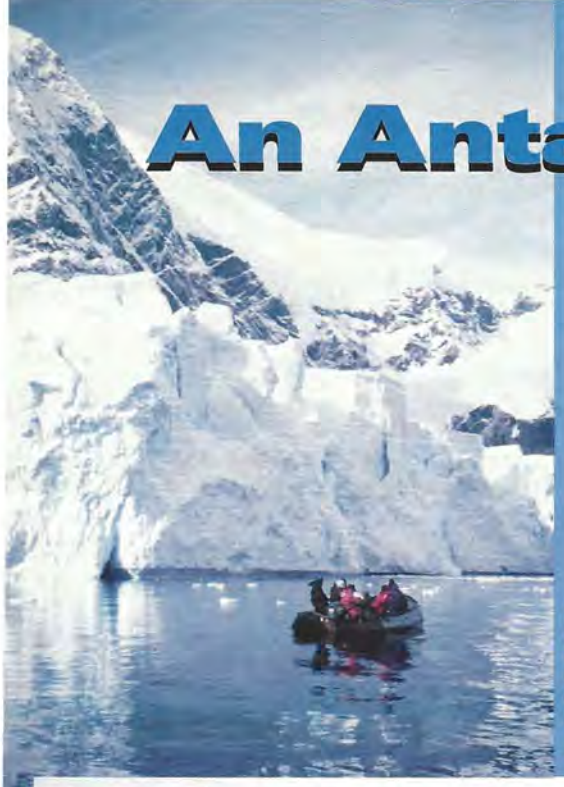
Another team of researchers, from the University of California, Berkeley, reported that they've found three new planets—all gas giants similar to Jupiter. They've also discovered a planet orbiting the star Epsilon Eridani (only 10 light-years away) that could begin to answer questions about the existence of life on other planets. Geoff Marcy, a member of the Berkeley team, said that while most of the planets in our solar system move in nearly circular orbits, this planet, as well as most other newly discovered ones, have oblong orbits. Earth's circular orbit provides a relatively stable environment, which balances out the hot and cold extremes affecting the surfaces of planets in oblong orbits. "It may be that life is possible here because of the circular orbit," he stated.

—from CNN and Reuters

For more information about the planet orbiting Epsilon Eridani, see "Previous Stories" on our website: **planetary.org**.

An Antarctic Idyll

by James D. Burke



Left: Whale watching in Paradise Bay.
Below: A typical debarkation. (That's our ship in the background.)
Photos: James Burke

"Hello?"
"Hi, Jim, you're going to the ends of the Earth."
"Oh, really? When?"
"Next week."

Thus began an adventure never to be forgotten. Because Planetary Society President Bruce Murray and his wife, Suzanne, suddenly were unavailable to lead the Society's February 2000 expedition to the Antarctic Peninsula (Bruce was to aid in replanning NASA's Mars program), I and my wife, Lin, were enlisted to go.

We grabbed our skiing and foul-weather sailing gear and headed south via Miami and Buenos Aires. Arriving in Ushuaia, we boarded the Russian oceanographic research ship *Akademik Sergey Vavilov,* set out through the Beagle Channel, and crossed the historic Drake passage to landfall in the South Shetland Islands.

From there we spent 10 days cruising among the islands and spectacular mountains, passages, and glaciers of the Peninsula. On board our superbly equipped ship we and about 80 other voyagers enjoyed lectures by naturalists and historians, daily shore excursions in big inflatable Zodiac boats, social events with the Russian crew, and fine cuisine prepared by the Austrian chef and galley staff. One highlight was a barbecue with music and hilarious dancing on the ship's fantail during a blizzard.

Half of the adventurers were from The Planetary Society and half from the Society of the Sigma Xi (I am a member of both). Lin's and my duties as leaders of the Planetary Society contingent were blissfully undemanding owing to the able and energetic leadership of our hosts. Each morning they would wake us up with an exciting plan for the day.

Society News

Planetary Society Kicks Off World Space Week

On October 4, 2000, the first day of the United Nations-designated World Space Week, The Planetary Society will co-sponsor two events in New York City, featuring Bill Nye the Science Guy and astronaut Franklin Chang-Diaz. The Society will join the official UN celebration at United Nations Headquarters in the morning, hosting a Student Press Conference for middle and high school journalists as part of a larger event. The program will also include presentations by space explorers from several nations. That evening, the Society will join forces with the Hayden Planetarium to present a public lecture about the search for life in the universe.

For information on attending either event, contact me at (626)793-5100 or **susan.lendroth@planetary.org**.
—Susan Lendroth, Manager of Events and Communications

PlanetTrek Evolves

A winning design proposal has been chosen for PlanetTrek, a sculptural model of our solar system to be built in Pasadena. The team of artists who will create the Sun and planets includes Barbara McCarren, Judd Fine, Ken Price, and Ned Kahn. A unique blend of fine art, science, and

Wanted: Explorers and Adventurers

Join us on our next expedition to Belize and Mexico to search for evidence of the asteroid or comet that ended the age of the dinosaurs. We're planning the expedition to take place during the first quarter of 2001, and we expect it to last 11–13 days and cost approximately $2,500 per person, excluding airfare. Call Lu Coffing at (626)793-5100 or e-mail her at **tps.lc@planetary.org** for more information or for an application to join the expedition.

Intrepid Antarctic explorers Jim and Lin Burke visiting an iceberg between a hearty breakfast and an elegant luncheon. Zodiac excursions occurred twice a day, followed aboard the Akademik Sergey Vavilov *by lectures, happy hour in the ship's bar, dinner, entertainment, and profound sleep.*
Photo: Bob Nansen

Photo at right: James Burke

The crew would deftly drop the Zodiacs over the side; we would race toward shore and land in our high boots through the surf, visiting enormous colonies of penguins, seal haul-out beaches, glaciers, and occasionally an isolated scientific base. We became explorers of the fantastic riches of the Antarctic animal world founded on vast hordes of tiny shrimplike krill and extending to mighty whales, once hunted here nearly to extinction and now slowly coming back.

Back on board each afternoon and evening we would assemble for lectures or videos, followed by convivial times around the bar, a gourmet dinner, and then instant sleep. If one happened to wake in the middle of the night, it was a delight to climb to the bridge and silently observe the crew as they guided the ship through narrow channels and iceberg fields.

At last it was time to turn back. We bade farewell to the Ukrainian crew of a former British base and headed north across the Drake passage. Infamous for its high winds and enormous seas, this funnel in the Great Southern Ocean was relatively calm for both our crossings. We were able to observe the miraculous soaring of wandering albatross and other pelagic birds that cruise endlessly, extracting wave energy and so seeming never to have to flap their wings. We made a pilgrimage to Cape Horn, then turned east for Ushuaia and dreamed our way home, laden with memories.

James D. Burke is Technical Editor for The Planetary Report.

education, PlanetTrek will become a permanent Pasadena monument and will be dedicated to the memory of Carl Sagan.

Ten spherical sculptures depicting the Sun and its nine planets will be built to scale and installed in select public areas around town. About 5 miles will separate the 5-foot-diameter Sun from Pluto—only one-tenth of an inch wide. Each celestial body will be mounted on a pedestal containing information about that world. Saturn will shine in laminated, milled limestone and marble in buff, gold, and beige, with stainless steel rings. Mars will be cast in brightly rusted iron, and Venus will be formed of red glass and verdigris copper, suggesting the planet's hellish surface. A rotating blue glass sphere overlaid with a bronze map of Pangaea will represent Earth.

Unlike other solar system models, PlanetTrek will include 100 important questions such as "Was the beginning of the universe a chance event?" inscribed on bronze plaques. If a question is answered, a new one will take its place.

To learn more about the project, submit a question, or contribute funds toward its completion, visit the PlanetTrek website at **http://planettrek.planetary.org**.
—Donna Stevens, Associate Editor

SETI@home Will Continue

Thanks to The Planetary Society's efforts, SETI@home, the two-million-people-plus project analyzing radio data for possible signs of extraterrestrial intelligence, will continue past its scheduled May 2001 end date.

We are able to assume funding SETI@home for at least two more years, thanks to an alliance with a new media company temporarily operating under the name "Project Voyager." This is a joint venture of Ann Druyan, wife and collaborator of Carl Sagan and CEO of Carl Sagan Productions, and Joe Firmage, founder of USWeb and a leading Internet entrepreneur.

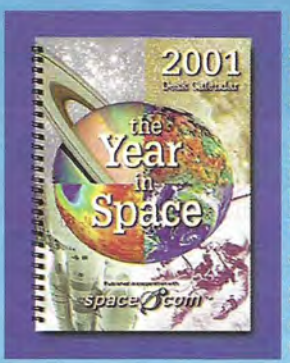
The fruits of this alliance will go beyond our sponsorship of SETI@home: as we develop and expand the Society's website with their support, we will also be providing content to a new Internet portal being developed by Project Voyager.

Check the websites of all three allies for developments: **setiathome.ssl.berkeley.edu**, **www.projectvoyager.com**, and, of course, **planetary.org**.
—Louis D. Friedman, Executive Director

The Planetary Society 2001 Catalog

Spacecraft Science Kits
Build your own spacecraft and learn how it works. All models are accurate representations of the robots now exploring the universe. Intricate, laser-precut paper elements make these models highly detailed yet easy to assemble. All models contain details such as trusses, baffles, and even movable scan platforms and are accompanied by fact sheets giving the particulars of the mission. Each sold separately.
1 lb. **$15.75**

#524 ***Galileo***
#525 **Hubble Space Telescope**
#529 **Keck Telescope**
#530 ***Lunar Prospector***
#531 ***Mars Global Surveyor***
#538 ***Magellan***
#560 ***Voyager***

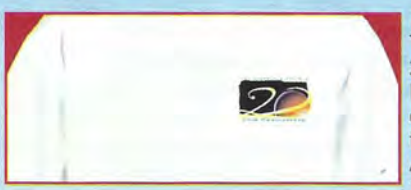


Explore the Universe! 2001 Wall Calendar
Enjoy full-color photographs, space art, and great reading on a variety of subjects each month. This 2001 wall calendar is produced by the creators of *Astronomy* magazine in cooperation with The Planetary Society.
2 lb. **#520** **$11.50**

The Year in Space: 2001 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** **$12.50**

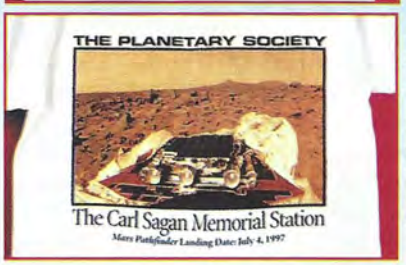
***Pathfinder* Images of Mars**
This collection of 20 slides features some of the most notable *Pathfinder/Sojourner* images, including the color panorama and images of *Sojourner* at work.
20 slides. 1 lb. **#215** **$7.50**

Future Martian T-Shirt
Are you raising Martians? Maybe you won't get to Mars, but your children or grandchildren might. The future is full of possibilities, and today's Earth child might be a future Martian. Child sizes: S, M, L
1 lb. **#565** **$13.50**



***NEW!* 20th Anniversary T-Shirt**
The Planetary Society is celebrating 20 years of "Making It Happen." This limited-edition long-sleeve T-shirt features our special 20th Anniversary Logo on the front and **planetary.org** on the back.
Adult sizes: S, M, L, XL, XXL
1 lb. **#600** **$22.00**

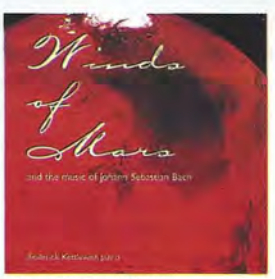
Search, Discover, Explore T-Shirt
Search for life, discover new worlds, and explore the planets with The Planetary Society. Show off this vibrant design that captures the true spirit of exploration.
Adult sizes: M, L, XL, XXL
1 lb. **#582** **$16.75**



Carl Sagan Memorial Station T-Shirt
Wear a piece of history. This T-shirt displays the triumph of *Mars Pathfinder*'s July 4, 1997 landing with a color image of the undeployed rover on the Carl Sagan Memorial Station.
Adult sizes: M, L, XL, XXL
1 lb. **#581** **$16.75**

Mini Mars Polar Lander Model
1 lb.
#778 **$3.00**

Winds of Mars and the Music of Johann Sebastian Bach
This audio CD features digitally simulated sounds of the winds of Mars between 17 of Bach's finest compositions, played on piano. The wind data were collected by an instrument on the *Mars Pathfinder* lander and were translated into wind sounds through a Musical Instrument Digital Interface (MIDI). CD includes extensive liner notes explaining the production of the Martian sounds and giving a general history of Mars exploration.



1 lb. **#785** **$15.00**

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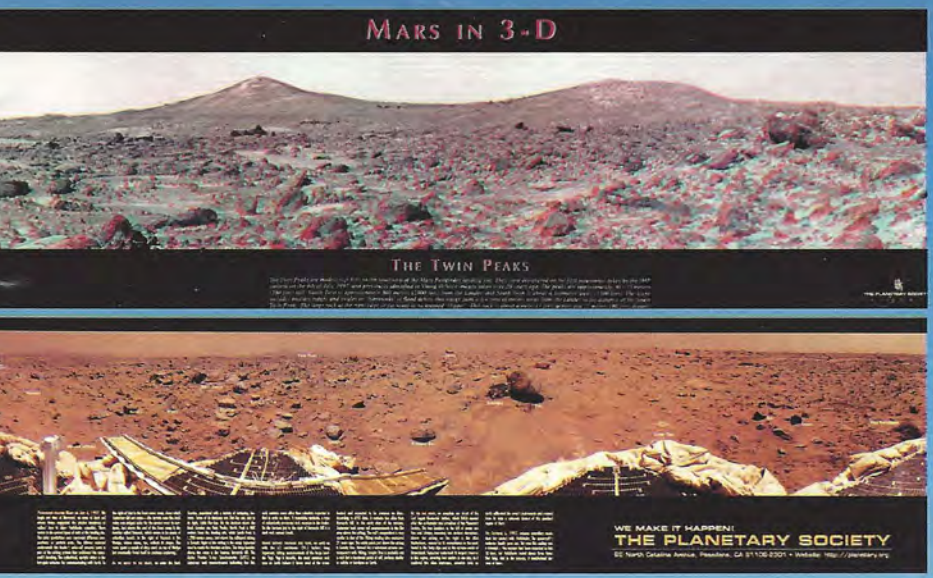

Mars in 3D Poster

Experience virtual Mars. Put on your red/blue glasses and step onto the Martian surface where *Mars Pathfinder* still rests today. Out on the horizon, the Twin Peaks loom over a garden of alien rocks. Red/blue glasses included. 12" x 39"
1 lb. **#306 $13.50**

Panoramic View of Mars

This famous color image offering a panoramic view from the Carl Sagan Memorial Station is accompanied by a "tour guide" caption to help you navigate through the rocky landscape.
10" x 36"
1 lb. **#328 $13.50**

Explore the Planets

This eye-catching poster is chock-full of fascinating facts about our planetary neighbors.
34" x 22" 1 lb. **#310 $11.50**

An Explorer's Guide to Mars

Images from *Mars Global Surveyor*, speculative paintings of the Red Planet's past and future, informative captions and charts, and images of Mars' surface from the *Pathfinder* and *Viking* spacecraft enhance a detailed US Geological Survey map. 24" x 37"
1 lb. **#505 $15.25**

"Worlds to Discover 2000" Presentation

This fully scripted assembly presentation includes the original "Worlds to Discover" 55-slide package plus the 8-slide "Worlds to Discover Addendum 2000," in addition to updated fact sheets, posters, program announcements, copies of The Planetary Society's magazine, *The Planetary Report*, and a follow-up teacher's packet. Adaptable to multiple grade levels, this virtual tour is designed to stimulate a child's imagination and covers how discoveries are made, what we know now, facts about the solar system, and what students might discover when they become the explorers! 2 lbs. **#791 $45.95**

Portrait of the Milky Way

Never get lost in space! This map of the Milky Way, painted by Jon Lomberg for exhibit at the National Air and Space Museum in Washington, DC, is the most accurate ever made. Find out where Earth, the Orion and the Crab nebulae, and many other objects really reside in our galaxy! Comes with detailed explanation and finder chart. 27" x 40"
1 lb. **#330 $18.00**

"Worlds to Discover Addendum 2000"

Add this 8-slide addendum to the original "Worlds to Discover" program, with slides showing the latest finds from *Mars Global Surveyor, GEM,* and *NEAR-Shoemaker.* If you purchased "Worlds to Discover" before September 2000, bring your presentation up-to-date by adding these new slides and updated text and follow-up materials to your original set. 1 lb. **#795 $6.95**

NEW! 20th Anniversary Mug

Celebrate The Planetary Society's 20th anniversary with our 14-ounce "latte"-style mug. This one won't be around long!
2 lb. **#605 $10.00**

Solar System in Pictures

Add some space to your home or office with these striking views of our solar system. All nine planets are featured on full-color, 8" x 10" mini-posters. Each includes detailed information and a scientific description of the planet.
1 lb. **#336 $11.25**

Search, Discover, Explore Mug

Start off each day with this inspirational slogan.
2 lb. **#579 $7.75**

Planetary Society Lapel Pin

We are pleased to show off our elegantly designed lapel pin, and we think you'll want to show it off too. This striking pin is approximately 1 1/4 inches long, with a vibrant blue background and gold lettering.
1 lb. **#680 $3.00**

The Planetary Society License Plate Holder

Let your Planetary Society spirit travel with you on our members-only license plate holder.
1 lb. **#675 $5.25**

Planetary Society Cap

Our new **planetary.org** cap is 100% cotton with an adjustable Velcro band.
1 lb. **#673 $13.50**

(Not Shown)

Images of the Planets—Large Prints

If a picture is worth a thousand words, this selection speaks volumes: a Mars landscape taken by a *Viking* orbiter, *Voyager* flyby photos, and a stunning composite of *Magellan* radar images. Great for classroom display. 20" x 16" 1 lb. **$9.00 each**

#319 Jupiter
#325 Mars (Full Disk)
#332 Saturn
#333 Eight-Planet Montage
#340 Venus

Planetary Report Binder

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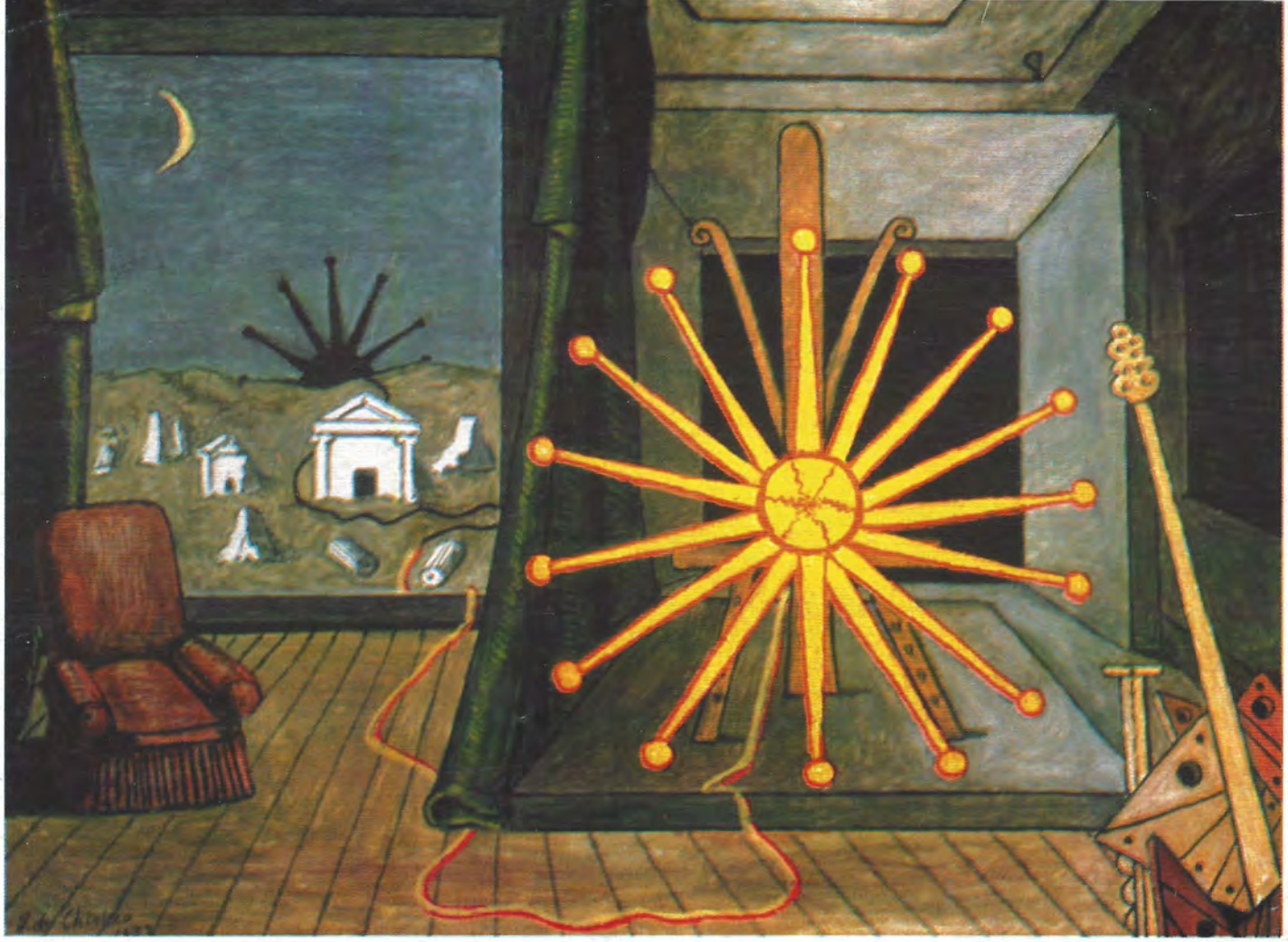

Removed from its post in the heavens, the Sun has come inside. A single cord snaking over a stark, ruin-scattered landscape is all that connects our star to its now empty place in the sky.

Greco-Italian painter Giorgio de Chirico (1888–1978) painted *Sun on the Easel* in 1972. This painting, along with others from the latter part of his career, was done in a style different from his early works, which depicted the palaces and squares of Roman and Renaissance Italy in a mood of intense and mysterious melancholy. De Chirico was a forerunner of the Surrealists, and in 1910 he began producing strange, enigmatic canvasses in which dreams and reality commingle. In 1919 he reverted to the classical manner of the Italian masters. However, his late work is infused with mythological references and Surrealist symbols, marking a return to the metaphysical motifs of his early years.

THE PLANETARY SOCIETY
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