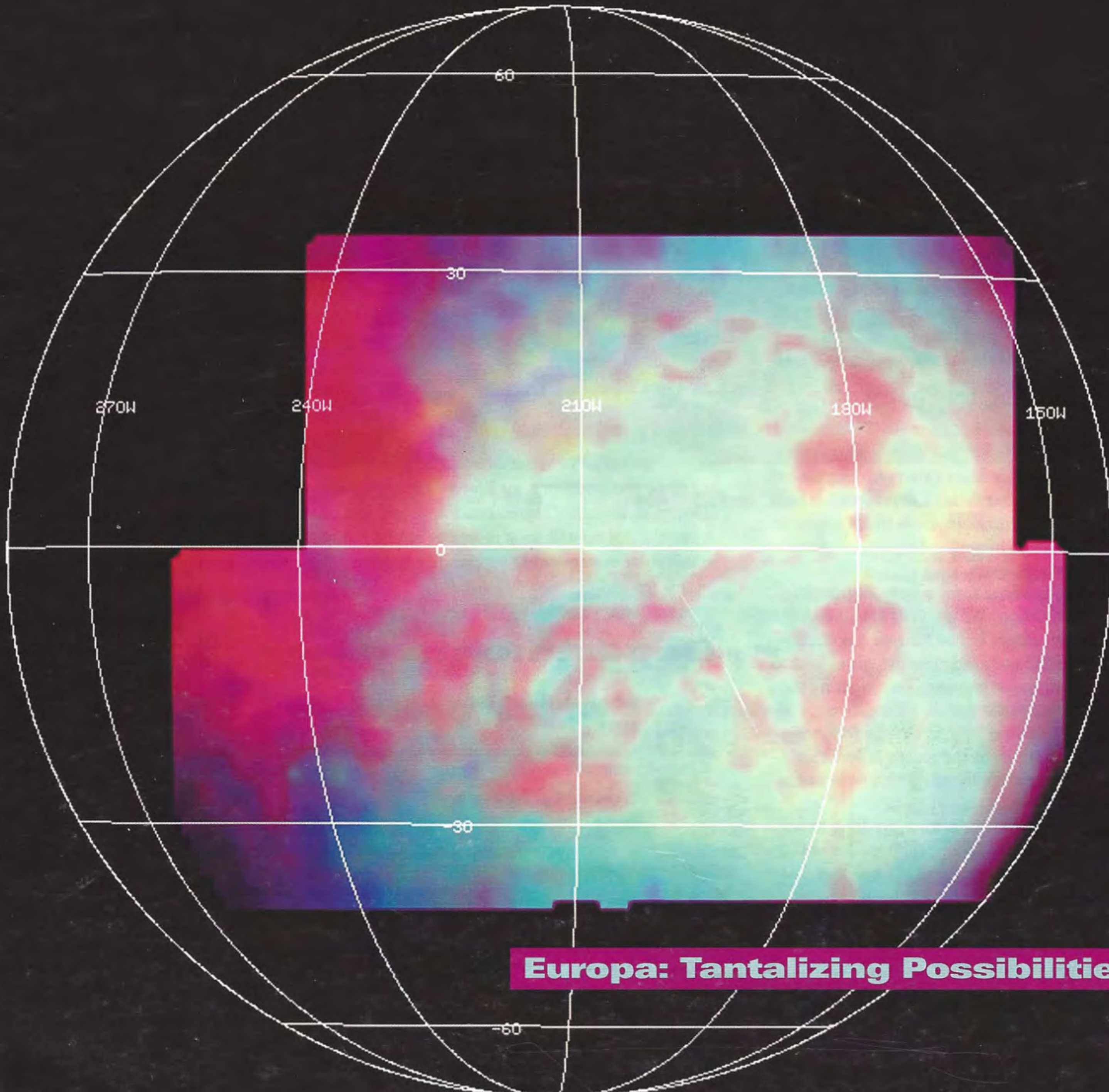
The PLANETARY REPORT

Volume XX Number 1 January/February 2000



Europa: Tantalizing Possibilities

On the Cover:

On the surface of Jupiter's icy moon Europa, scientists have discovered frozen sulfuric acid and sulfur. This map shows, in false color, the distribution of sulfuric acid (red) and water ice (blue) obtained by *Galileo*'s Near-Infrared Mapping Spectrometer. The source of the sulfur compounds may be Io or possibly an acidic or briny ocean below Europa's icy crust. Geologic processes such as tectonism and cryovolcanism redistribute sulfurous material, creating variable concentrations in Europa's disrupted terrain.

Image: JPL/NASA

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From The Editor

Disappointed. That's probably the best way to describe our feelings after the loss of the *Mars Polar Lander*, which carried the Mars Microphone, conceived of and paid for by members of The Planetary Society. It was the first privately sponsored instrument to fly on a planetary mission, and we had let our hopes soar—perhaps a bit too high—in anticipation of what we would hear and learn of Mars.

But we will rebound. This isn't the first time a lost spacecraft has taken a Society project down with it: our Marslink program slowly faded after *Mars Observer* disappeared, and our Visions of Mars CD project fell back to Earth with *Mars '96*. Both times we came back with even bigger and more ambitious ideas. We will again.

Now is the time for recovery, regrouping, and rededication. We are very proud that Society President Bruce Murray has been chosen as the only independent consultant to the blue-ribbon committee investigating the loss of *Mars Polar Lander*. Executive Director Lou Friedman is closely following the ramifications of the recent failures for future Mars exploration—both inside and outside NASA.

As always in these efforts, we look to our members for backup and support. It's not easy to convince the world at large that something as difficult as exploring distant worlds is worth the effort, time, and expense. There's so much out there to see and to know. We've got to keep trying—together.

—Charlene M. Anderson

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Members' Dialogue

Encouraging Words

To all the people who worked on the *Mars Polar Lander* mission:

When Thomas Edison was intent upon creating incandescent light, he went through more than nine thousand experiments in an attempt to produce the bulb. Finally one of his associates asked, "Why do you persist in this folly? You have failed more than nine thousand times." Edison looked at him incredulously and said, "I haven't even failed once. Nine thousand times I have learned what doesn't work."

I am proud of what you all have accomplished and hope that someday it can be looked at in the same light as Thomas Edison's work—it's all part of the process for the inevitable success that will occur.

It takes a lot of courage to do the kinds of experiments you all have done on the scale you've done them. I honestly applaud your efforts and hope that no one plans on giving up.

—JULIET L. HARDESTY,
Bloomington, Indiana

Planetfest '99

Thanks to everyone who contributed to our wonderful Planetfest '99 experience. Kudos to the designers of and volunteers in the Child's Universe section. There was so much to entertain and educate my five- and seven-year-old boys that the failure of the primary mission did not dampen their spirits at all. In fact, on the plane ride back to Ohio, they took turns using their airplane headsets to report to each other on all the possible failure and success scenarios for the lander and probes.

When we left the Fest, we discovered that our return vehicle had a dead battery in the garage. A quick jump start from a human technician sent us on our way. As robust as our fail-safe planning and computerized and robotic backup systems might be, it is hard to substitute for the flexibility and ingenuity of the human organism in a spot of trouble. We need to send our own technicians to the Red Planet ASASP (as soon as scientifically possible), perhaps in one of Robert Zubrin's tuna-fish cans. To Mars, then to the stars.

—ELIZABETH, IAN,
and CONNOR COLEY,
Dublin, Ohio

I really enjoyed Planetfest Online. The PlanetCast worked out fantastically. I have a 56K connection and the quality of the webcast was fine. The production was done as well as any large event I've attended in person or watched on TV. I really enjoyed the interviews with the various guests—especially Donna Shirley. She has a speaking style that can capture and hold your attention, and she makes complex ideas easy to understand.

It's unfortunate that the Mars landing did not meet with the success we all hoped for. But despite that major point, I feel we should keep pushing ahead with Mars exploration. I also feel that we should not yet give up on the "faster, better, cheaper" method.

Planetfest '99 was a great success. I hope I can attend the next one in person, but if not, I'll be there online.

—DAVID NORMAN,
Wilton, New Hampshire

Europa or Bust!

Why is it that we are putting so much expense into going to Mars when we have learned that Europa might have an ocean beneath its icy surface? To me it seems like everybody is trying to go to Death Valley instead of Lake Tahoe. Let's go where the action is and not waste our time and money going to a dead and empty vacation spot.

I'm running out of lifetime. I would love to know what is under the ice of Europa. Please tell me before I head that way myself.

—ROBERT TURNER,
Charles City, Iowa

Assorted Notes

I really enjoyed Richard P. Binzel's article about the Torino Scale in the November/December 1999 issue of *The Planetary Report*. His method may indeed prove useful in bridging the gap between responsible information and media arm-waving.

However, the caption for the photo of the Barringer/Meteor Crater in Arizona (page 8) says that the age of the crater is "about 20,000 years." According to the information I have, the real age is closer to 49,000 years. You may want to double check on that.

I'd also like to take this opportunity to thank all the people involved in *The Planetary Report*. Each time I see the next issue in my mail, it's like a long-awaited treat that I truly enjoy, page by page, and it always seems to be too short. Keep up the excellent work so we can keep "looking over the shoulders" of the people working on the very front line of the most amazing human enterprise.

—CARLOS E. COVIELLA,
Riverside, California

Thanks for catching our error on the age of Meteor Crater.
—Charlene M. Anderson,
Associate Director

On page 6 of the July/August 1999 issue, it says that "From spring tide to spring tide is one month." Spring tides occur at both new Moon and full Moon, so there are actually two spring tides per synodic month.

—BOB ALLEN,
La Crosse, Wisconsin

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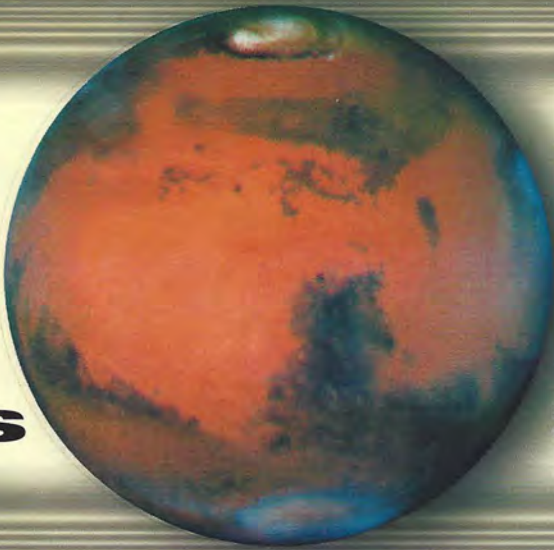
Mars Exploration: Faster, Better, Cheaper

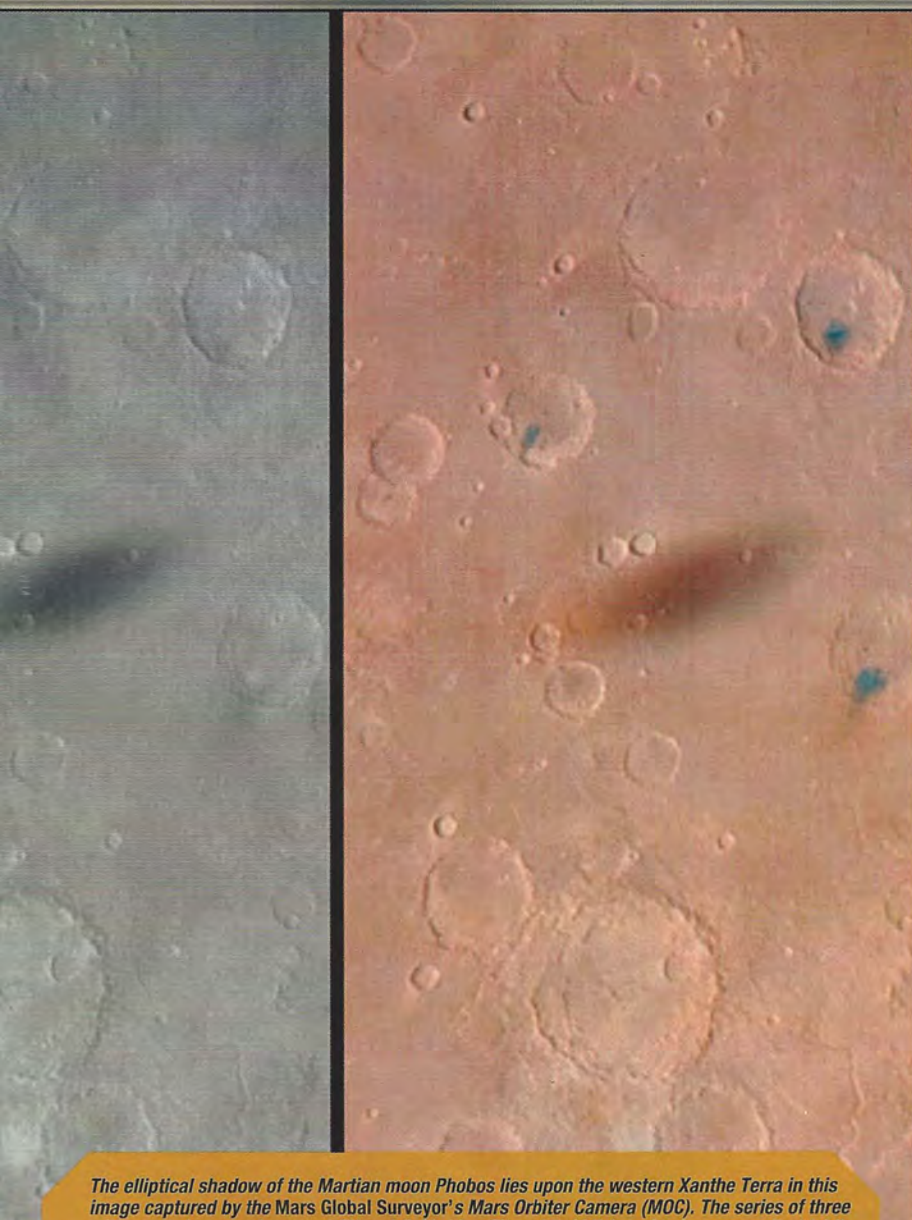
by Louis D. Friedman

What happened to the *Mars Polar Lander* and its *Deep Space 2* companions? No one knows. The engineers are in a position similar to trying to reconstruct an airplane accident without the aid of the black box. It could have been a hardware failure, a system error, a human error, a management error. All of these were cited in the review of the earlier loss of *Mars Climate Orbiter*. It's also possible that there is some bizarre or hostile surface on the polar terrain that is radically different from that expected by scientists. But right now, and perhaps forever, there is no hint of what went wrong. And many are asking: is the new "faster, better, cheaper" way of building spacecraft at fault?

Faster, better, cheaper is not the culprit. Even if it were, there is no other choice. The reality of American (and every other spacefaring nation's) politics is that we are not going to have bigger budgets for bigger space science projects in the foreseeable future. We can protest how wrong that is—indeed The Planetary Society has led and will lead the fight for space exploration projects worldwide. But if we decide to give up on faster, better, cheaper, then we will have slower and fewer projects. Whether or not they will be better will be known only by hindsight. But we will surely do less and suffer the political uncertainty of budget approvals, the way we used to in the post-*Viking* era, from 1976 through the early 1990s.

Everyone has understood from the beginning that the new approach requires taking risks—acceptable risks. That was set forth clearly by NASA Administrator Dan Goldin. And we should keep in mind that risk is not the exclusive property of faster, better, cheaper missions. There have been many failures with spacecraft that were expensive and time-consuming to build. The *Mars Observer* spacecraft, which failed catastrophically in 1993, had a total cost more than twice that of all three Mars Surveyor 1998 missions—*Mars Polar Lander*, with the *Deep Space 2* penetrators onboard, and *Mars Climate Orbiter*.

Is  Still the Way



The elliptical shadow of the Martian moon Phobos lies upon the western Xanthe Terra in this image captured by the Mars Global Surveyor*'s Mars Orbiter Camera (MOC). The series of three wide-angle images shows red-filtered (left), blue-filtered (middle), and color-composite (right) views of Phobos' shadow. The image covers an area about 250 kilometers (155 miles) across. Nanedi Valles meanders in the lower right corner of the scene. Note the dark spots on three crater floors—these appear dark in the red image (left) but are barely distinguished in the blue image (middle), while the shadow is dark in both images. These spots on the crater floors are probably small fields of dark sand dunes.* Images: Malin Space Science Systems/NASA

Moreover, the 1998 missions were developed in half the time. That this year's loss is so much less, and that we have a Mars program that can respond to failures and successes and continue, is a vindication, not an indictment, of faster, better, cheaper. The Mars program is robust and can accommodate change. The missions planned for 2001, 2003, and 2005, fulfilling US policy for a "sustained robotic presence on Mars," are capable of adaptation. As a consequence, the recent losses are disappointing accidents, not catastrophes.

Learning From Experience

Faster, better, cheaper is also newer, and we may not have learned yet to do it right all the time. "We" means NASA, the Jet Propulsion Laboratory (JPL), the aerospace industry, scientists, the policy makers funding and constraining the program, and even we, the public, with our expectations. Right now, the responsibility lies at JPL—that is where the *Mars Climate Orbiter* navigation and systems errors occurred and where the lack of data is hampering efforts to learn what happened on *Mars Polar Lander*. And JPL is where the responsibility for future NASA Mars missions lies. JPL will have to make some changes to those future missions.

Unlike the close-knit *Mars Pathfinder* tiger team, located together at JPL, the Mars Surveyor 1998 group was divided into three projects, two missions, at three contractor sites. And they had to cope with all these interfaces on a much smaller budget. The dispersed organization of the 1998 missions may have been closer to the old way of doing business than to the streamlined process advocated in the faster, better,

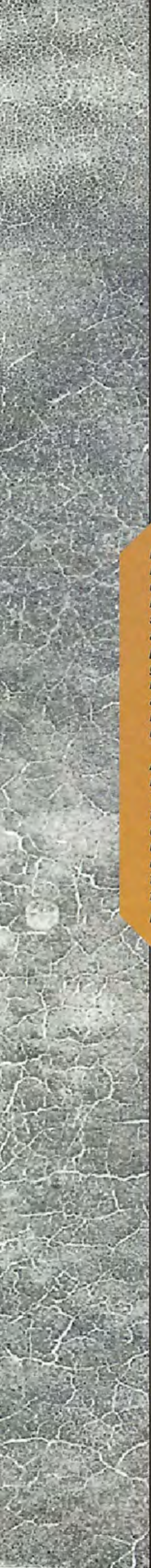
Left: Almost as soon as northern fall began, the MOC started documenting the arrival of autumn frost—foreshadowing the arrival of winter in late December 1999. Sand dunes surrounding the north polar ice cap were the first features to become covered by frost. The image shows a 3-kilometer (about 1.9-mile) area near 74.7 degrees North, 61.4 degrees West. The dunes seen here would appear almost black if they were not covered by pale frost. Why dunes begin to frost sooner than the surrounding surfaces is a mystery. One theory suggests that perhaps the dunes contain water vapor that emerges from the sand during the day and condenses again at night.

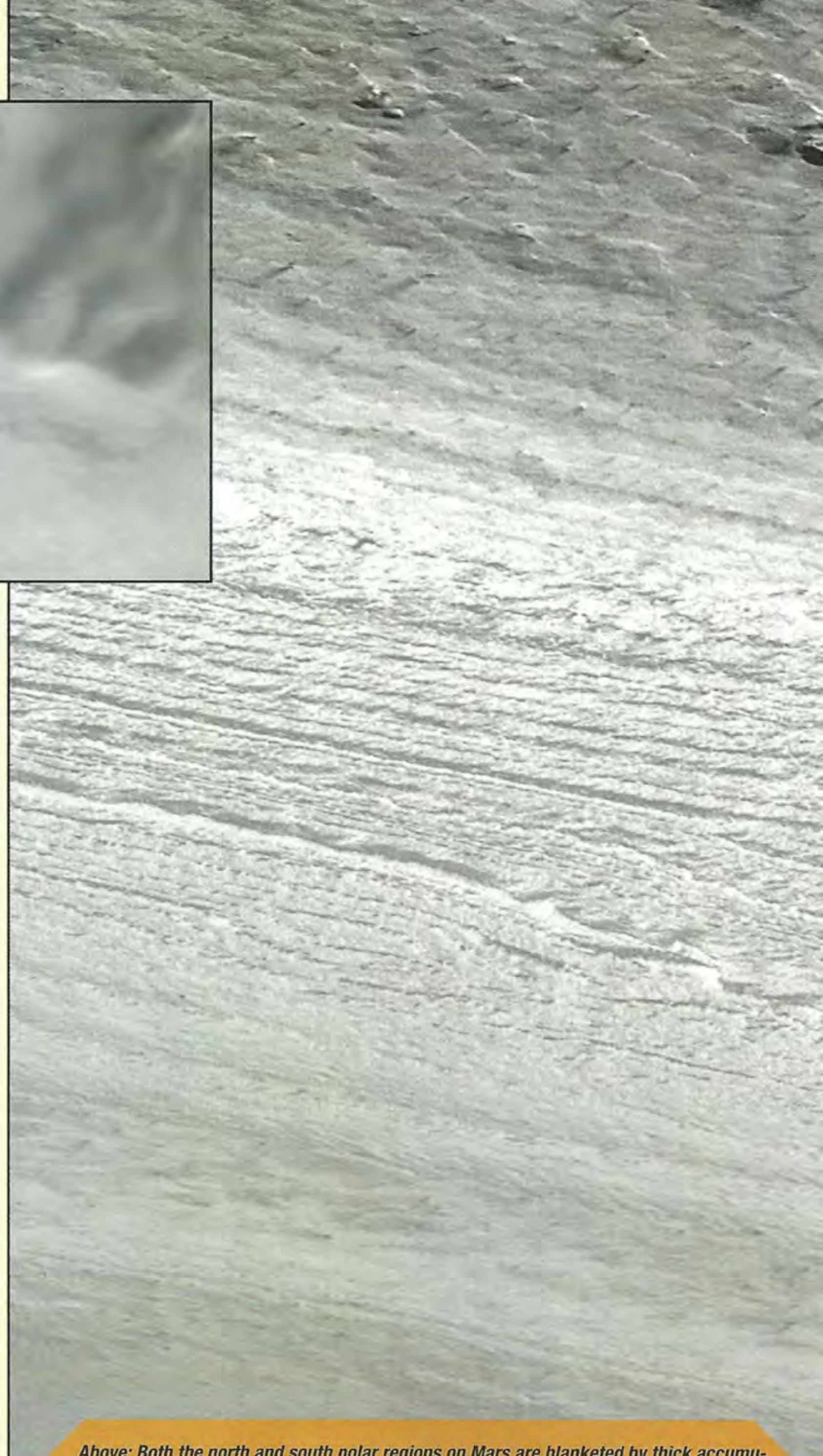
Image: Malin Space Science Systems/NASA

cheaper philosophy.

Perhaps the 1998 missions were simply too ambitious to succeed under all the constraints. If so, it would not be solely JPL's fault—NASA, Lockheed Martin, the science community, and the decision makers and funders in Washington all contributed to the ambitions and the constraints. To be overly ambitious isn't required by faster, better, cheaper. This flaw could be avoided by making tough choices and proper system trade-offs.

The loss of the spacecraft will provide lessons learned—and they should be applied to future missions. Changes need to be made, and future mission plans may be a little less ambitious or may have their constraints relaxed. There is no reason to fear that faster, better, cheaper missions cannot be done, because JPL and other centers are conducting many successfully, including NEAR, *Lunar Prospector, Stardust, Deep*





Left: Remnant frost from the retreating south polar ice cap, trapped in cracks, enhances the visibility of polygonal patterns in this new picture of Malea Planum in the far southern regions of Mars. This scene, taken by the MOC in October 1999, shows a relatively smooth portion of Mars covered with polygons at large and small scales. Smaller polygons are mostly found on the surfaces of old, mantled impact craters, while larger polygons appear on the surfaces between the craters. The image covers a narrow strip of Martian terrain only 1.5 kilometers (about 0.9 miles) across.

Polygons such as these are common in Earth's Arctic and Antarctic regions, and they usually indicate the presence of water ice in the ground. The features form from the cycle of freezing and thawing of ground ice over the course of years, decades, and centuries. The presence of polygons on all surfaces in this Malea Planum scene indicates that the ice is not deeply buried—only a thin veneer of material appears to have covered the crater at the top of the image.

Image: Malin Space Science Systems/NASA

Space 1, Mars Pathfinder, and *Mars Global Surveyor,* which continues to send back fantastic pictures from the Red Planet.

Shipwreck and Exploration

There is reason to be hopeful. Mars exploration itself is not being questioned; public support remains high. At Planetfest '99 in Pasadena, we saw great public enthusiasm, with cheers for NASA Administrator Dan Goldin and for *Mars Polar Lander* Project Manager Richard Cook. Several new media polls have found decisive public support for Mars exploration. The public supports exploration of the unknown and taking the attendant risks, as long as the risks are taken wisely and honestly.

Mars exploration remains high in public interest because it represents the raison d'etre of

(continued on page 19)

Above: Both the north and south polar regions on Mars are blanketed by thick accumulations of layered material. From Mariner *and* Viking *data, scientists have identified the polar layered deposits as accumulations of dust and ice. The layering may indicate changes in ice and dust accumulation over the course of millennia. Changes in climate may affect the thickness and composition of these polar layers the way tree rings on Earth are affected by years of drought and years of plentiful rain.*

MOC pictures taken at extremely high resolution reveal new details in the south polar layered deposits. The inset picture is a context frame, taken at the same time as the high-resolution view behind it. The context image covers an area about 115 kilometers (71 miles) across and shows a thick, smooth blanket of material covering the upper two-thirds of the frame. This thick blanket is the layered deposit. The craters at the lower left are outside the layered deposit. Other craters occur underneath layered deposits. The white box locates the area shown in the high-resolution image (right), along the edge of the polar layered deposits. The large picture is one of the clearest and highest-resolution images of south polar layered material ever obtained. The area shown—at 73.0 degrees South, 224.5 degrees West—is approximately 550 kilometers (340 miles) northwest of the Mars Polar Lander *target. The smallest objects in this image are about the size of automobiles. Small dark streaks in the upper right were formed by winds blowing sediment across the layered material.* *Image: Malin Space Science Systems/NASA*

PLANETFEST '99

There was one simile that recurred again and again at Planetfest '99: we felt like we'd thrown a lavish and spectacular wedding—only the bride and groom didn't show up.

PLANETFEST '99 was to have been a millennium-marking celebration of space exploration, keyed to the touchdown of the *Mars Polar Lander*, carrying The Planetary Society's Mars Microphone. But you know what happened. The lander and the two *Deep Space 2* probes that accompanied it were never heard from. Even so, at Planetfest '99 we managed to have a lot of fun.

Some 8,000 people joined us at the Pasadena Center from December 3 to 5 and shared in the displays, talks, demonstrations, and camaraderie. That was only a third of the number we hoped for; still we were pleased that so many people came out even without pictures or sounds from the Martian surface.

About 500,000 joined us remotely through our website, which featured streaming video of the activities and distinguished participants at Planetfest. The live webcast enabled people around the world to join in the festivities, and the large number who visited us virtually again demonstrated the deep support for planetary missions worldwide. Indeed, we had visitors from around the world at Planetfest itself, and we welcomed guests from nearly every continent.

On these pages, we share a few of the moments we'll remember, and we hope that, with us, you'll look forward to the next Planetfest, when people from around our world will again celebrate—more happily next time—another mission to another world.

—Charlene M. Anderson, Associate Director

FROM LONGSHIPS TO SPACESHIPS: A THOUSAND YEARS OF EXPLORATION

BY MICHAEL CARROLL

Every Planetfest has had an art show, and each one has been different. This time the occasion called for a retrospective of exploration. We commissioned Michael Carroll to produce a mural, especially for Planetfest '99, telling the story of human exploration over the last thousand years. This series of 16 paintings highlights special milestones in humanity's quest to know our surroundings, from Earth's ocean floor to the mysteries of deep space.

The following caption lists every entry on the mural; however, because the original panels are 5 feet high and 4 feet wide, certain details are not visible in these small frames. —CMA

Shortly before the doors opened for Planetfest '99 Friday morning, we held a special students-only press conference, with middle- and high-school kids from nearly 40 California schools attending.

Photo: Nancy Ostertag

A direct link to the Jet Propulsion Laboratory (JPL) kept everyone at Planetfest '99 up to date on the status of Mars Polar Lander (MPL) *and the two* Deep Space 2 *probes every step of the way. As the mission team waited in nervous anticipation, so did we. In the photo above, Planetary Society President Bruce Murray describes plans for Mars science. On the giant screen behind him, a mission team member tries to narrow down where the spacecraft might have landed.*

Photo: Donna Stevens

In the photo above, Planetary Society Executive Director Louis Friedman presents a model of a Mars sundial, slated to fly on the Mars Surveyor 2001 *lander, to Bill Nye the Science Guy. Also shown, left to right, are astronauts Sally Ride and Dan Barry and actor Jerry O'Connell. The panel fielded questions about Planetfest '99, the* Mars Polar Lander *mission, and future missions to Mars.*

Photo: Nancy Ostertag

Panels 1-6: The Sea

Under the bright rays of the Sun, an ancient map delineates a coastline. Its compass rose lines point the way into the new millennium. We begin in the year 1000 A.D. when a Viking longship plies the water of the northern Atlantic Ocean. In the background we see the raft of Incan ruler Tupac Yupaqui, a Chinese junk, and Polynesian outriggers exploring the islands of the South Pacific. Beyond them, Captain Cook's ship HMS *Resolution* has arrived at the volcanic Hawaiian islands. In the foreground, one of Magellan's vessels, the *Victoria,* braves a ferocious sea to circumnavigate the globe. Beneath the waves we find the *Turtle*, one of the earliest successful submarines, and beneath it is *Nautilus*, the first nuclear submarine. At right, the diving vessel *Alvin* has discovered a "black smoker," and, at the bottom of the frame, scuba divers explore a sunken ship. The bathysphere, or diving bell, hovers above a reef, and *Trieste*, the bathyscaph, touches down near the ocean floor.

Panels 6-10: The Land

The undersea reefs become mountains around Machu Picchu. On the plains below, Mayan temples provide the backdrop for a royal Mayan procession using a sedan. Behind the entourage, we see China's Temple of Heaven complex, an Islamic mosque, →

Between attempts to contact the spacecraft, we had the experts right there at Planetfest '99 to explain their search plans and talk about what might have happened to the spacecraft. Planetfest '99 guests close to the MPL *project included NASA Administrator Dan Goldin, MPL Project Scientist Richard Cook, and David Paige (shown above), Principal Investigator for the Mars Volatiles and Climate Survey instrument package.* Photo: Donna Stevens

Above: With more than 100 guest speakers at Planetfest '99, there was always someone to meet. In this photo, Apollo 11 *astronaut Buzz Aldrin welcomes questions, photographs, and autograph requests.* Photo: Nancy Ostertag

Right: Every day at Planetfest '99, we had a full schedule of lectures and panel discussions featuring authors, astronauts, scientists and engineers, actors, and artists. Star Trek Voyager*'s Nick Sagan, Robert Picardo, and Andre Bormanis (left to right) discuss science and science fiction.* Photo: Susan Lendroth

and a Christian cathedral, all symbolizing the fact that religious beliefs and ideologies drove much of history's exploration. Native Americans and European pioneers move across the frontier on foot, using travois, by canoe, and in Conestoga wagons. The mountains of North America transform into desert sand dunes traversed by Arabian camels, an ancient mode of transportation still in use today. The camel train leads us to Land Rover-like vehicles of Roy Chapman Andrews' expedition to the Gobi desert. Below, America's green plains evolve into an arctic wasteland explored on skis and by dogsled. Ernest Shackleton's ship, the *Endurance*, lies frozen in the ice of Antarctica.

Panels 10-12: The Air

Above Shackleton's ship floats Umberto Nobile's exploratory blimp, the *Norge*. Beyond the blimp are, to the left, the Montgolfier balloon and, to the right, the *Breitling Orbiter 3*, first balloon to circumnavigate Earth. Otto Lilienthal's glider gives rise to the Wright Flyer. Behind these early aircraft, Leonardo da Vinci's study of the wing spans the sky. Also shown is Richard Evelyn Byrd's plane over the North Pole, Amelia Earhart's twin-engine craft, the Bell X-1 *Glamorous Glennis*, in which Chuck Yeager broke the sound barrier, and a NASA SR-71, better known as the Blackbird. In the icy plain below we see the McMurdo dome at the Scott-Amundsen South Polar Station. Above,

PLANETFEST ONLINE

While the main hall at Planetfest '99 was standing-room only, the worldwide Internet audience also awaited news from *Mars Polar Lander* via Planetfest Online. The Society's Internet traffic reached capacity on Friday, December 3, with hundreds of thousands of people jamming the lines to access our website. Outside the United States, the highest numbers of visitors came to Planetfest Online from France, Germany, Switzerland, Russia, Poland, Canada, Argentina, Netherlands, Brazil, Spain, and Australia.

Through streaming video, made possible by Intel, visitors experienced the opening ceremonies at Planetfest, with the Society's Executive Director Louis Friedman and President Bruce Murray as well as Planetfest '99 cochairs Buzz Aldrin and Bill Nye the Science Guy. In addition to activities on the main stage, PlanetCast, the official webcast of Planetfest '99, spotlighted interviews with prominent speakers such as NASA Administrator Dan Goldin, astronaut Story Musgrave, and NASA scientists from the *Mars Polar Lander* mission teams. Special guests included Arthur C. Clarke, who appeared via satellite link from Sri Lanka, and SETI pioneer Philip Morrison, interviewed from his home in Massachusetts.

These interviews and much more will be available on The Planetary Society's website for the next several months. Make sure you experience the exciting Planetfest '99 highlights at **http://planetary.org**.

Our appreciation goes to our generous Internet sponsors: Intel Corporation, Cisco Systems, Oldsmobile, Akamai Technologies, BeHere Corp, and Pacific Bell Internet Services. *—Cynthia Kumagawa, Electronic Publications Manager*

the USS *Skate* has broken through the Arctic ice.

PANELS 13-16: THE COSMOS

***Sputnik* opens the door to the space age, followed by Alexei Leonov's space walk from *Voskhod* and a *Gemini* link-up with an *Agena*. *Mir* and the Hubble Space Telescope orbit overhead. Back on the ground, the Pic Du Midi Observatory rises out of the French Pyrenees as Edmund Hillary and Tenzing Norgay conquer Mount Everest. Outlines of *Vostok*, *Mercury*, *Gemini*, *Apollo-Soyuz*, and *Apollo* glow in the sky before the rainbow trail of Japan's M5 booster, carrying *Nozomi* to Mars. The icy terrain has taken on the silvery-gray of the lunar landscape, where *Luna* and *Surveyor* meet *Apollo 15*'s Lunar Module and Rover at Mount Hadley. Above, a space shuttle blasts us into the mural's last frames. As the ground becomes red, the sky lightens into the familiar pink of the Martian day. We see *Mars 3*, *Viking*, and *Pathfinder*, with *Mariners 4* and *9* as well as *Mars Global Surveyor* overhead. In the foreground is the ill-fated *Mars Polar Lander*. Beyond lies a future sample-return mission and a rover with astronauts. The sky is cut by a crescent Mars. Above the Red Planet's limb are *Galileo* at Jupiter, *Cassini* at Saturn, and *Giotto* at comet Halley. *Voyager 2* and *Pioneer 11* sail past the outer planets and out of the solar system, into the promise of tomorrow.** ■

SEARCHING FO

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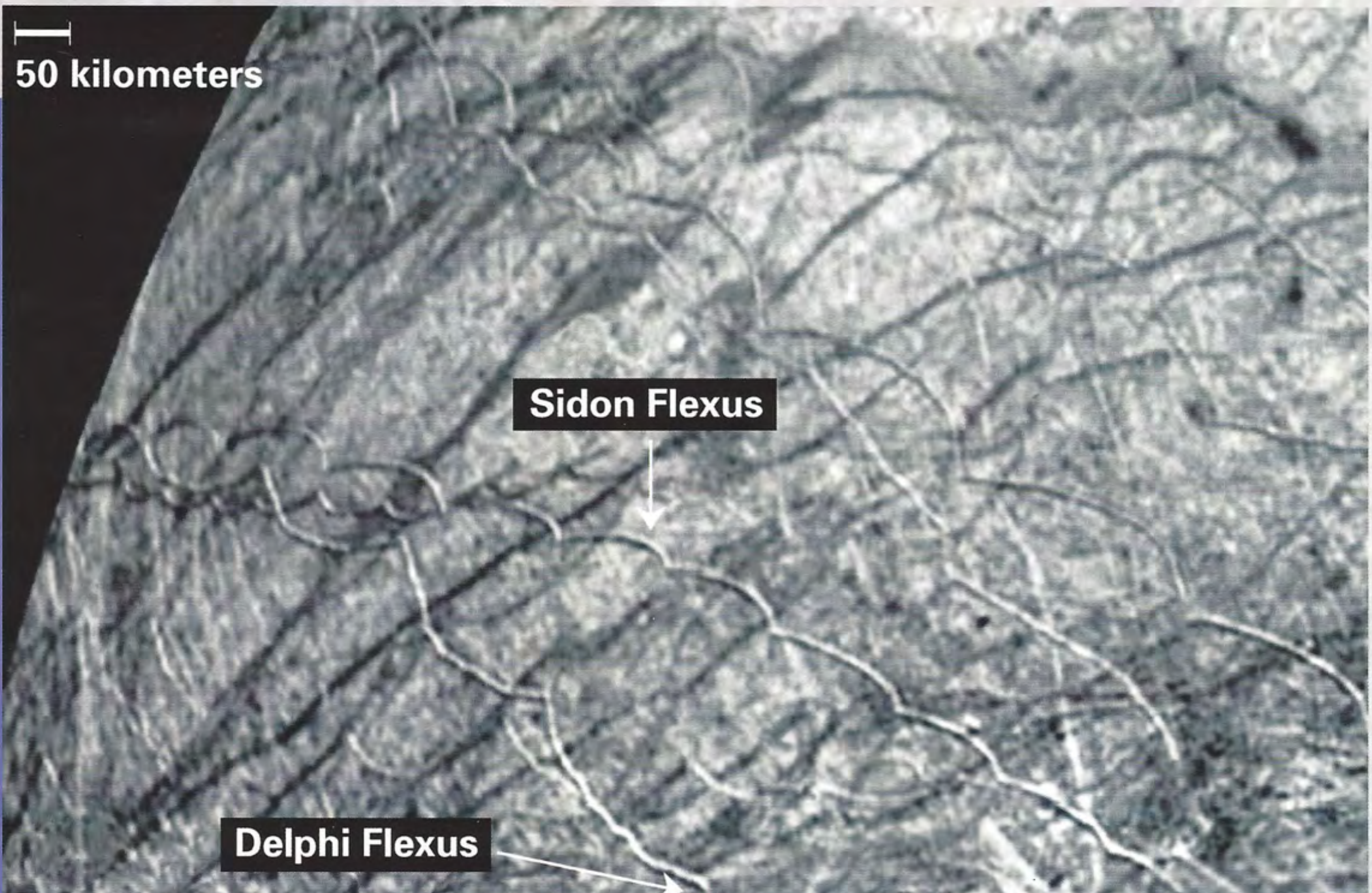
by Charlene M. Anderson



Europa, as seen by the Voyager *spacecraft in 1979, was a weird place, and among the strangest of its features were the bands of curving lines that looked like the scalloped edging on lace. In the 20 years since, scientists have been trying to work out what forces might have created these unique landforms. They may now have an answer: tides raised in an ocean below.* Image: JPL/NASA

Life . . . is it there? This has become the preeminent question driving the scientific research into Jupiter's moon Europa.

Ever since we first saw it close up, when the *Voyagers* flew through the Jovian system in 1979, Europa has stood apart from all other moons in our solar system. Its smooth, icy crust, devoid of the high-relief mountains, canyons, and craters that mark other rocky worlds, suggested that something was going on beneath the surface, something remarkable, something like the flow of an ocean.

We know for certain of only one world with an ocean.

R LIFE [?] ON

OPA

And we know that that world is coated with life. We hypothesize that living things first appeared in ocean waters and that those waters are still necessary for its survival.

So when our robot explorers revealed another world that might have an ocean . . . well, the first thing we think of is the possibility of life.

Europa has become a focus for planetary exploration second only to Mars, the planet Percival Lowell firmly established in our imaginations as an abode for life (even if his ideas about Martian life were dead wrong). Mars is a prime target because it is a world where we might someday establish human habitation. The chances are very slim that Mars supports native flora and fauna today. In the past, when water flowed over its surface, life may have arisen. But today, any naturalists investigating the Red Planet would be looking for exotic subsurface microbes or just the fossilized remnants of life.

On Europa, there may be a slightly better chance of finding something else. If there is liquid water beneath the crust, and if there are an energy source and organic compounds, the three known conditions for life will have been met. However slim, that chance encouraged NASA to extend the *Galileo* mission in the Jovian system for two years and to allow team members to swing the spacecraft again and again past the enigmatic Europa.

Galileo was not designed to confirm the existence of an ocean on Europa: its instruments have told us much about that moon, but they can't collect the types of data needed. NASA is now evaluating proposals for a Europa Orbiter mission that would launch in 2003. This spacecraft would carry a suite of instruments focused on the question of an ocean beneath the ice, so with good planning and luck, we may have an answer—about the Europan ocean at least—in the next few years.

Meanwhile, there are plenty of intriguing and suggestive data to analyze. Here are a few recent highlights.

THE CYCLOIDS

On Europa, a day lasts 85 hours. Like Earth, Europa is subject to diurnal tides raised by the

What exquisite tracery embellishes the face of Europa, carved out by the forces of physics! As seen in this highly detailed image from Galileo, *a fine network of lines covers much of this moon's surface. So many different processes are at work, it will take years to unravel them all. One step toward understanding is the hypothesis that the sequences of scalloped lines are due to the gravitational pull of Jupiter upon the waters beneath the surface.* Image: JPL/NASA mass of a nearby body. In the case of Earth, it's a smaller body—our Moon. For Europa, it's the largest planet in our solar system—Jupiter. If there is a water ocean beneath the ice, the Jovian tides would rise about 30 meters each day, putting stress on the icy shell above.

But how would these tides manifest themselves on Europa's surface? Some researchers at the University of Arizona may have found the answer to that question and to another mystery that has puzzled scientists since the *Voyager* flybys.

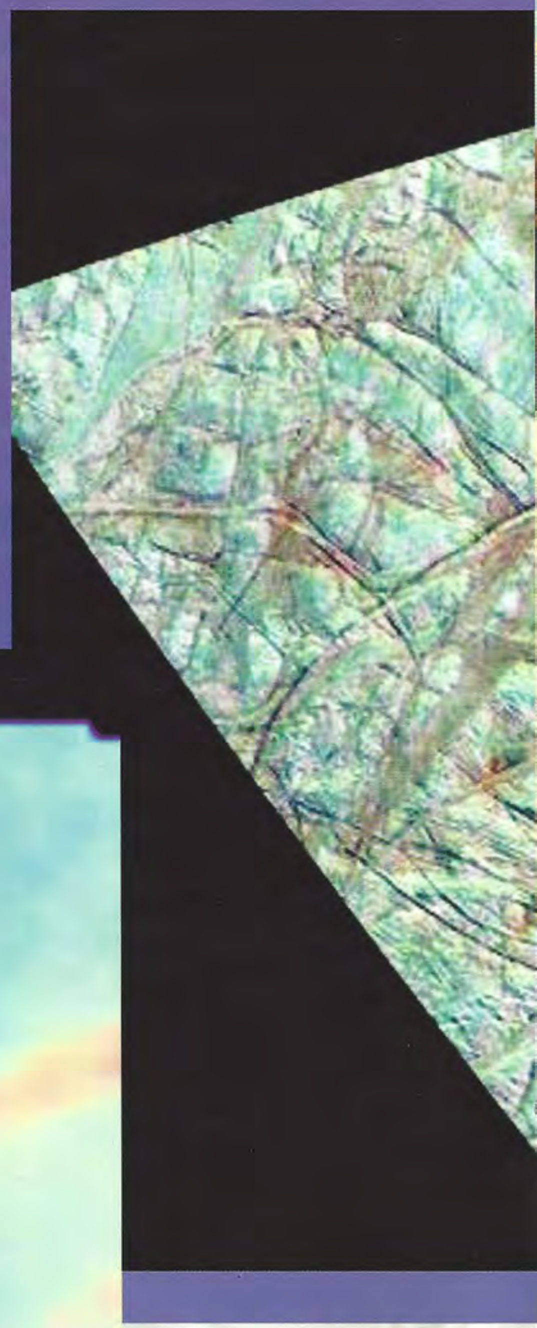
Some of the lines marking Europa's skin form scalloped patterns, looking a bit like the edge of crocheted lace. As *Galileo* flew closer and closer, it found more scalloped lines, which the scientists poetically called cycloidal features. Whatever geologic process produced these features must operate on a regular cycle and in a manner not seen on any other worlds.

Two "post-docs" at the university, Gregory Hoppa and Randall Tufts, wondered if the cracks could be connected to the diurnal tides on Europa. At Tufts' suggestion, Hoppa applied to the cracks a computer model of tidal stresses on Europa that he had been developing and discovered that the model could explain how the scallops formed.

Their success did more than solve a mystery about Europa; they have provided the best evidence yet of an ocean beneath the ice. If there was not an ocean-sized layer

Right: Dark, reddish stains mark much of Europa's face. Here we see Thera and Thrace, some of the larger blots on the chaotic terrain. Thera (left) rides slightly below the surrounding plains; curved fractures on its edge suggest it formed by collapse. Thrace (right) is longer and bumpier and stands slightly above the older plains. How do blots like Thera and Thrace form? One possibility is that a liquid ocean below melted through the icy crust, staining the feature with salty contaminants. Another idea is that warm ice pushed up from below, melting and disrupting the surface. *Image: JPL/NASA*

Below: This false-color map of Europa's frozen surface shows concentrations of sulfuric acid in red and water ice in blue. Sulfuric acid and related sulfur polymers on Europa's surface are often associated with geologic features, such as the **lineae** ***depicted here. These patterns indicate a geologically active ice-crust and suggest that some of the sulfurous material on the surface may have come from a sulfur-rich interior—through venting of sulfur-dioxide gas or other sulfur compounds. Europa may have subsurface acid lakes and springs (the melting point of sulfuric acid solutions can be much lower than that of pure water) or an acidic or briny ocean.*** **Galileo*****'s Near Infrared Mapping Spectrometer obtained this image, which covers an area 480 by 260 kilometers (300 by 160 miles).***
Image: JPL/NASA



of liquid water beneath an icy crust, the model wouldn't fit. But it does.

From gravity measurements, we know that Europa is primarily made of rock, wrapped in a layer of water some 100 kilometers (60 miles) thick. Whether or not any of that water persists in liquid form is the crucial question.

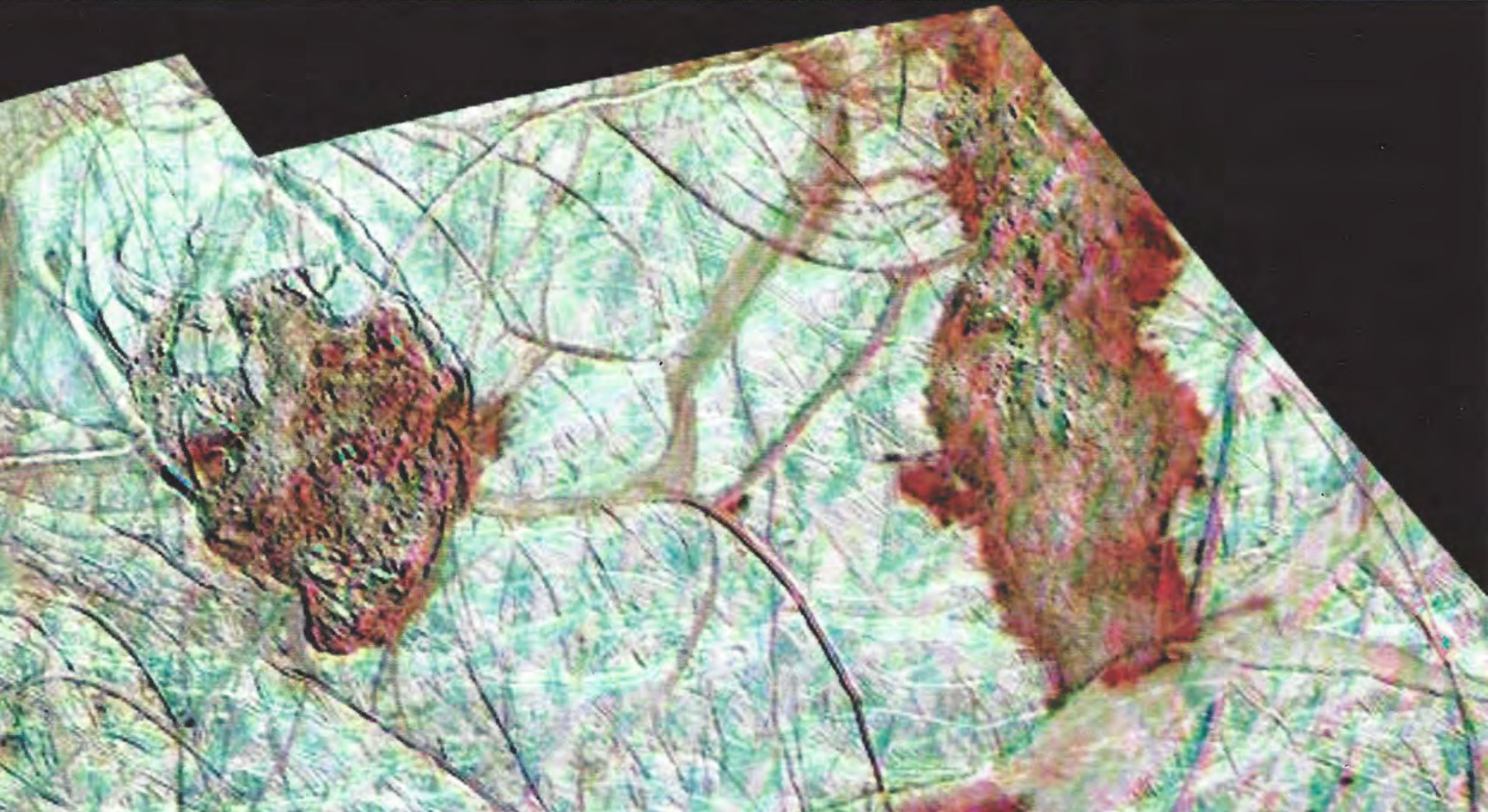
If the water layer were frozen solid, the tides would rise only tens of centimeters each day. That would not induce enough movement to form the cycloids. The Arizona model suggests that the ice is only a few kilometers thick, with enough ocean beneath to produce tides of 30 meters.

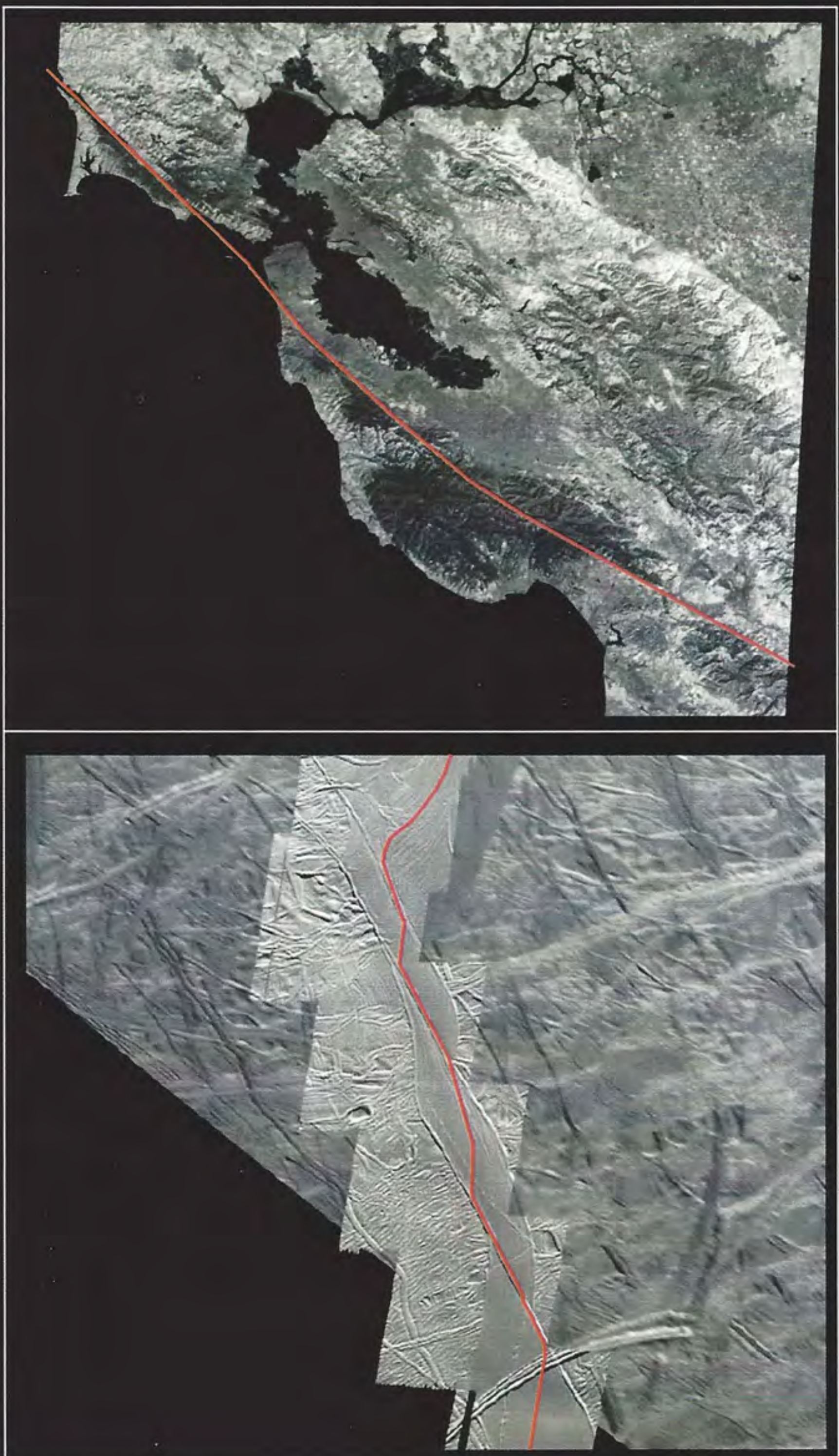
However impressive this evidence may sound, it does not confirm an underground ocean. Other models of the ice-liquid-rock ratios suggest that the ice layer is 10 kilometers deep or even thicker. Then there is the question of why the ice rips slowly over the tidal cycle, taking an arched path, instead of cracking all at once.

As the *Galileo* Europa mission ends, scientists have plenty of data to work with, and they continue to develop and refine hypotheses about what's going on with this strange moon of Jupiter. The story will continue.

THE STAINS

Even a casual observer of the Europan ice would notice that it's not particularly pristine. Assorted blotches, freckles, lines, and wrinkles give it color and character. And they





Left: Earth and Europa are two wildly dissimilar worlds, and yet similar features have been carved in their surfaces, albeit by distinct forces. The famous San Andreas fault (red line, top image) in California formed when two plates in Earth's crust collided as they slowly crept across its globe. A superficially similar strike-slip fault, Astypalaea Linea (bottom image), cracks the globe of Europa. Along a strike-slip fault, two crustal blocks grind past each other in opposing directions. On Earth, the two plates are made of rock: on Europa, they are ice. Plate tectonics moves the San Andreas fault; Astypalaea Linea may be set in motion by tides raised by giant Jupiter.

These two images are scaled to the same size and resolution. Each covers an area about 170 by 193 kilometers (106 by 120 miles).

Image: University of Arizona and JPL/NASA

also tell us that, although the ice of Europa is primarily water ice, there are other components that give it that color and character.

The Near-Infrared Mapping Spectrometer (NIMS) is designed to pick out the diagnostic spectra of chemicals on the surface. Among the species it has identified on Europa are magnesium salts, better known on Earth as Epsom salts, and hydrogen peroxide, a highly reactive compound useful in cleaning wounds.

But while these useful household chemicals are abundant there, they are not all that lies on the surface. Scientists recently announced that they have discovered that large parts of Europa are covered with sulfuric acid—the highly corrosive compound in car batteries.

What does the discovery of so nasty a compound—seemingly inimical to terrestrial-type life-forms—mean to

Above: These distinctive curving cracks and edges were shaped by the strike-slip motion of Astypalaea Linea in the icy shell of Europa. As the fault pulled apart, warmer, softer ice from below, or maybe water from a subsurface ocean, rose to the surface and froze hard. The upwelling created new surface near the original fault. The main fault structure is now barely visible as a faint line that travels north-south near the center of the image.

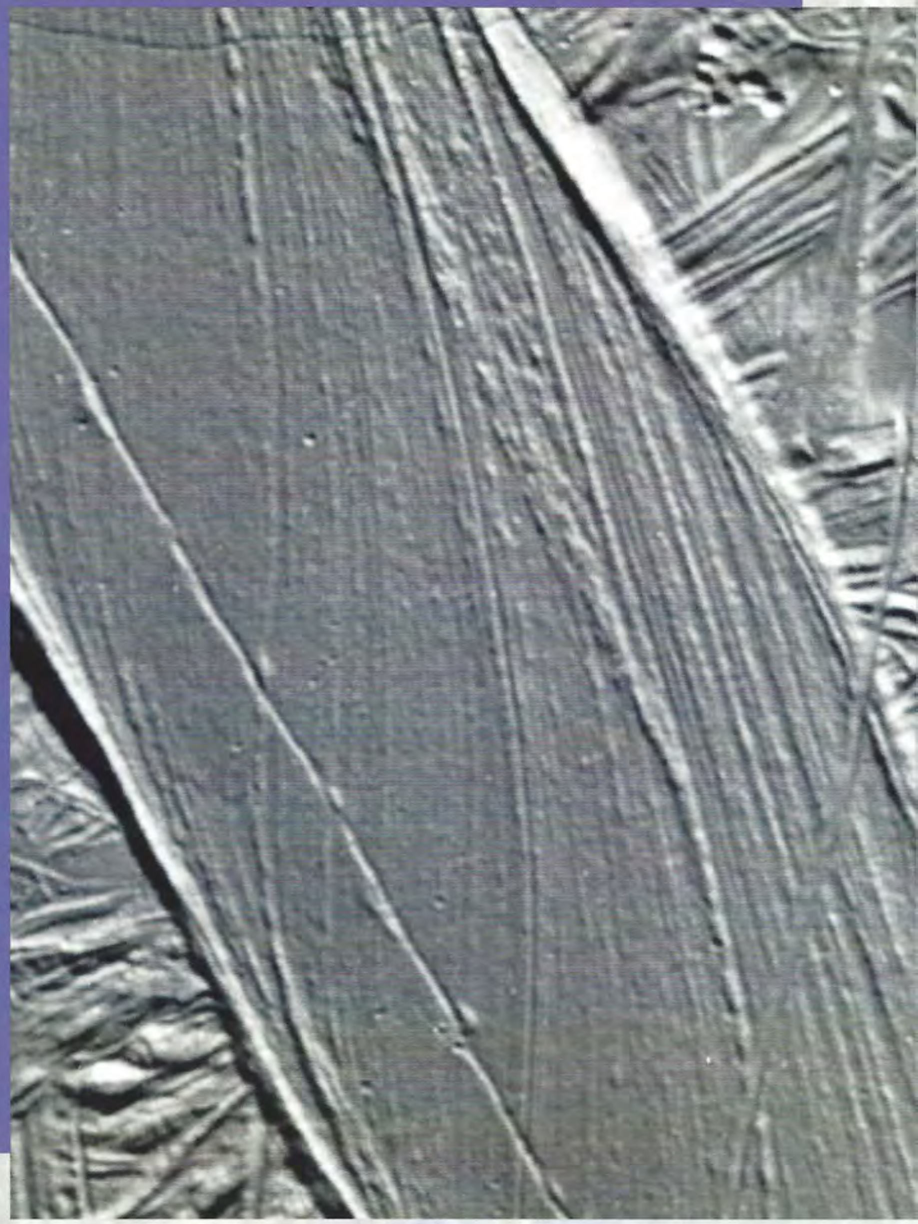
We see here an area about 15 by 10 kilometers (9 by 6 miles) with details as small as 40 meters across.

Image: PIRL/University of Arizona

Below: Through the center of this image, you can see the gently curving crack that marks the original opening in this section of Astypalaea Linea. As the fault slipped, it created openings in the ice through which softer, perhaps liquid, materials could flow up to the surface. On either side of the original crack lie successive bands, indicating that the process repeated itself many times. The distinct, segmented crack paralleling the left side of the main band is a younger formation and so suggests that the main fault has not been active lately.

This image covers an area 24 by 15 kilometers (15 by 9 miles) and shows details as small as 40 meters across.

Image: PIRL/University of Arizona



the possibility of life on Europa? Robert Carlson, leader of the *Galileo* NIMS team, first thought that his discovery would lengthen the odds against life dramatically. But it turned out to have the opposite effect.

One of the necessities for any life is a source of energy. On Earth, life has access to solar, geothermal, and chemical energy. In any Europan ocean, beneath the thick ice, the faint sunlight reaching the Jovian system would not be much use. Scientists who tried recently to inventory the potential geothermal and chemical sources concluded that it was unlikely that any multicellular forms, or even single-celled organisms, could exist on the limited energy available.

So Carlson was surprised when Ken Nealson of the California Institute of Technology and Jet Propulsion Laboratory, one of the inventory takers, was excited by the discovery of sulfuric acid. As Nealson explained, "Although sulfur may seem like a harsh chemical, its presence on Europa doesn't in any way rule out the possibility of life. In fact, to make energy, you need fuel and something with which to burn it. Sulfur and sulfuric acid are known oxidants, or energy sources, for living things on Earth. These new findings encourage us to hunt for any possible links between the sulfur oxidants on Europa's surface and natural fuels produced from Europa's hot interior."

And so, Europa continues to tantalize with what just might be possible.

Charlene M. Anderson is Associate Director of The Planetary Society.

As the Galileo *Europa mission wound down, the spacecraft swung dangerously close to Jupiter's innermost moon, Io, which it had seen only distantly for most of its four-year tour of duty. On October 10, 1999, from an altitude of 617 kilometers (383 miles),* Galileo *took this image, which shows features as small as 9 meters across. It is the highest-resolution image ever taken of Io.*

The image shows lava flows erupted from the volcano Pillan, which has been obligingly active during Galileo*'s mission. Clusters of pits and domes lie close by smooth and rough surfaces, displaying a jumble of different types of lava flows, never before seen in such a small area. Io seems graced with an unusual repertoire of volcanic processes. The cliff visible on the left ranges from 3 to 10 meters high.*

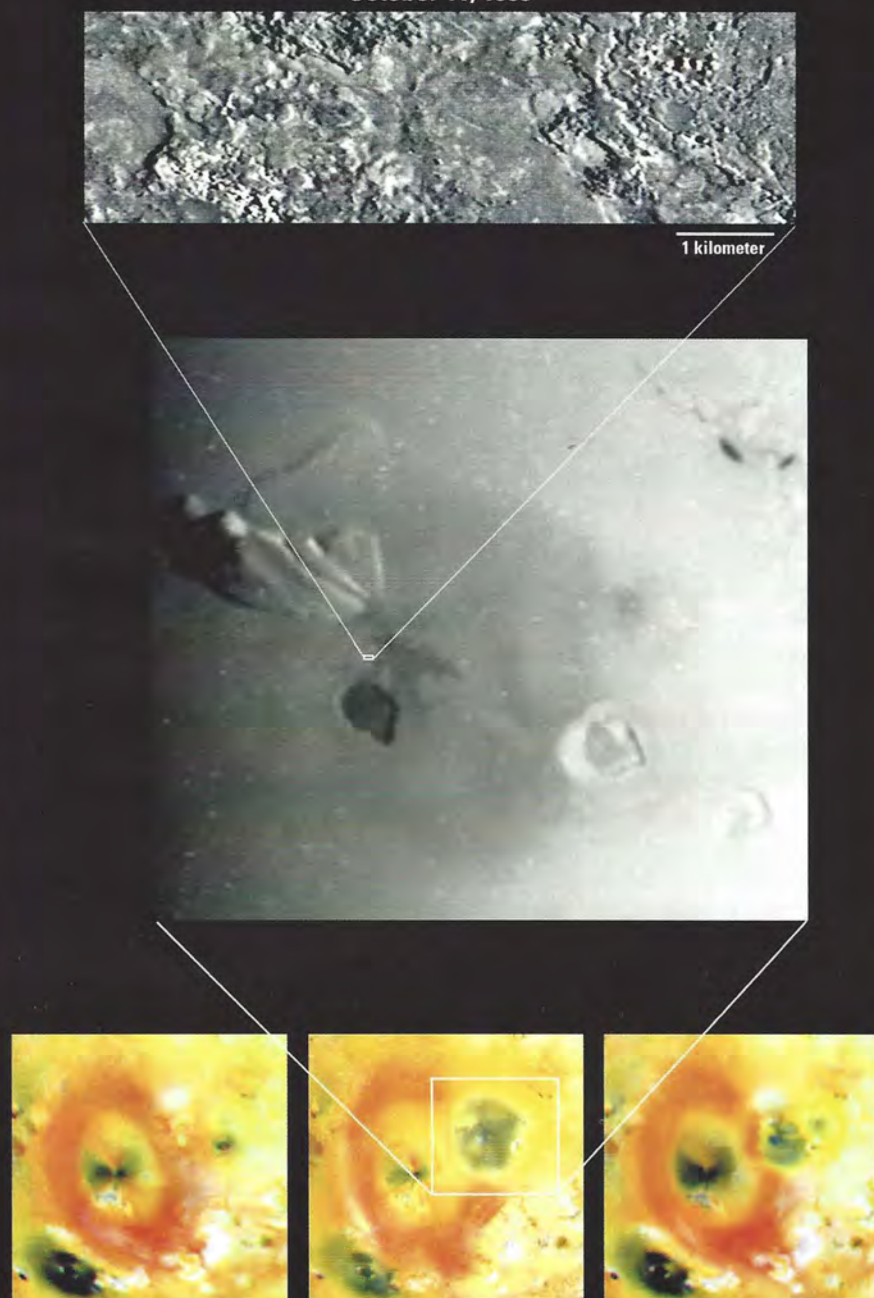
The lower-resolution image below, taken earlier in the mission and showing a smooth face on Io, demonstrates how difficult it is to read a satellite's true nature without close-up images.

At the bottom is a series of three images demonstrating the changes that Pillan has caused in the past three years. From this volcanic vent have erupted lavas hotter than any known on Earth in the past 2 billion years.

Images: JPL/NASA

Highest Resolution Image Ever Obtained From Io (9 m/pixel)

NASA's *Galileo* Spacecraft, Orbit 124
October 11, 1999



G7: April 1997 — C10: September 1997 — C21: July 1999

(continued from page 7)

the space program—exploring the unknown to understand ourselves better. Mars is the only planet where we can imagine a future for humans beyond Earth. It is where we can better understand life itself. Does life fill every niche where conditions are right, or is life some cosmic accident unique to Earth?

Just as explorers of the 16th and 17th centuries, seeking a "new world," could not be deterred by shipwrecks and setbacks, neither should our generation, or the next, be discouraged by the loss of these missions. We have to improve our ships, their navigation, and other systems and voyage forth again. The robotics being developed and the scientific knowledge sought on the upcoming missions lead directly to the capability for creating robotic and human outposts on Mars.

We share the disappointment of losing the mission. The Planetary Society was part of the 1998 lander. Our microphone was to broadcast the first sounds from Mars. We are also part of the 2001 lander mission, with Red Rover Goes to Mars. That mission plan is now in jeopardy. But The Planetary Society is not giving up, any more than NASA should. We plan to be part of future missions, giving students a chance to help control the next rover on Mars. And we will continue to support the sustained exploration of Mars, leading to human flight to Mars in the not-too-distant future. We, like NASA, the other space agencies, and all explorers, will learn as we go—and go as we learn, too.

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

Reflections on the Loss of the *Mars Polar Lander*

by David A. Paige

As the principal investigator of the *Mars Polar Lander*'s integrated science payload, for the last four years I've lived with the possibility that the mission might fail. After all those interminable meetings, all those late nights, and all the hard work, who would have thought it would end like *this*? No signal and as yet no clue to what went wrong.

Everyone is, of course, extremely disappointed. The polar lander captured the imaginations of many people, including NASA administrators, the scientific community, the media, students, and the public. What could be more exciting than landing in a completely unexplored region of Mars, taking some pictures, and digging for ice?

There will be other chances, maybe soon, maybe in the distant future. For now, we are left with a nebulous situation in which the future of the entire Mars exploration program appears to be at least as uncertain as the fate of the lander itself. As the days go by, as NASA and other agencies investigate, many lessons will be learned. For me, two important lessons are immediately apparent.

First, science and exploration are very important. In the aftermath of the loss of the lander, our team has seen a huge outpouring of sympathy and support from around the world. Would people care as much about us and our mission if it were only an engineering demonstration or a public relations gimmick? I don't think so. The fact that cutting-edge science and exploration were integral parts of this mission gave it an importance that everyone could appreciate.

If we, in our efforts to save money, remove these key elements from the Mars program, we will put the entire effort at serious risk, especially if we have more failures. *Mars Polar Lander* demonstrated that state-of-the-art science and faster, better, cheaper can coexist, and in this respect it set a high standard for future missions.

The second important and immediate lesson is that we need to overhaul our planning process for future missions. The fact that we are hastily replanning all future Mars missions out to 2007 in the wake of the failure of the 1998 missions demonstrates that our Mars program has very little technical or scientific resiliency.

In my view, the problem is not with the concept of faster, better, cheaper but with the way it is being applied. To be successful, we have to completely discard all vestiges of the 1960s planning process, in which leaders would propose lofty space exploration goals without consideration for the technical difficulties, hard deadlines, and funding.

What we need is a grass-roots process in which the goals, the schedule, the funding, and the risks are defined by the scientists, engineers, and managers who will be carrying out these projects.

For each launch opportunity, researchers should submit multiple, competing proposals. This is the only way to ensure that we are flying the best possible missions and maintaining the strongest program possible with the resources available to us.

In this model, ambitious goals such as a Mars sample return would eventually be accomplished, but only after the required technologies are in place and not at the expense of the much broader goal of studying Mars in all its diversity.

If the *Mars Polar Lander* teaches us anything, it is that there is a tremendous latent interest out there in exploring the many wonders of Mars. I hope that this small taste of what exploration could be like, energized by the public response to this mission, will keep us coming back for more.

David A. Paige, an associate professor in the Earth and Space Sciences Department at the University of California, Los Angeles, led the team that developed the Mars Volatiles and Climate Surveyor instrument package on the Mars Polar Lander.

Questions and Answers

What are the Lagrangian points and where are they all? Who was Lagrange?
—Richard McConnell,
Hessle, East Yorkshire, England

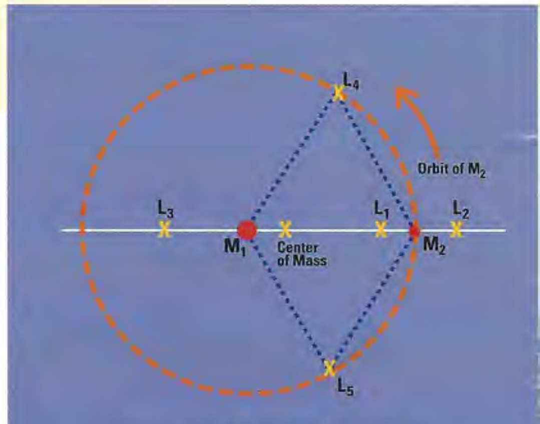
The Lagrange points are locations of equilibrium for a particle moving under the gravitational influence of two massive bodies that are in a circular orbit around each other. For example, the two massive bodies might be the Sun (which travels in a small orbit) and Jupiter or the Sun and Earth, and the particle might be an asteroid or a space station. There are five Lagrange equilibrium points, as labeled in the diagram at right.

Three Lagrange points lie on the line defined by the two massive bodies. One of the Lagrange points, L_1, lies between the two massive bodies. A particle placed at that spot with just the right velocity would stay in that position relative to the two masses, because their combined gravitational pull (in opposite directions) would exactly match the centrifugal acceleration needed to keep the particle moving in a circle around the center of mass (that is, staying at the L point).

Similarly, there are two places (L_2 and L_3) on either side of the two-body system where the total pull of the two masses matches centrifugal acceleration.

There are also two Lagrange points in the plane of the circular orbit that make equilateral triangles with the two masses (dotted lines in the diagram). How can L_4 and L_5 be equilibrium points? Again the total force of gravity from the two masses exactly equals the centrifugal acceleration of the particle.

Only the L_4 and L_5 points can be stable. If something pushes a particle off one of the other Lagrange points, the



Lagrangian Points in a System of Two Massive Orbiting Bodies (M_1 and M_2)

Factinos

At left, a Hubble Space Telescope infrared image shows the dusty ring around the star HR 4796A. The center panel shows a computer-generated model of the same image with the dusty ring transformed into a distinct ring with a diameter nearly twice that of Pluto's orbit.

Some scientists feel that the dust and debris that formed our solar system went through a similar stage of evolution once Pluto formed. The Kuiper belt, comprising small bodies beyond the orbit of Pluto, may be a leftover of such a ring of "building materials." The image at right is a model of our solar system at an HR 4796A-like stage of evolution, with a ring (at Pluto's distance) that may have evolved into the Kuiper belt. The white squares mark the positions of HR 4796A and our Sun.

Images: Left—Glenn Schneider, University of Arizona/NASA. Right—Scott Kenyon and Kenny Wood, Harvard-Smithsonian Center for Astrophysics; and Barbara Whitney and Michael Wolff, Space Science Institute

A new computer model may change the popular image of gestating planetary systems as thin, rotating pancakes of cosmic dust and debris. Once Pluto-like planets begin to form, that dusty disk may transform into a very distinct ring (see image above).

After analyzing Hubble Space Telescope images of what might be a young planetary system recently detected around the star HR 4796A, scientists from the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts and the Space Science Institute in Boulder, Colorado developed a computer model indicating that the ring around HR 4796A is probably a feature of all planetary systems.

Most theories of planetary formation suggest that planets like Earth, Mars, and Jupiter grow from the coalescence of much smaller bodies, or planetesimals, embedded in a thin, disk-like nebula of dust and gas spinning around a young star. The researchers simulated this process on the computer. In the simulation, once planets like Pluto formed, the dust turned into a distinct, compacted ring instead of a diffuse, flattened disk.

This dust donut may be the signature of an emerging planetary system, with the ring forming a dividing line between the inner, freshly formed planets and outer "under construction" bodies.
—from the Harvard-Smithsonian Center for Astrophysics and the Space Science Institute

particle will just move away. The L_4 and L_5 points are stable as long as the smaller of the two main masses is less than about 4 percent as massive as the larger, and as long as there are no other bodies around that are large enough or near enough to upset the gravitational balance.

The stability at L_4 and L_5 is maintained by the Coriolis effect, an inertial property of rotating bodies, the same acceleration that on Earth drives spinning weather systems and ocean currents. A particle pushed off L_4 or L_5 loops right back again, thanks to the Coriolis effect.

The Trojan asteroids are locked on the L_4 and L_5 points of the Sun and Jupiter, and the Sun-Earth L_4 and L_5 points are sometimes proposed as sites for space colonization.

Joseph Louis Lagrange (1736–1813) was a French-Italian mathematician and physicist, which in those days meant he did celestial mechanics. In addition to sorting out the "restricted three-body problem" as described above, he made fundamental contributions in theoretical mechanics and mathematics. The French quite properly regard celestial mechanicians as national treasures; consequently Lagrange was treated well by those in power before, during, and after the French Revolution. He is buried in the Pantheon in Paris.

—RICHARD GREENBERG,
University of Arizona

The center photograph of the elliptical pits observed by the Mars Orbiter Camera is eluding me [see pages 12 and 13 of the May/June 1999 issue of* The Planetary Report*]. I see bumps on a raised terrain instead of the pits described.

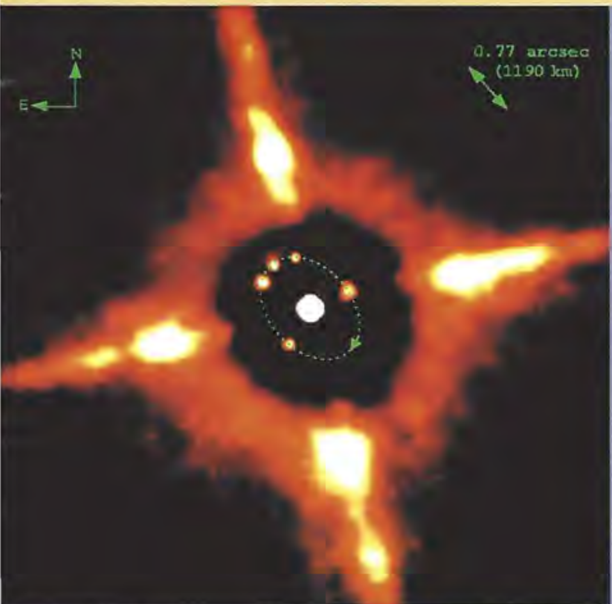
In the data returned from the probe, how does one tell a bump from a hole? What prevents optical illusions or inverted negatives?

—Harvey S. Levine,
Boynton Beach, Florida

The key to determining whether something is a bump or a pit is the direction of illumination. Where is the Sun in the picture? A raised feature will be brightest on the sunward side, because the Sun shines more directly on its slopes. It will be darker on the opposite side—facing away from the Sun—because that side is illuminated more obliquely, even if the slope isn't steep enough to cast a shadow. The Sun is shining from the upper left in the Pavonis image you mention. The sunward slopes of the elliptical features (the left-hand sides) are dark, indicating that these objects are depressions [this picture can also be viewed at **http://www.msss.com/mars_images/moc/3_23_99_pavonis/**].

It's easy to form an incorrect perception of topography, especially when the illumination is from the bottom of the picture. That's because we are accustomed to illumination from above—from artificial lighting or the midday Sun. This is why the shaded-relief Mars Orbiter Laser Altimeter map on the cover of the September/October 1999 issue of *The Planetary Report* looks normal when the magazine is rotated 90 degrees counterclockwise; yet it appears inverted in the opposite orientation.

—PAUL GEISSLER,
University of Arizona



This infrared image is a composite of five November 1998 detections of the moon orbiting asteroid 45 Eugenia. The moon travels in a clockwise direction in this view, and the green dashed line depicts its 4.7 day orbit. Eugenia is about 215 kilometers (134 miles) in diameter, and its companion is estimated to be 13 kilometers (8 miles) across. The large "cross" is a common artifact caused by stray light in the telescope.

Image: Laird Close, European Southern Observatory and Bill Merline, Southwest Research Institute

Another asteroid, 45 Eugenia, has a moon of its own (see image at left). An international team of scientists made this discovery using the Canada-France-Hawaii Telescope on Mauna Kea in Hawaii. The images they captured are the first pictures of an asteroidal satellite taken from Earth.

The researchers were surprised to find that the primary asteroid is only about 20 percent denser than water. "A picture is emerging that some asteroids are real lightweights," said the team's leader, William Merline of the Southwest Research Institute.

This discovery was made possible by a new technique, called adaptive optics, that reduces telescopic blurring caused by Earth's atmosphere. Before this, faint or close satellites would have been lost in the glare from the primary asteroid.

These are the first results from a program to search for satellites around almost 200 asteroids. Eugenia orbits the Sun in the main asteroid belt between Jupiter and Mars.

The first asteroid known to have a moon was Ida, observed by *Galileo* on its way to Jupiter.

—from the Southwest Research Institute

Scientists from the University of Notre Dame have found evidence of a planet orbiting a pair of stars in Sagittarius, 20,000 light-years away. This is the first time a planet has been detected circling a binary star system. The Microlensing Planet Search Project, led by David Bennett and Sun Hong Rhie, used a technique called gravitational microlensing to detect the planet, which has about three times the mass of Jupiter.

"Between half and two-thirds of the stars in our solar neighborhood are known to be members of binary or multiple star systems," said Morris Aizenman of the National Science Foundation's Astronomical Sciences Division. "To find evidence of a planet orbiting a pair of stars means there could be more planetary systems than we previously thought."

—from the National Science Foundation

Society News

In Loving Memory

India Wadkins, the Society's former administrative assistant, passed away on December 7, 1999.

From 1983 to 1997, India "took care of business" for The Planetary Society in a style all her own. She was professional, hard working, devoted, gregarious, thoughtful, generous, insightful, and trustworthy. She was also wild and crazy, loud, mischievous, funny, and an incorrigible matchmaker and junk collector. Her gleeful (often wicked) laughter seasoned our days with fun. One long-time associate summed it up nicely by saying, "India was a character—who had real character."

India faced her illness (brain cancer) in a brave and matter-of-fact manner. She let us know that she loved us all and that she'd had a very happy life. We loved her too and will never forget her.

She is survived by her loving husband, Dennis, son Tony, daughter Hollie, stepdaughters Denise and Dena, stepson Raymond, and grandchildren Ashley, Harrison, and Tony.

—Donna Stevens, Associate Editor

Asteroid India

Before she died, India received a special honor—an asteroid of her own. Elinor F. Helin of the Jet Propulsion Laboratory discovered 1992 WZ5 from the Palomar Observatory on November 21, 1992. Last fall, Helin gave the asteroid its official name: 7299 Indiawadkins.

The Society presented India with a certificate (which will be made into a plaque) bearing her asteroid's name, discovery information, and the following citation:

"Named in honor of India Wadkins, who, for 14 years, was the voice and heart of The Planetary Society. India helped initiate and administer many planetary research and public-involvement programs, including the Society's Near-Earth Object discovery and observation projects. She became known to thousands of people around the world for her unfailing kindness and enthusiasm as she fostered communication among the proponents of and participants in planetary exploration." *—DS*

Sounds on Mars Essay Contest Winner

The Planetary Society's Mars Microphone Essay Contest asked students from all over the world to predict what sounds the Mars Microphone might hear on Mars and to imagine what sounds might be heard on Mars 100 years from now. The contest produced more than 500 international entries. A third-grader from Scottsdale, Arizona, Harry Kent, was selected as the first-place winner. The second-place winner, Stephanie Wong, is from Edmonton, Alberta, Canada. Third-place winner Anja Volland is from Cottbus, Germany.

The Society conducted the essay contest in cooperation with Arizona State University's Mars K-12 Education Program. Harry read his imaginative and thoroughly researched essay at Planetfest '99 and appeared on the PlanetCast's live video of the event. The top three essays are posted on our website.

—Linda Hyder,
Manager of Program Development

Our Green Penguin Has a Name

On December 24, 1999, the Planetary Society announced the winner of its Name the Penguin Contest. The green-tinged creature is part of the whimsical logo for the Planetary Society's Mars Microphone project.

Jeffery E. Thomas of Delanco, New Jersey named the penguin Admiral Bird. In his winning entry, Thomas wrote, "We think the following name would fit this penguin, who is far from home—Admiral Bird, in honor of the great explorer."

US Admiral Richard Evelyn Byrd was known for his five expeditions to the South Pole, in 1930, 1933, 1939–1940, 1946–1947, and 1955–1956. The Mars Microphone was also set to explore a south pole, but on Mars, as part of the *Mars Polar Lander* mission.

Contest winner Jeffery Thomas receives one of only two penguin beanbag toys that were custom-made in the likeness of the penguin in our Mars Microphone logo.

—Michael Haggerty, Newsletter Editor

More News

Mars Underground News:
Aftermath of *Mars Polar Lander*; also, life in Mars-like conditions.

Bioastronomy News:
An overview of astrobiology; the Encounter 2001 project—sending signals into space.

Our list server will keep you updated with e-mail about Society projects and programs, political action notices, and other planetary news and information. To receive this free service, leave your e-mail address in our website's Guest Book at **planetary.org**

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

Last Chance for Planetfest '99 Memorabilia!

Mars Microphone Mission Patch
1 lb. **#622 $3.00**

Planetfest '99 Button
1 lb. **#820 $1.00**

Red Rover Goes to Mars Mission Patch
1 lb. **#626 $3.00**

Mars Microphone Magnet
1 lb. **#685 $1.50**

Planetfest '99 Poster
24" x 18" 1 lb. **#810 $10.00**

Planetfest '99 T-Shirt:
Adult sizes:
S, M, L, XL, XXL
1 lb.
Black **#593 $15.00**
Gray **#594 $15.00**
Child sizes:
S, M, L
1 lb.
Black **#595 $12.00**
Gray **#596 $12.00**

Planetfest '99 Sweatshirt:
(not shown)
Adult sizes only:
S, M, L, XL, XXL
1 lb.
Black **#591 $25.00**
Gray **#592 $25.00**

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

Mars Microphone T-Shirt
Adult sizes: M, L, XL, XXL
1 lb. **#770 $15.00**
Child sizes: S, M, L
1 lb. **#771 $12.00**

FRONT

BACK

NEW! **Mars in 3D Poster**
Red/blue glasses included.
10" x 36" 1 lb. **#306 $9.00**

Mars Microphone Lapel Pin
1 lb. **#775 $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 $14.99**

An Explorer's Guide to Mars Poster
24" x 37" 1 lb. **#505 $10.00**

Panoramic View of Mars Poster
10" x 36" 1 lb. **#328 $5.00**

Carl Sagan Memorial Station T-Shirt
Adult sizes: M, L, XL, XXL
1 lb. **#581 $15.00**

Future Martian T-Shirt
Child sizes: S, M, L
1 lb. **#565 $12.00**

Search, Discover, Explore T-Shirt
Adult sizes: M, L, XL, XXL
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These attractive prints are 20" x 16"
1 lb.
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Special Sale—Any Combination!
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Nine 8" x 10" mini-posters.
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Planetary Society Lapel Pin
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Planetary Report Binder
2 lb. **#545 $13.00**
Special Value—Order two binders
$23.00

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Spacecraft Science Kits
1 lb. **$14.00 each**

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David Egge has been a space artist for more than 20 years. He is currently working with John Lewis of the University of Arizona on three projects: a book about space resources, another book about extrasolar planets, and a science-fiction novel on extraterrestrial beings.

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