The PLANETARY REPORT

Volume XXI Number 4 July/August 2001

A New Mars

On the Cover:

Socrates declared he knew nothing except the fact of his ignorance. Indeed, when it comes to Mars, the more we see, the less we understand, thus realizing the extent of our ignorance. This Mars Orbiter Laser Altimeter (MOLA) image of the Red Planet's Argyre planitia was produced by combining MOLA altimetry with color from a *Viking* image mosaic. The Argyre impact basin, measuring 1,200 kilometers (about 745 miles) in diameter, formed when a large object struck Mars about 4 billion years ago.

Image: MOLA science team and G. Shirah, Goddard Space Flight Center

From The Editor

We can't say it enough: space exploration is hard. Nearly every step forward is a step into unexplored territory, whether technical or scientific. We have to expect the unexpected and prepare to deal with failure. In fact, that's why we test new spacecraft, again and again, to discover where potentials for failure may lie. And that's why we have a test phase in our *Cosmos 1* solar sail project.

You've probably heard by now that our sail deployment test went awry when the third stage of the *Volna* rocket failed to release the test capsule. They fell together somewhere in Kamchatka. Executive Director Lou Friedman is still in Russia, meeting with the project's technical teams to determine exactly what went wrong and to figure out what we do next.

The test mission launched just as we were going to press with this issue of *The Planetary Report*. So in the next issue we will bring you a full report on the separation failure and update you on the project's status.

Our orbital flight is still planned for late this year. The Planetary Society and our *Cosmos 1* sponsors, Cosmos Studios and the Arts and Entertainment Network, remain committed to the project. Our goal is an orbiting solar sail spacecraft that gains orbital energy from sunlight and begins to spiral away from Earth.

Planetary Society members have let us know over and over again that, in spite of the setbacks, you, too, remain committed to the project. Together we will fly the first solar sail.

—Charlene M. Anderson

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Members' **Dialogue**

Cosmos 1's Test Flight

As a member, I am both proud and disappointed with the outcome of the recent suborbital test flight of The Planetary Society's *Cosmos 1*. You have my unwavering support for this historical project. As we all know, doing space science is extremely difficult and does not always turn out as we hope. But, ironically, many scientific breakthroughs result from analyzing failures and unintended results. I urge The Planetary Society to learn everything we can from this experience and use the knowledge |to further our goals.
—CRAIG HENSON,
Tustin, California

Support for SETI

Support for SETI is one of The Planetary Society's most important activities, and it is the reason I originally joined. I believe SETI is technically achievable at our current level of development. The fact that we have not succeeded yet is no indicator that we cannot succeed, just that it will take a while.

I take issue with the statement that living in space is the goal of all true space enthusiasts. Although a future in space is a worthy goal, it is not my goal, for my lifetime. I believe we need to explore a great deal more, both robotically and with people. My own top goals include to succeed with SETI and to see human exploration of Mars, as well as maybe to find an answer to the question of whether there ever was life on Mars. Determining if there is, or was, life on Europa is right up there too. The Society is making a difference today. To support pie-in-the-sky goals would only be throwing away the money as well as the enthusiasm of its members.

I enthusiastically support your solar sail project. What other grassroots organization could achieve something like this? The Society is to be congratulated. Keep up the good work, and please stay on course!
—STEVEN DePALMA,
Holbrook, New York

I strongly disagree with Zenon Kulpa's letter in the May/June 2001 issue of *The Planetary Report*. While it may be challenging to distribute limited funds, there is no need to think of SETI and space exploration as mutually exclusive or philosophically opposed. I am also at a loss to follow the logic behind Kulpa's assertion that SETI should be stopped because any discovery would have "little, if any, impact on our ability to live in space." That's like saying we should stop listening to the radio because it has little impact on our ability to drive a car.

I agree that living in space is a goal we all share, but it's unreasonable to assume that therefore all our means should be focused on that one end. The Society should continue a broad-spectrum approach—promoting robotic and human exploration, multinational space stations, and SETI.

Just the idea, and the hope, embodied in SETI is an inspiration to me and to many others, as the success of SETI@home has shown. I think the Society would forfeit some of its dreams, not to mention some of its supporters, if it abandoned SETI.
—SCOTT PEARSON,
St. Paul, Minnesota

Rallying for Io

One important item I have yet to see addressed in your magazine is that for want of a mere $1.5 million, NASA is not planning for *Galileo* to carry out any imaging or infrared observations of Io during the last of its three upcoming flybys (the "I33" flyby in January 2002)—despite the fact that imaging during this flyby would cover a major sector of Io that has never been photographed at high resolution.

I sympathize with the Society's current efforts to encourage NASA to reinstate its plans for a 2004 Pluto probe. But it seems even more incredible that NASA is not planning to spend the relatively tiny amount of funds needed to keep an already flying spacecraft operable so it can make additional observations of a mysterious world, that will not be seen again at close range for at least 15 years.

Jason Perry, a Kansas high school student, has singlehandedly organized a Web petition drive ("Pennies for Pele") to acquire signatures from planetary scientists and others urging NASA to provide funding for imaging during I33. Jason's website is located at *http://home.earthlink.net/~volcanopele*. If this cause is to succeed, The Planetary Society's help will be badly needed.

As a member, I request you use your resources to join in the effort to provide imaging during *Galileo*'s last Io flyby and perhaps also during its Amalthea flyby. Passing up an opportunity like this is even worse than passing up a once-in-a-lifetime opportunity to observe Pluto's atmosphere for half a billion dollars.
—BRUCE MOOMAW,
Cameron Park, California

Errata

In the May/June 2001 issue, the images of asteroid Eros in "A *NEAR* Perfect Landing" were incorrectly credited to the Jet Propulsion Laboratory (JPL) rather than to the Applied Physics Laboratory (APL). In that same article we lost a digit—200 kilometers converts to 124 (not 12) miles.

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OPINION:

Let's Put Martian Life First

by Christopher P. McKay

If Mars proves barren, we might be able to import life from Earth and terraform the Red Planet into a habitable world. But what if we discover living or dormant organisms unique to Mars? Rather than terraform, should we alter Mars' environment so that any vestiges of native life can flourish and thus create a Martian biosphere? Depending on which process takes place, this scene of astronauts working in and around an inflatable greenhouse on Mars could happen later—or way later—in the future. Illustration: Carter Emmart

If Mars is indeed a lifeless planet, there is potential scientific, cultural, and human value in bringing life from Earth to Mars. The re-creation of habitable conditions on Mars, called *terraforming*, is within our technological reach, and to a Mars long since dead, Earth could give the gift of its genome: a biological heritage encapsulating billions of years of evolution. This could jump-start Mars into a biological future.

But we are not sure Mars is lifeless. If we discover living or dormant organisms on Mars and these forms represent a different type of life than is found on Earth, I argue we must refrain from transferring life from Earth to Mars. Instead, we should alter the Martian environment so that this native Martian life can expand to fill a planetary-scale biosphere.

A Second Genesis?

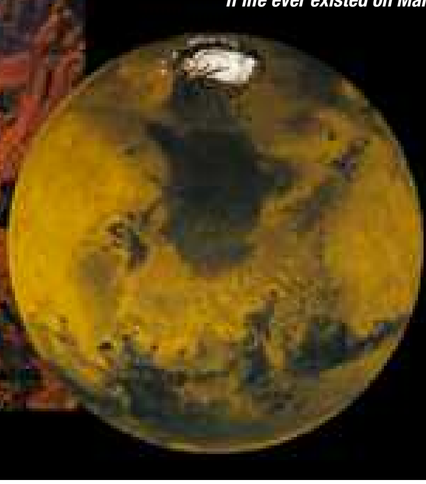
If there is life on Mars, it may be biochemically related to life on Earth. Indeed, given our current understanding of the history of the two planets, this is most likely the case. Yet there exists the possibility of indigenous life-forms on Mars, representing a second genesis—an independent origin of life.

Some argue that our primary ethical obligation to life indigenous to Mars is to leave it alone. However, I judge this approach too limited and not consistent with the clear biological potential of Mars. If we do nothing to assist indigenous Martian life, we deprive it of the opportunity to develop into a global-scale biological system and the planet of the opportunity to host such a system.

If indigenous life is present on Mars, it is not doing well. On Earth, biology dominates the cycles of carbon and nitrogen. On Mars this is clearly not the case. A global-scale biosphere on Mars is lacking or it would produce obvious and planet-wide effects on Mars' atmosphere—and no such effects are observed.

Our experience on Earth strongly suggests that life achieves maximum richness and diversity when it becomes fully global and dominates the biogeochemical cycles of a planet. Absent this, Mars may be, and perhaps would remain, a planet with life,

Views expressed in this article are those of the author and do not necessarily represent those of The Planetary Society.

Left: Bleak and freeze-dried, the Mars of today appears inhospitable to anything living. Humans will probably shape any future life on the Red Planet. The question is how.

Right: Large lakes and seas of liquid water may have formed on the surface of Mars 3 to 4 billion years ago. Some of these bodies of water might have been covered by ice (white areas) or colored by suspended sediment (red zones). If life ever existed on Mars, it would have seen its heyday here.

Illustrations: Mars landscapes by Susan Kitchens, global mosaics by Alfred McEwen and NASA, digital effects to globe by Slim Films

but it is not a living planet.

I propose that if we discover remnants of an indigenous Martian biota, we alter the planet to promote that biota's emergence as a global biological system controlling the planet's biogeochemical cycles. Given the similarity of the early histories of Earth and Mars, the ecological requirements of indigenous life on Mars likely equate with those of life on Earth: sunlight as the primary energy source, liquid water the reaction medium, and carbon the key building block. Enhancing the habitability of Mars for indigenous life would thus approximate the task of making Mars habitable for Earthly life.

Furthermore, it is unlikely that the process of extending the habitability of Mars would threaten any native Martian microorganisms with extinction. As we know from Earth, specialized microorganisms are able to live in small localized environments within a global biosphere. The greatest environmental change in the history of the Earth—the rise of oxygen—failed to destroy the anaerobic microbial life preceding it. In a newly habitable Mars, some species of indigenous Martian life may dominate the expanded biosphere, but chances are, the previous environments would still be represented on some scale in the new world. Biologically speaking, Mars would, without loss, begin a new and separate evolutionary trajectory. It would be of enormous scientific interest to us to be able to observe this process.

Moving Beyond Competition

We do not yet know if we could inhabit Mars and still leave ecological room for an indigenous Martian biota. Cohabitation is unsupported by our experience on Earth. Earth microorganisms have expanded into every possible niche and would be expected to do so on Mars. Thus Earth microorganisms would probably compete ecologically, if not biochemically, with the Martian microbes.

Ecological principles suggest that either system would eventually displace the other, that the two life-forms could not both occupy the same ecological space for long. However, this uncertainty can only be resolved by careful study and experimentation, and, in fact, we may discover that Earthly life inhabiting Mars is not inconsistent with the flourishing of indigenous Martian life.

It has been argued, meanwhile, that human actions are as much a part of nature as the origin of life and its inexorable drive to expand. This view holds that actions by humans are exempt from ethical constraints. Our introduction of terrestrial life to Mars is not any more unnatural—or censurable—than a meteorite transporting a microorganism from Earth to the Red Planet.

I dispute the validity of this argument. We humans have accepted that our unique (as far as we know) capabilities include a responsibility to judge and control our biological impulses. Such purposeful actions by humans as causing the death of other humans are ethically restricted even if these actions occur naturally.

Justification for removing, or imposing on, a native and biologically distinct Martian life-form follows from the view that actions are measurable only by their benefit to humans. There is certainly merit to the position that ultimately all value derives from human value. However, I contend that even if this purely utilitarian view is accepted, encouraging a separate system of life on Mars remains our best option.

Reaping the Benefits

I conclude that human self-interest is best served by contributing to the enhancement of an indigenous Martian biota. We would then reap maximum benefits from the scientific study of that biota and its development into a full-scale global biosphere. These benefits include advances in fundamental biology, planetary ecology, and possibly medicine.

Clearly, I am presenting a personal view: there are no absolute criteria for assigning value to life and diversity or for weighing the value of a human outpost against the removal of an indigenous Martian biota.

Moreover, our current, if limited, knowledge of Mars tells us it is now a lifeless planet. Thus we may never have to face the dilemma of how to treat indigenous Martian life. Nonetheless, we should be prepared to confront this issue and to defer to indigenous Martians—however microscopic—and even to revive them if necessary and assist them in regaining biological control of their planet. We will be the better for this, scientifically as well as ethically.

Christopher P. McKay is an astrobiologist at NASA Ames Research Center, where he is conducting research on life in extreme cold and dry environments. He currently chairs The Planetary Society's Advisory Council.

Cosmos 1 Test Capsule

Repaired After Prelaunch Accident

by Louis D. Friedman

On April 11 (Moscow time) the spacecraft for the suborbital test flight of *Cosmos 1*, the first solar sail, was damaged when the onboard computer started the reentry sequence with the spacecraft on its test stand. The craft was undergoing routine tests after being delivered from Moscow to Severomorsk, the Barents Sea port from which the launch submarine will depart.

Fortunately, the accident occurred on the ground; therefore, the spacecraft could be quickly returned to its manufacture and assembly area, repaired, retested, and readied again for launch. The team accomplished all this in six weeks, with the spacecraft returned to the launch operations area in Severomorsk on May 26.

Accidents during prelaunch tests are not uncommon and, indeed, are among the risks of spaceflight. But our solar sail project is unique in that *Cosmos 1* is the first mission conducted by a public interest space group. Our experiences should be educational as well as pioneering, and we feel we should share with Planetary Society members, who are making the solar sail possible, the lessons learned. We present here a report on the accident and its causes.

Above: In this view the Cosmos 1 *test capsule sits ready for integration with the launch vehicle. The cameras, antennas, and solar sails mounted on top are visible. The white-colored material is the craft's inflatable reentry system. The odd shape of the capsule is due to the fact it was designed to fit within a space formerly occupied by nuclear warheads.*

Left: Louis Friedman observes as a Russian technician assembles the instrument container that would later be placed in the center of the Cosmos 1 *test capsule.*

Images: NPO Lavochkin

Launching an Investigation

Any spacecraft accident is a big deal. Immediately after the test flight accident, the Russian Aviation and Space Agency (RosAviaKosmos) and the Babakin Center, our prime contractor for the spacecraft, convened a review board to investigate what went wrong. Representatives from Babakin Center; its parent organization, the Lavochkin Association; the Space Research Institute of the Russian Academy of Sciences; and the Makeev Rocket Design Bureau all participated.

The review board proceeded to uncover the cause of the accident and prescribe the repairs and corrections to be made. Participants shared their results fully with us.

The Planetary Society conducted its own review, led by Harris M. (Bud) Schurmeier, former associate director of the Jet Propulsion Laboratory and one of America's leading space project managers.

In this photo, Russian engineers (at left), along with Bud Schurmeier and John Garvey, examine the set of flight unit solar sail blades to be deployed during the Cosmos 1 *test flight. The location is NPO Lavochkin, where the spacecraft is being manufactured.*

Image: NPO Lavochkin

He and I, along with two aerospace engineer-consultants—*Cosmos 1* contract manager Jim Cantrell and *Cosmos 1* data systems manager John Garvey—went to Moscow and conducted our own review and inspection of the spacecraft assembly and test. The Russian organizations were extremely cooperative, and we were given excellent access to previously restricted areas where the spacecraft hardware was being developed.

This broken cable was meant to pass data from the camera to the spacecraft's computer. All wiring and all damaged connectors were replaced for the suborbital test flight.

Seen here is the site of the short circuit that damaged the Cosmos 1 *test spacecraft. In view is the G5 ground support connector, with its metallic cap installed over the connector pins. The team believes this cap shorted across several pins, causing the descent computer to begin its sequence.*

Anatomy of an Accident

So what happened? Bud Schurmeier, in his report to The Planetary Society, produced the most lucid technical analysis of how the accident occurred.

According to Bud's analysis, a technician involved in measuring the voltage of the spacecraft batteries at Severomorsk caused an electrical short between two pins in the G5 test connector—either in the process of removing the metal connector cap or while connecting the cable from the ground test equipment.

The design of the connector contributed to the blunder. The G5 connector on the spacecraft was male, with a very high pin density (50 pins in about a 1-inch, or 2.5-centimeter, diameter). The connector contained "hot pins" that were connected directly to each of the two spacecraft batteries (the cause of the *Ranger VI* failure).* Protective high resistance in this voltage measurement circuit was lacking.

Whatever its cause, the electrical short activated the descent controller that sequences the test capsule's reentry and descent functions. (This controller is one of three on the spacecraft: one for ascent functions, one for descent functions, and one for the solar sail functions. The ascent and descent controllers are in a single electronics box and use the same G5 connector for ground testing.)

About three minutes later, the controller started sending signals to fire the pyros on explosive bolts, cable cutters, and

(continued on page 8)

This is the upper part of the instrument container, showing the camera with its "remove before flight" lens cap (red) and shredded inflatable reentry material on the left. Images: Babakin Space Center

*Bud Schurmeier served as project manager for *Ranger VI* and succeeding flights in that series, which were the first US spacecraft to reach the Moon.

(continued from page 7)

inflate. The inflation of the reentry shield inside the capsule resulted in fairly extensive damage.

Because of the three-minute delay, it is not possible to determine whether removing the cap or connecting the cable caused the short. In fact, connecting the cable was a blind operation. Access to the connector with the spacecraft in the flight configuration, as at Severomorsk, was very poor. When the connection was made during checkout at Babakin, the solar sail package had yet to be installed, so access was much better. Also, the technician at Severomorsk was not the one who had done the job at Babakin.

Summing Up

A couple of design errors, a procedural error, and the bad luck of having them all come to bear at once evidently caused the test flight accident. The design errors included the arrangement of pins on the connector and the electrical circuit's susceptibility to a fault. The procedural error involved access to the connector.

During the accident the platform on which the solar sail packages were mounted was bent, some of the cables were pulled out, and some minor structural damage occurred. No electronics were damaged; however, 26 of 53 components had to be replaced.

Fortunately, the financial cost of the accident was minor and the delay to our overall schedule slight. The launch, including all prelaunch operations and checkout as well as travel to the launch site, is covered by insurance. Obtaining such an insurance policy was not easy, but the result is that the policy picks up the expense of Babakin's rebuilding the spacecraft.

Shown here is the test spacecraft's damaged and deformed mounting platform, with the solar sail blades packed on top. The deformation was caused when the craft's inflatable reentry system engaged inside the capsule and pushed on internal components. Flight unit backups of the sail blades and the damaged tanks and structures were used to repair the test capsule. *Image: Babakin Space Center*

Status Report

As it now stands, the faulty designs have all been changed and the damaged parts replaced. The spacecraft has been retested and all parts and working operations verified. We believe we have a good and reliable spacecraft ready for launch.

Meanwhile, work continues on the spacecraft intended for the orbital flight late this year. In Moscow our team also reviewed progress on that development.

Babakin has come up with a modular design for the solar sail spacecraft—in three parts: the engine (for orbit insertion), the spacecraft bus (for control and data handling), and the solar sail. The first two modules may be useful for future spacecraft missions—perhaps to the Moon and Mars. But first we must meet our solar sail mission goals; we have all accepted the challenge.

Louis D. Friedman is executive director of The Planetary Society.

Solar Sail Test Flight Launched

On July 20, 2001 (Moscow time) the *Cosmos 1* suborbital test flight launched from a submarine in the Barents Sea. The *Volna* rocket failed to send the final command to separate the test capsule from the upper stage. Without separation, the spacecraft could not initiate either its solar sail deployment sequence or the inflation sequence for the reentry capsule. A full report of the test launch will be published in the September/October 2001 issue of *The Planetary Report*. For up-to-the-minute information about the launch, visit the Solar Sail section of our website, *planetary.org*.

Get Ready to Set Your VCRs

Befitting its significance as the first solar sail, as well as the first mission launched by a public interest space group, *Cosmos 1* will be the subject of its very own TV documentary. Cosmos Studios, our sponsor and partner in the *Cosmos 1* project, announced that the Arts and Entertainment (A&E) Network has joined on as a project sponsor. Early next year, A&E will air a documentary (produced by Cosmos Studios) about the development of the sail.

"Sub-bing" for a Nuclear War-

by Jim Cantrell

The submarine from which Cosmos 1 *was launched is a* Delta III (Kalmar) *nuclear ballistic missile submarine, a type that entered service in the 1970s.* *Photo: Makeev Rocket Design Bureau*

Submarines have long been feared for their ability to attack ships at sea without warning. During the 1950s a terrifying addition was made to the world's submarine fleets: Sea Launched Ballistic Missiles (SLBMs) carrying nuclear warheads. This force allowed both sides in the Cold War to park nuclear weapons close enough to each other's coasts to launch strikes with minimum warning to those under attack.

Some of the first deployments were fairly crude by today's standards. The first Soviet SLBM, the liquid-propellant missile R-11FM, was a modified version of the now infamous Scud-A. The missile was deployed in a dry tube that penetrated the hulls of the submarine, and the launch was conducted from the surface.

Later designs in the 1960s and 1970s developed the ability to launch quietly from below the surface and to carry multiple warheads capable of aiming at multiple targets. This frightening capability, matched by the US, lurked menacingly below the seas.

Introducing the Volna

Both solar sail launches will be conducted with a *Volna*, or SS-N-18 ballistic missile. This system, developed in 1971, was the first sea-based Soviet ballistic missile to carry seven multiple, independently targetable reentry vehicles. It is carried on the *Delta III* (*Kalmar*) ballistic missile submarine. The *Volna* missile has two rocket stages, both fueled by hydrazine and nitrogen tetroxide, and features a post-boost vehicle for dispensing the warheads.

During both solar sail launches, the *Volna* will place our spacecraft onto suborbital trajectories that intersect the Earth. This is desired for the first test flight since it is designed to be recovered. The second solar sail spacecraft has its own additional propulsion system, which will thrust the craft up to the proper altitude and attain orbit.

A major challenge for the solar sail design team has been to utilize what is basically a suborbital launch vehicle for an orbital flight without modifying the basic vehicle and thus affecting the reliability of the rocket. Our solar sail design scheme utilizing the *Volna* has creatively solved this problem. The solution could prove a blueprint for future missions using submarine-based launches.

For reasons of military training and maintenance of missile stockpiles, SLBMs are occasionally launched in realistic conditions at sea. Typically these launches carry no warheads but, instead, simple dummy masses in their place.

Our solution is to use our spacecraft as the dummy mass. For the cost of a training exercise, some of the missile cost, and other miscellaneous expenses, we get a ride into space.

Inquiring Minds Want to Know . . .

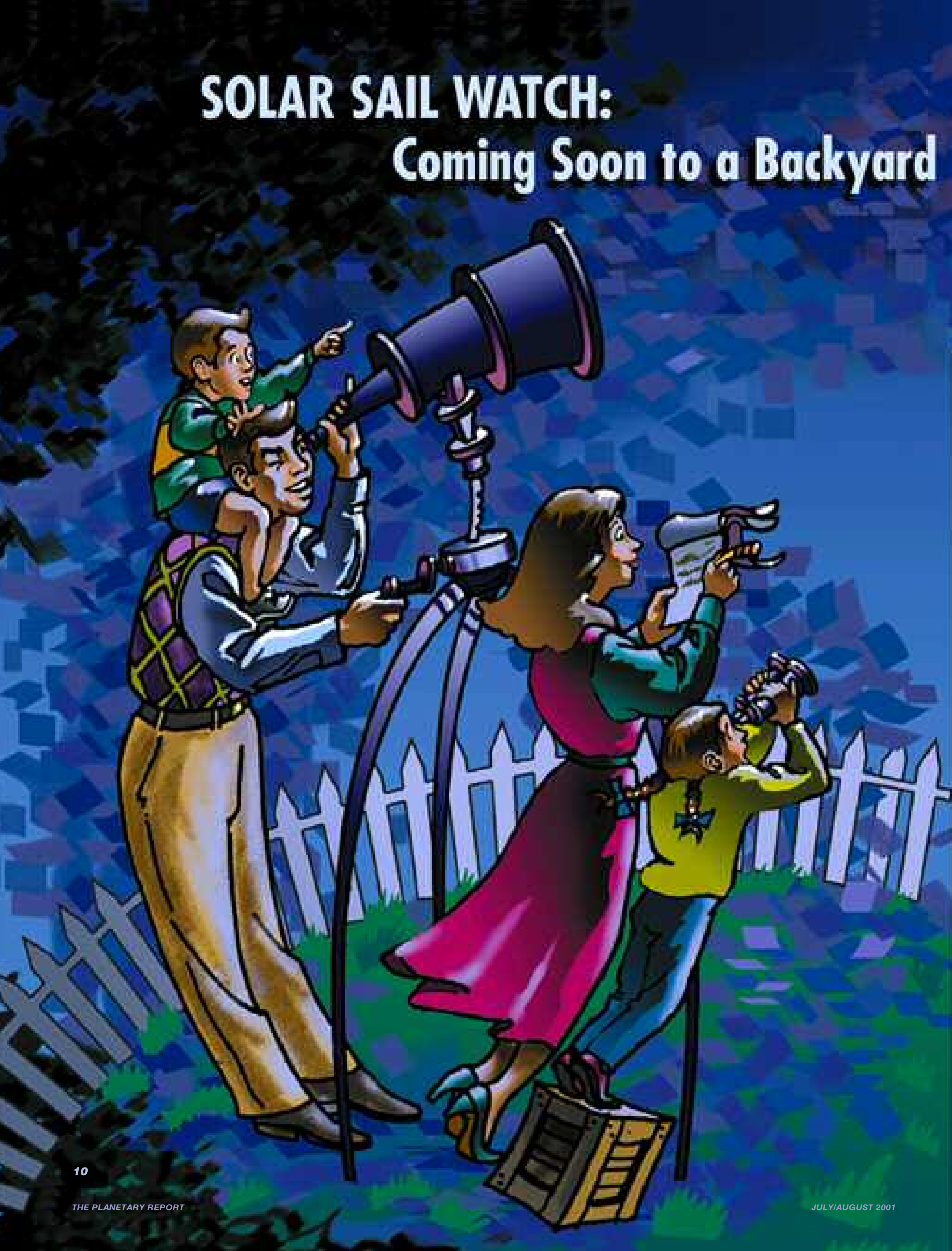
One often asked question is "Why use an SLBM for launching satellites?" In most cases the answer involves cost. Put simply, a Russian SLBM launcher costs about 1/10th to 1/100th that of a comparable Western land-based launcher.

Another often asked question is "Why launch under and not above water?" The answer is as unexpected as it is amusing—launching from the surface means that crews have to clean the submarine afterward, since the rocket plume leaves corrosive residue on the sub.

Besides the cost factor, our solar sail project team found the idea of using these once feared machines for peaceful exploration extremely appealing. The Planetary Society solar sail is not the first submarine-based launch of a satellite, however. The German *Tubsat* was launched in 1998 aboard a *Shtil* SLBM, a larger cousin to the solar sail's *Volna*. The submarine was submerged during the launch, which is its normal mode of operation for combat firing.

Jim Cantrell has worked on many Russian projects, including Mars '96 *and several joint missile defense programs, and on the Mars Balloon for France's Centre National d'Etudes Spatiales. A longtime friend of The Planetary Society, he co-invented the Mars SNAKE. He is currently director of program development at Space Dynamics Laboratory in Logan, Utah.*

SOLAR SAIL WATCH:
Coming Soon to a Backyard



Near You

by Susan Lendroth

It's a bird! It's a plane! It's *Cosmos 1*, the world's first solar sail! When The Planetary Society and Cosmos Studios launch *Cosmos 1* late this year, people around the world will be able to visually track the sail's progress from the comfort of their own backyards. Sporting 625 square meters of silver aluminized Mylar covering eight 15-meter blades, *Cosmos 1* will sail across the sky with the reflectivity of a giant mirror, a sparkling point of light that will sometimes be as bright as the brightest stars.

To help track the sail's progress, The Planetary Society will begin Solar Sail Watch this October on our website, *planetary.org*. Solar Sail Watch is designed for everyone, from the most casual viewer who asks "How do I find *Cosmos 1* in the sky?" to amateur astronomers who want to help monitor the sail as it circles our planet.

Cosmos 1 will start orbiting the Earth approximately every 100 minutes at an altitude of 850 kilometers (530 miles). To maintain its orbit and slowly increase altitude over time, the spacecraft will continually adjust its panels to reflect sunlight at an optimum angle, like a schooner tacking in the wind. The force from the photons bouncing off its lightweight, highly reflective surface is what propels *Cosmos 1*.

Be on the Lookout

Depending on the time of year and how far north or south of the equator you live, the sail will pass overhead from two to seven times per day. You won't be able to see it on every pass because the sun will outshine the sail during daylight hours. Even at night the sail will sometimes be in eclipse or turned edge-on toward Earth. The best viewing times will be soon after sunset or before sunrise, when the craft's mirror-like surface is illuminated by the sun but the sky is dark.

When viewing conditions are right, *Cosmos 1* will be seen to arc across the night sky like a fast-moving airplane (only without blinking lights). The solar sail will take 10 to 15 minutes to transit from horizon to horizon, with the exact amount of time varying, depending on your location. After *Cosmos 1* launches, the Solar Sail Watch section of our website, coordinated with that of Cosmos Studios, will enable you to learn when the sail will pass over your location each day and how reflective it might be.

The brightness of *Cosmos 1* will vary depending on the tilt of the sails relative to both the Earth and the Sun. Although *Cosmos 1* will often be visible to the naked eye, binoculars or a telescope will enhance your viewing. Under prime observing conditions, with just a regular pair of binoculars, you should be able to spot the sail as a tiny disk. Under perfect conditions, with telescopes larger than 80 millimeters (approximately 3 inches), you will begin to make out details of the sails themselves. Of course, this all depends on dark, clear skies, the sail's directly facing the observer, and the Sun's angle being just right. With larger telescopes, you might see more detail.

Solar Sail Watch participants are encouraged to observe the sail through the course of its mission, noting changes in its brightness (magnitude) and orbit.

Something for Everyone

For parents and educators, *Cosmos 1* will be a great teaching tool, helping young people learn how astronomers determine the orbits of objects and judge their magnitude. More broadly, it will provide an object lesson about light, optics, and orbital motion.

The Planetary Society is also asking skilled observers to help us track how the orbit of *Cosmos 1* changes, as well as to accumulate data about its visibility and magnitude. Participants will be able to assume a more active role in Solar Sail Watch by recording and submitting details about the solar sail's appearance in their locale.

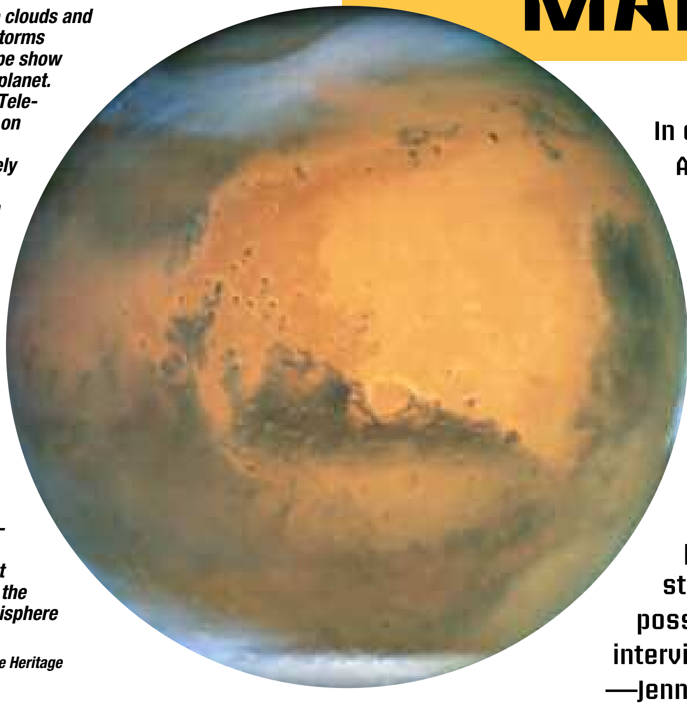
Another important contribution to the solar sail project will be to photograph the sail as it passes overhead. We will be collecting photos of *Cosmos 1* and will post several on our website. In fact, we will offer a contest for the best solar sail photographs taken by observers.

So whether you want to kick back in your lawn chair and just be inspired as *Cosmos 1* glides overhead or to actively participate in a global network of sail trackers, Solar Sail Watch offers something for everyone. Join us this fall and see our solar sail in action.

Susan Lendroth is The Planetary Society's manager of events and communications.

Illustration: Sid Bingham

MARS, OLD AND N



Frosty white water-ice clouds and swirling orange dust storms above a rusty landscape show Mars to be a dynamic planet. NASA's Hubble Space Telescope took this image on June 26, 2001, when Mars was approximately 68 million kilometers (43 million miles) from Earth—the closest Mars has ever been to our planet since 1988. Especially striking is the large amount of seasonal dust storm activity visible. One large storm system is churning high above the northern polar cap (top of image), while a smaller dust storm cloud can be seen nearby. Another major dust storm is spilling out of the giant Hellas impact basin in the planet's southern hemisphere (lower right).

Image: NASA and The Hubble Heritage Team (STScI/AURA)

In early June, *Planetary Report* editor Charlene Anderson and I sat down with our resident expert, Planetary Society president and co-founder Bruce C. Murray, to talk about how his view of Mars has evolved over nearly four decades of exploration. Murray has been a key player in the exploration of Mars since the first American mission to the planet: the *Mariner 4* flyby in 1965. Since then, he has been part of nearly every mission to the Red Planet, both American and Russian. Our two-hour exchange produced plenty of insights, explanations, and personal stories—much, much more than we could possibly print here. Look for more of the interview on our website, planetary.org.
—Jennifer Vaughn, Managing Editor

The Planetary Report: Clearly, a "New Mars" seems to be emerging from *Mars Global Surveyor* [*MGS*] data. How have your views of Mars changed?

Bruce C. Murray: *Mars Global Surveyor* has, for me, renamed Mars the land of broken paradigms. *MGS* not only produced stunning results but also revealed that we can't explain them, as we thought we would be able to.

When you look at Mars up close, you don't see the signatures of what you're expecting to see. Instead you see the signatures of something you don't recognize. I'll give you an example. Everybody had expected the planet's south polar layered terrains, where *Mars Polar Lander* was to touch down, would be smooth. They're smooth on the scale that we could see from earlier spacecraft. They seemed smooth in radar observations. So you can imagine our surprise when the first Mars Orbiter Camera [MOC] pictures showed a granulated, ridged surface. We don't know what causes these ridges, and there is no terrestrial analogy I can think of to try to explain them. Evidently there is some process occurring on the polar regions of Mars that we don't understand.

On the Moon's surface there are very few morphological features that are not easily attributable to impact. The Moon has a debris layer increasing at about 1 meter in thickness per billion years—so a 3-billion-year-old lunar mare [volcanic plain] has a debris layer about 3 meters thick. We know that because you can see the layering in the impact craters. Astonishingly, Mars lacks a debris layer.

Persistence Pays Off

Mariner 4 was an extraordinary accomplishment. Those 21 tiny little framelets—each 200 by 200 pixels—that *Mariner 4* delivered revolutionized the view that Mars was somehow like the Earth. Mars has great big craters, 300 kilometers [185 miles] wide, which had to have formed at the same time the Moon formed similar craters, roughly 4 billion years ago. *Mariner 4* also discovered that Mars has no appreciable atmosphere, which was a big surprise. With no appreciable atmosphere, you can't have liquid water. Talk about shattering paradigms.

After *Mariner 4* I participated in *Mariner 6* and *7* in 1969; on *Mariner 9* I headed the polar studies group. It wasn't until 1985 that I came back to Mars. [During this apparent break from Mars, Bruce served as director of the Jet Propulsion Laboratory and oversaw the *Viking* missions.] I was selected as a participating scientist on *Mars Observer*, which was scheduled to reach Mars in August 1993. And, of course, *Mars Observer* failed.

In the meantime I had become involved in a similar capacity with the television cameras on the Soviets' *Phobos 1* and *2*. *Phobos 1* failed shortly after launch, and *Phobos 2* got into Mars orbit, in a very clever mission co-orbiting Phobos itself, before it failed.

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EW: A PERSONAL VIEW BY BRUCE MURRAY

Back in 1997, *Pathfinder* landed on Mars, looking for the debris from ancient floods. At the time I thought this was a dumb idea, because any such debris would be covered up by regolith. [Regolith is a layer of surface material fractured and pulverized by repeated impacts.] But there were the targeted sedimentary remnants from giant floods that occurred billions of years ago, lying on the surface as if they were produced yesterday. Now that's astonishing. An explanation at the time was "Well, there probably was a sand dune protecting the area that moved off later." But here comes *MGS* and especially Mike Malin's MOC images that show us many, many parts of the planet likewise with no regolith.

Along with the lack of regolith, Mars is deficient in small craters. It is as though something has been operating to either protect the surface or scrape it clean, but we don't know what that something is. And the explanation of protective sand dunes that come and go doesn't work for the whole planet. So what's the answer?

Allow me to mention indications of another broken paradigm. Because *MGS* suffered a solar panel problem, aerobraking maneuvers were unable to be performed as planned. An extra year was spent going from an eccentric, loose orbit to a tight circular orbit. During this period, the spacecraft came very close to Mars' surface—less than 150 kilometers [90 miles] above the surface instead of up higher, as originally intended. Why is this important? Well, mostly because the onboard magnetometer and electrometer obtained some intriguing data results.

The magnetometer measures how strong the magnetic field is and in which direction it appears to be pointing. The electrometer measures the direction in which the electrons, the charged particles, are coming into the system. The reason that's important is you perceive not only the magnetic field at the elevation you're measuring but also the electron path, so you can infer where the electrons came from and, to some extent, reconstruct the field down below. But this is only possible when you're below the ionosphere. Above the ionosphere, the electrons can't get through. The aerobraking maneuver brought the instruments below the ionosphere long enough to map the magnetic field.

The data were great—much better than anyone expected—but all of a sudden we discover there are huge anomalies on Mars' surface. We see crustal magnetism [magnetic fields from solid rocks in the crust; most of Earth's magnetic field originates much deeper and is due to molten rock in the core], originating in the upper, say 200 or 300 kilometers [120 to 190 miles], and it's bewildering. First of all, because the anomalies are so large—ten to a hundred times the size of crustal rock anomalies on the Earth. And on Mars we have no clue what causes them. Second, the anomalies are mainly in the southern hemisphere, not in the north. That's a clue to something if only we are smart enough to figure it out. And then there's Hellas—a huge basin, almost 2,000 kilometers [1,250 miles] across, with no anomalies. One interpretation is that Hellas is younger than the phenomena that created the anomalies. Perhaps when the Hellas basin formed, the shock and heat demagnetized the crust in that area. The problem is that Hellas has got to be close to 4 billion years old, meaning these darn anomalies have survived for a very long time. This is a major mystery.

TPR: How has Mars Orbiter Laser Altimeter [MOLA] data added to the new view of Mars?

BCM: What MOLA has done is equivalent to mapping the topography of all the land areas of the Earth to 1-meter precision [i.e., relative to a nearby point] and 10 meters absolute [i.e., accuracy of all data, for example, relative to a fixed point like the center of the Earth]. Plus, MOLA is always

In 1965 Mariner 4 *flew by Mars and captured 21 images, giving us our first close-up view of the Red Planet. Flying as close as 9,800 kilometers (6,000 miles),* Mariner 4 *revealed Mars to have a heavily cratered surface. The spacecraft took this image (number 11 of the 21) at approximately 12,500 kilometers (7,800 miles) above the surface of Mars. The image captures a part of the planet's Atlantis region riddled with impact craters, some as large as 120 kilometers (75 miles) in diameter.* *Image: JPL/NASA*

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own the "shadow of the valley of death," or whatever you want to call it, is that we were finally able to get good data, and lots of it. —*BCM* taking data, day and night, every orbit. So what results is an incredible set of data that are just beginning to be explored. We are using the topographic data at Caltech [the California Institute of Technology] right now to find new craters, believe it or not, that are not visible on the *Mariner*, *Viking*, or even the MOC wide-angle camera images.

What has been discovered? For one thing, the Hellas basin is much deeper than we thought. But if it's 4 billion years old, as we calculate, how could it have stayed empty so long? Valles Marineris is also deeper in places than we imagined.

But probably most surprising is that the north polar basin, which is a huge area, is not only, as had been expected, very low, but it's extremely smooth. So smooth, many people are saying, "Hey, there must have been a standing body of water here." Shorelines I'm not so sure of, but I do think this was the place where liquid water on Mars was directed and accumulated. The southern hemisphere is much higher than the north, and the ancient flood features that we see all point from south to north, so the destination of water must have been the north polar basins. So it's now pretty obvious there was a lot of water on Mars, though we still have no clear explanation for what happened to it or how it ever could have existed in the first place.

TPR: Do you believe it's possible that Mars had a warm, wet, maybe even Earth-like period?

BCM: I don't see any evidence that an Earth-like environment ever existed, at least not in the last 4 billion years. While there was a lot of water on the surface, I think it was ice covered. Here on Earth there are ice-covered lakes in the Antarctic, and the Arctic Ocean is ice covered much of the year. So ice-covered oceans or ice-covered bodies of water on Mars make a lot of sense. Whether there was any potential life habitat, who knows?

Since *Mariner 4* we've known that Mars has big craters that are very old, though they've not been eroded away entirely. They've got to be 3 to 4 billion years old, and the smaller ones look just like lunar craters, bowl-shaped with sharp edges. Meteor Crater in Arizona is only 20,000 years old, and it already has had a lake at the bottom and suffered eroded sides. But these craters on Mars look all fresh and new.

So the crater evidence says Mars was never Earth-like. But, on the other hand, you see these giant flood features, so clearly water was present at times. Personally, I think you resolve the dilemma by saying ice covered any standing water existing on Mars' surface. Now that still doesn't explain where the water went—there's not enough room up in the polar regions for all that water to exist there now as ice layers. So plenty of mystery remains.

TPR: What about the hematite that the Thermal Emission Spectrometer [TES] detected? [Hematite is a form of iron oxide that usually forms only when in contact with liquid water.] Isn't that an indication of a warmer, wetter period?

BCM: TES has had a hard time penetrating the atmosphere to pick out these very subtle mineral signatures on the surface. Remember, TES doesn't use reflected sunlight the way an ordinary spectrometer does—instead it uses emitted thermal radiation. It senses the thermal radiation and then tries to get a spectral [emission] signature from that. This is hard enough to do on the Moon, where you have no atmosphere. When you have a carbon dioxide atmosphere with dust and water vapor, it gets even more difficult. So the TES team has worked hard to construct atmospheric emission and transmission models. And they have found some things. For one, the dark areas, presumed to be lava, in the northern hemisphere are more silica-rich than places in the southern hemisphere that we think are also lava.

That's big news because, on Earth, you don't get things that silica-rich without plate tectonics, and we have strong evidence that plate tectonics never happened on

(continued on page 16)

Breaking Paradigms Is Hard To Do

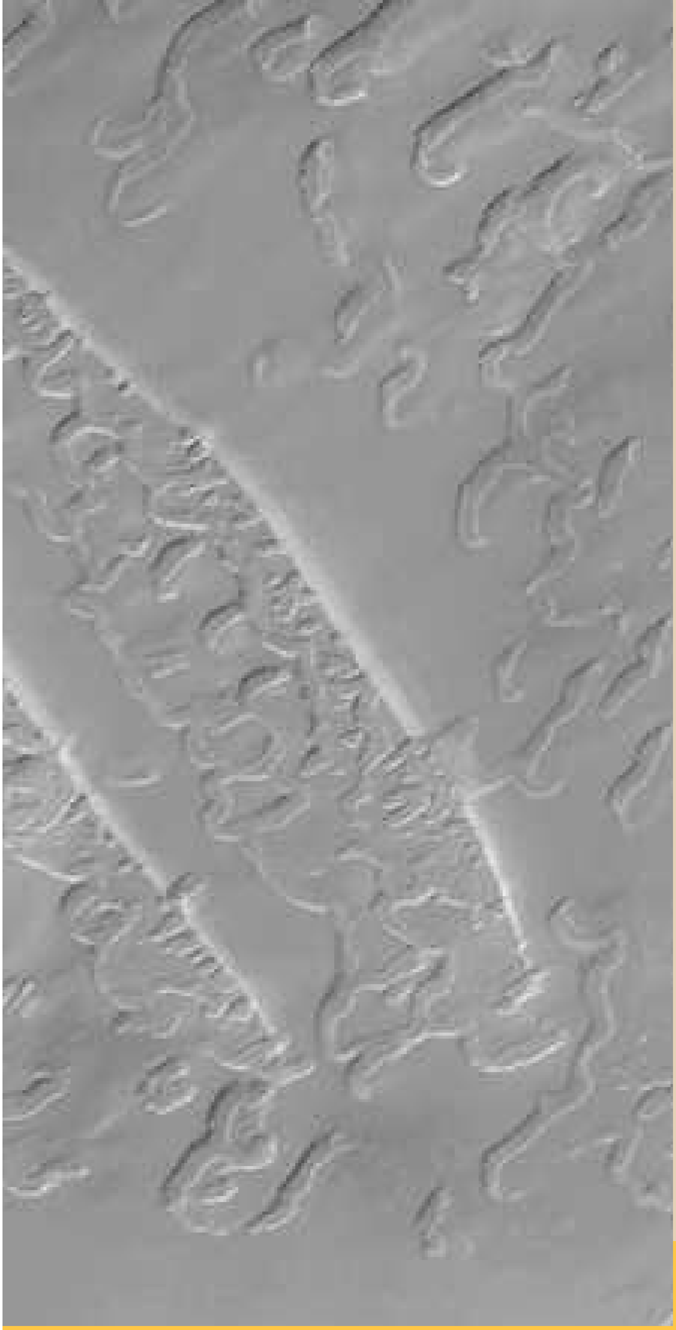
In 1955 I did my Ph.D. dissertation on the Lower Mississippian-Horton sedimentary layers in Nova Scotia. They include a rare sedimentary unit up there, an oil shale. There's no other unit like it in North America. But there is one at Spitzburgen in Norway and also one in Greenland, and I had read about them.

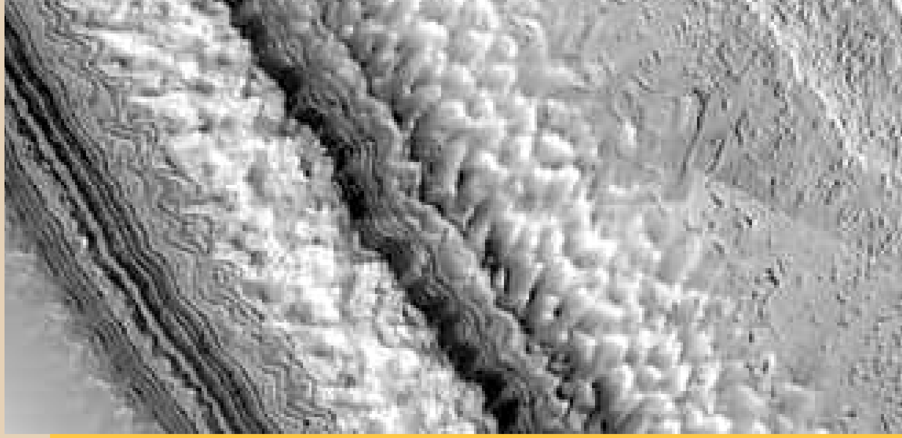
Then, while doing my fieldwork, I found a Ganoid fish fossil, which is like a sturgeon, with thick scales—an early, primitive kind of fish. Apparently it had an air-breathing bladder. It lived in water so foul that it had to surface periodically and gulp the air.

Remember, this was before continental drift was accepted. So I said to myself, there's no way this fish could have swum across the ocean, between Spitzburgen and Nova Scotia, yet the fossils were found in both places.

Other people had encountered similar evidence suggesting the continents had once been joined, going back to the German paleontologist [Alfred] Wegener. But my colleagues in geophysics at the Massachusetts Institute of Technology, where I was a graduate student in geology, questioned how a continent could "slide." They stated that continental drift could not happen, because too much friction would be generated at the base of the crust. Of course, we didn't know then about the low-velocity layer, a peculiar situation that now helps explain the phenomenon. Most important, this was shortly before magnetic "striping" was found, which finally made people realize the seafloor was expanding.

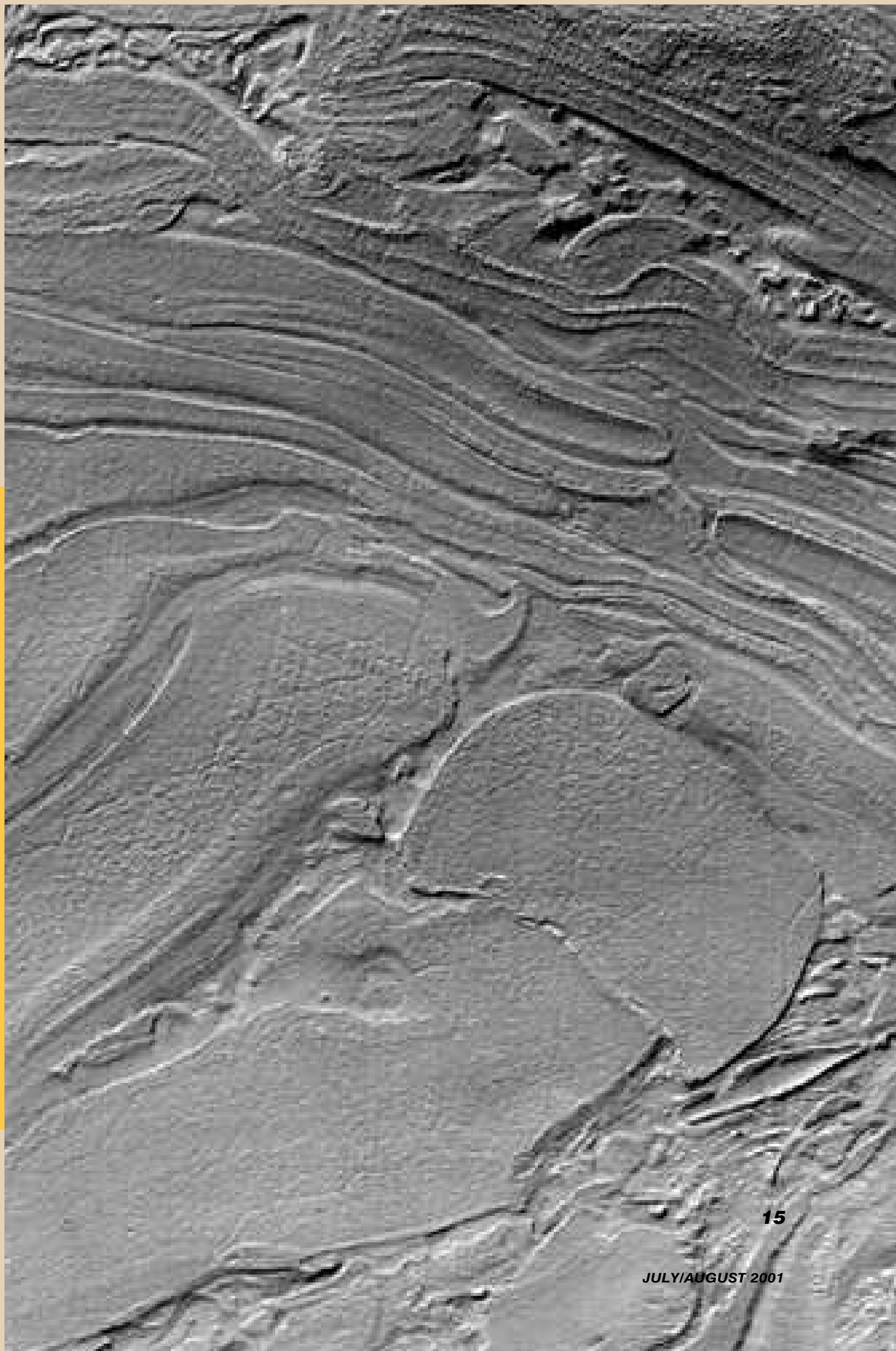
Still, I had the evidence right in front of me. I had asked myself the right question, but I backed away from it because it challenged the conventional paradigm. That's how it is with Mars. A lot of paradigms are still going unchallenged. Some that we now know are wrong have been broken, but there are other problems we haven't yet been imaginative enough to puzzle out. That's what makes for a very exciting time, when we move from the broken paradigm phase to the new paradigm phase.
—BCM





This image is a mosaic of many individual MOC images taken near the central region of the permanent—or residual—south polar cap in October 1999. The layers exposed in the south polar residual cap are thought to contain detailed records of Mars' climate history over the last 100 million years. The materials that constitute the south polar layers may include frozen carbon dioxide, water ice, and fine dust. Because the south polar terrains are so strange and new to human eyes, no one (yet) has adequately explained what is on view. The mosaic covers an area about 10 kilometers (6 miles) wide by 4 kilometers (2.5 miles) long, with sunlight illuminating from the left.

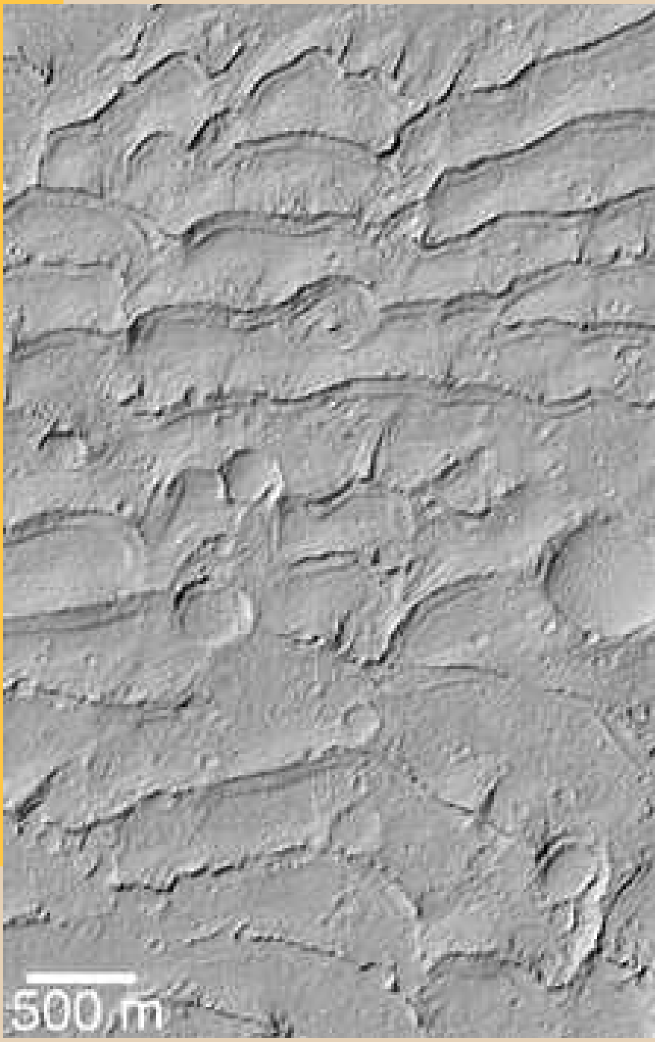
Image: NASA/JPL/Malin Space Science Systems/USGS Flagstaff



Above: The large pits, troughs, and "Swiss cheese" look of Mars' south polar residual cap appear to have formed in the upper four or five layers of the polar material. Some earlier Mars Global Surveyor *Mars Orbiter Camera (MOC) images of this same terrain show examples of older, pitted and eroded layers previously buried and now being exhumed. The example shown here includes two narrow diagonal slopes that trend from upper left to lower right. Along the bottoms of these slopes, an underlying layer shows many more pits and troughs than in the upper layer. Very likely the lower layer produced these features before being covered by the upper layer, suggesting that those of the south polar cap are very old and formed over long time scales. The image was taken on August 29, 1999 during Mars' southern spring and covers an area 3 kilometers (2 miles) wide by 5 kilometers (3 miles) long.*

Right: Sometimes MOC images show bizarre-looking things. Take this example, one of a suite of pictures of northwestern Hellas planitia. It appears to show a jumble of plates or layers exposed at the surface but subsequently covered by a thin mantle to lend the scene a uniform brightness. What are these materials? Perhaps time and careful study will tell. The image, acquired in late October 2000, covers an area 3 by 4 kilometers (1.8 by 2.5 miles).

Images: NASA/JPL/Malin Space Science Systems



Left: High-resolution MOC images have revealed small cone-shaped structures on lava flows in the northern hemisphere of the Red Planet. The most likely interpretation is that they are volcanic features known as* pseudocraters *or* rootless cones. *Pseudocraters form by explosions resulting from the interaction of molten lava with a water-rich surface. The possibility that lava and water or ice have interacted to create such features indicates that Mars has had a diverse and complex past, which researchers are only just beginning to understand. This high-resolution image shows several possible pseudocraters forming atop a rough-textured lava plain. The image covers an area 3 kilometers (2 miles) across.

Image: NASA/JPL/Malin Space Science Systems and University of Arizona

Right: This MOC image shows close-up views of a sand dune field first detected by* Viking *orbiters in the late 1970s. The dune field pictured here is unlike any other seen on Mars so far—notice all the impact craters! Apparently once the dunes hardened, they were exposed long enough for many small impact craters to form. The dunes are therefore quite ancient. One might even call this a "fossil" dune field.

Image: NASA/JPL/Malin Space Science Systems

(continued from page 14)

Mars. So some other process has been involved on Mars, which, once again, we have no idea about, some unearthly process that leads to geological and chemical differentiation. Another crustal mystery that we had no way of anticipating.

But getting back to hematite—the crystalline form of rust—it forms on Earth all the time, on ships, in pipes, and so on. It results from the natural interaction between any kind of iron-rich material, over time, with water and oxygen. What's surprising is to get a report of detection on Mars, and not just a little, but 300 kilometers' worth over a flat, oval-shaped area. What could possibly cause this? Did it precipitate out of a lake?

The detection of hematite is the only evidence we have on Mars of what we would call chemical weathering. After all our hopes for finding clays or calcium carbonates [which on Earth are usually formed in water], what we find instead is unweathered feldspar and pyroxene. Feldspar, which is a very common igneous mineral on Earth, weathers very quickly. You can get a piece of feldspar from a Hawaiian lava flow, and although it may only be a few decades old, you can already see the weathering. Add the combination of water and warmth, and boom, you've got clay. It happens in situ right there on the surface.

On Mars, what is being reported from the TES experiment is feldspar, not clay. It's astounding that you would get a signature that shows feldspar with no weathering. This stuff is 2 billion years old. That means there has been no significant water moisture available. So the same instrument, TES, detected hematite, which needs moisture to form, and also feldspar, which wouldn't exist if moisture were present. While there are those who still argue for a warm, wet period on Mars, to me, it's another mystery, another broken paradigm.

TPR: Describe your view of the future of Mars exploration.

BCM: I liken exploring Mars to the historic exploration of the Antarctic—however, the South Pole is a far nicer place to be than any place on Mars. Exploration is of course geographic, and it's about discovering things we didn't know were there. In my view, the first exploration of Mars was telescopic, and that, in Antarctic thinking, would be at best like Captain [James] Cook skirting around the edge of the icy continent and recognizing there was a land mass out there. The next phase began with *Mariner 4*, the start of very primitive robotic exploration, and continued on through *MGS* and the next decade of missions. This compares to the whalers reaching the

Antarctic shore for the first time, the first people building a hut at McMurdo station, and then from there organizing expeditions to the interior. They did not initially have map coverage of the whole place. It wasn't until after World War II that the United States possessed affordable technology to fly over Antarctica and survey the continent from the air. Now it's done from satellites.

The first human occupancy in Antarctica followed in 1976. So, in the case of Antarctica, you can probably count 80 to 85 years of exploration before human occupancy begins. If you start with *Mariner 4* back in 1965 as the beginning of Mars exploration, by scale, it wouldn't surprise me if it were at least 2030 before humans reach the surface of the planet.

So this endeavor, in which we are all involved, and which I have allegiance to, started before I came on the scene and will continue long after I leave. I think historians writing in 2201 will probably characterize the exploration of Mars as an effort that started in the 1960s, driven by Cold War rivalry, which developed into progressively greater robotic missions and landers, then established outposts—robotic first, and eventually a permanent human base.

Right now, in 2001, the best thing we could do is more real exploration—to maximize the chance to find things we couldn't imagine. That, in the case of Mars, means something like a Discovery Program for Mars. NASA just announced what is being called the *Scout* mission, planned for 2007. Already roughly 50 different groups have submitted study proposals, only one of which, unfortunately, will be chosen to fly. And currently there are no plans for another *Scout* mission, ever.

The good news is that, until the failure of *Mars Polar Lander* in 1999, there were no plans for any kind of exploratory mission like *Scout* at all. The overriding thrust was toward sample return and technological development. Now the balance has shifted. But I was hoping it would shift more. I was hoping there would be one *Scout* mission every other launch opportunity—that is, every four years indefinitely. But at this point we know of only one shot. Now it's apparent from the number of groups that have shown interest in *Scout* there's a mismatch between scientific interest and NASA flight availability.

TPR: You mentioned the idea of Mars Outposts, which we featured in our last issue. Would you talk a little about your view of an outpost program?

BCM: An outpost phase in exploring Mars would alleviate the disconnect between those who want a human mission and those who consider that a threat to robotic exploration. We need both. We need the dream of human exploration and we need the practical manifestation of that dream. My view of exploring Mars is not Tom Paine's [former administrator of NASA and Planetary Society Board memberuntil his death in 1991]—I don't see humans in space suits lowering themselves by rope down the sides of Valles Marineris. I see an advanced symbiosis of humans and machines. The outpost plan permits that to happen.

This goes back to my point that we're in an exploratory process very much paralleling that of the Antarctic. What's different is not the human factor. There's no astronaut any more resourceful or braver now than was Ernest Shackleton. The machines are what are getting better—especially information technology. That's what's going to make the effort affordable, but it requires that future human explorers of Mars fall in love with machines.

Although some people think the dark features in this image look like vegetation, they are really sand dunes in the polar regions that are beginning to defrost after a long, cold winter. Because the Martian air pressure is very low, ice on Mars does not become liquid when it warms. Instead, ice sublimes—that is, it changes directly from solid to gas. The process of sublimation is not uniform everywhere on a dune but begins in small spots and then, over several months, spreads until the entire dune is spotted like a leopard. The dark sand underneath the ice probably absorbs sunlight, thereby accelerating defrosting. In this MOC image, taken of the south polar region of Mars on July 21, 1999, the bright, smooth surfaces dotted with occasional nearly triangular dark spots are frost-covered sand dunes.

Image: NASA/JPL/Malin Space Science Systems

TPR: Did we miss anything? Any more broken paradigms come to mind?

BCM: I've lost track of how many broken paradigms I've discussed here! A lot. Anyway, with *MGS*, we have enormously more data, and better data, and better coverage than we've ever had, and yet we have less knowledge. Now how can that be?

It's because the knowledge we thought we had was wrong. We were deceived, and I am guilty as charged. I'm probably a coconspirator in the process of misjudging what we've been seeing. I didn't grasp how complex the processes are that operate on Mars—I was thinking in too simplistic terms. I was, however, in good company.

MGS is an incredibly elegant mission, it really is. The data set from *MGS* will probably be *the* data set on Mars for a full 30 years. But NASA's current Mars program is based on objectives that were in place before *MGS*.

We are very early in the exploratory process, much earlier than we even realized. That means exploration is the thing we should be doing, and a lot more of it. ■

Merton Davies, Space Pioneer, Warmly Remembered

by Bruce Murray

A colleague snapped this photo of Mert Davies and friend in 1967. Mert was part of a five-person team appointed to represent the United States in an inspection of Antarctic stations operated by parties to the Antarctic Treaty. The treaty prohibits use of the continent for anything other than peaceful endeavors.
Photo: Courtesy of M. Randel Davies

I had the good fortune to start collaborating with this tall, lanky RAND staff member in 1963. Mert Davies then had the same gentle smile (really a barely suppressed giggle) that remains a luminous residual image in the memories of so many who knew him. Mert passed away unexpectedly on April 17 at age 83 due to complications from surgery.

Planetary exploration was just beginning back in '63, but Mert was already deeply interested in it and remarkably insightful about space imaging. He soaked up from me every detail about the Jet Propulsion Laboratory's first attempt to fly to Mars a tiny, primitive spacecraft carrying the world's first digital camera. Dubbed *Mariner 4*, that spacecraft in July 1965 would ultimately shatter expectations of an Earth-like Mars.

Wisely, I recruited Mert for the television team tracking the follow-on Mars flyby missions, *Mariners 6* and *7*. He then went on to an unparalleled career in planetary exploration. Mert served as a key member of the imaging teams of *Mariners 6*, *7*, and *9* to Mars; *Mariner 10* to Mercury; *Voyagers 1* and *2* to the outer planets; *Galileo* to Jupiter; *Cassini* to Saturn; *NEAR Shoemaker* to Eros; and *Magellan* to Venus.

It was Mert who invented the photogrammetric control point technique that provided the basic framework for all planetary surface mapping and coordinates systems. His fundamental contributions to planetary mapping led to long service on the International Astronomical Union committees that named many of the surface features of Mercury, Venus, Mars, and the satellites of Jupiter. In 1998 he was elected a Fellow of the American Geophysical Union.

But it was as a gentle, unassuming mentor that so many of us knew Mert. Hardly a member of the exploratory missions to which he contributed failed to benefit—professionally from Mert's persistent efforts to squeeze out intriguing clues about the shapes and motions of planets and their satellites, personally from his generous friendship. I think he was privately very pleased to be the only person in the world to "visit" robotically all the planets except Pluto, which was not to be explored in his lifetime.

What I learned only gradually through our decades of working together was that Mert had already achieved near-legendary status in the early military reconnaissance satellite program—that is, even before he left the classified world behind to pursue the dream of planetary exploration. He obtained his degree in mathematics from Stanford in 1938, just in time to be swept up in US World War II aviation development with Douglas Aircraft. Then in 1947 he became one of the first employees of the RAND Corporation. Participating in pioneering studies leading to CORONA, the world's first successful reconnaissance satellite, he was a member of the farsighted RAND team highlighting the potential of space well before October 1957, when *Sputnik* transformed that potential into reality. By 1958, Mert had written a RAND report on how to take pictures of the Moon from a spin-stabilized spacecraft.

In October 1962, at about the time I was making my first observations from the 200-inch (5-meter) telescope on Palomar Mountain, Mert was deep within the Pentagon helping interpret alarming U-2 images of new Cuban missile sites. In 1964 he was awarded a patent for a space reconnaissance camera utilizing the spin/pan approach for wide-angle mapping. In 1966 he won the George W. Goddard Award for distinguished contributions to photo reconnaissance. In 1999 he was honored as one of the founders of national reconnaissance by the National Reconnaissance Office in Washington, DC.

Finally, Mert was an early member of The Planetary Society, joining in 1985. Graciously, he'd answer questions from the editorial staff, who'd call him at the drop of a hat about anything to do with geodesy and planetary mapping. He served as a consultant on the first Explorer's Guide to Mars poster, that very popular Society product, and was a longtime and generous donor to our special appeals.

That he could "morph" from one extraordinary career to another so effortlessly testifies to a personal flexibility that belied Mert's conservative dress and demeanor. Indeed, he proved remarkably innovative and adaptive in life as well as in science. Universally admired, he remains a sterling role model for today's would-be explorers.

Truly, Mert Davies was a special person contributing in a special way to the extraordinary times in which he found himself. He will be greatly missed.

Bruce Murray is president of The Planetary Society.

World Watch

by Louis D. Friedman

Washington, DC—NASA has selected two proposals for flying a mission to Pluto, with launch as early as 2004. To implement these proposals would require that Congress add significant funding for the upcoming fiscal year, which begins October 1, since the US administration has taken a Pluto mission out of its proposed budget.

The Pluto mission was effectively canceled when the Bush administration failed to request its funding in the budget the president submitted to Congress. However, following pressure from The Planetary Society and others, congressional committees overseeing NASA's budget ordered that, until Congress could consider the 2002 budget this summer, the agency take no action that would preclude carrying out a mission in the 2004 time frame. NASA then proceeded with the competition to select a proposal.

After evaluating the contenders, NASA selected two winners for detailed feasibility studies. Both winning teams were led by scientists from Boulder, Colorado: Alan Stern of the Southwest Research Institute and Larry Esposito of the University of Colorado. Stern's team includes the Applied Physics Laboratory (APL) of Johns Hopkins University, which would develop the spacecraft; Esposito's spacecraft would be developed by the Jet Propulsion Laboratory (JPL) and the Lockheed Martin Company.

The plan is to complete the feasibility studies in three months and then, if money is appropriated by Congress, select one of the two teams for project implementation. The *if* here is a big one—because the money would have to be added to a budget greatly constrained by Congress' passage of a large tax cut.

Furthermore, to overcome the Bush administration's objection to the project, NASA Administrator Dan Goldin made it clear that the money would have to be provided in such a way as to not impinge on existing programs or other priorities. The congressional practice of "earmarking"—directing that specific projects be carried out without allocating funds for them—often requires severe cuts in other priority programs. Goldin wishes to avoid such an outcome in the case of Pluto.

The Pluto mission has been in jeopardy for the past year, since JPL's initial plan for the *Pluto-Kuiper Express* was deemed too expensive. The Planetary Society has been leading advocacy efforts for a Pluto mission.

Thousands of Society members have written Congress to show their support for the mission. We've also been active behind the scenes lobbying congressional committees and individual offices in Congress.

Such efforts have helped keep the mission alive (at least as I write this column), but the difficulty of adding to the NASA budget a mission opposed by the administration should not be underestimated. We will post the latest information about the mission and any political action on our website, *planetary.org*.

Pasadena, CA—NASA has presented basic plans for its next three Mars launch opportunities. In 2003 and 2007 the agency will send lander/rover missions, and a very high resolution orbiter will fly in 2005. For the 2007 opportunity, NASA has provided for one additional, small but novel Mars mission, called *Scout*, to be developed by a scientist-led team. Hundreds of scientists competed to be part of NASA's Mars exploration efforts through this mission, and in June, NASA announced study awards to 10 contenders (see our website, *planetary.org*, for details on the 10 proposals).

Mars will, we hope, be a busy place—although experience teaches us to be cautious. Japan's *Nozomi* orbiter, currently headed to the Red Planet, is scheduled to arrive there in December 2003. Europe is developing the *Mars Express* orbiter with the *Beagle 2* lander, to launch in 2003. NASA is working on two Mars Rovers that will launch the same year. In 2005, NASA plans to send an orbiter with five to ten times the resolution capability of the already impressive Mars Orbiter Camera on *Mars Global Surveyor*.

In 2007 the French and Italian space agencies will begin their participation in the grand international launch plan leading to returning a sample from Mars. Both nations are developing orbiters: the French spacecraft to capture a sample launched from the Mars surface and send it on to Earth, the Italian orbiter to serve as a communications node for spacecraft on and around Mars. Additionally, in a surprising and welcome development, Canada has said it intends to partner with other spacefaring nations for a Mars exploration mission in 2007 or 2009.

Also, France plans to launch *NetLander*, a set of four small landers designed to establish a seismology and meteorology network on Mars. Each lander will carry a Mars Microphone, courtesy of The Planetary Society. (Our first Mars Microphone was lost with the *Mars Polar Lander* mission.)

But mission plans, as we have learned, are subject to real-world experience—so we all should stay alert and involved, watching the actual data from Mars and the way they affect our planning.

Louis D. Friedman is executive director of The Planetary Society.

The Planetary Society Goes to Pluto?

The Planetary Society was a member of one of the winning team proposals. We will not cite which one, as we wish to emphasize that although we frequently join in proposals for planetary missions, our official position is one of neutrality and nonexclusivity. Generally, we will work with anyone with a serious proposal. No matter how or where a project is implemented, we will cooperate with the team carrying out the mission, to inspire and involve the public.

Furthermore, we will not accept government or aerospace industry funding for any of our projects. This allows us to be independent advocates, with no issues of agency priorities or funding clouding our advocacy. We are able to carry out this policy because of the tremendous support of our members. —*LDF*

Questions and Answers

The February 2001* National Geographic *map of Mars makes me wonder how they decide where the prime meridian on other planets should be. Is there a commission that determines such things, or is the decision completely arbitrary?

What about gaseous bodies like the four largest planets or even the Sun, where there is no landmark to define as longitude zero?

—Carl O. Gragg II,
San Jose, California

The prime meridian of planetary bodies other than Earth is defined by international agreement through the Working Group on Cartographic Coordinates and Rotational Elements of the Planets and Satellites. This is a joint group of the International Astronomical Union and the International Association of Geodesy. The prime meridian (that is, the 0-degree meridian) is usually defined by a particular feature, such as a small crater, on planetary bodies with a solid surface.

The choice of the feature is essentially arbitrary. For moons that are tidally locked to their primary planet (like Jupiter's Galilean satellites or Earth's Moon), the prime meridian usually faces the primary planet, and a feature is selected on or near that meridian.

In the case of Mars, a dark marking now known as Meridiani Sinus was (arbitrarily) chosen in the early 19th century to define 0-degree longitude. The positions of objects determined during later telescopic observations were referenced to that feature. When *Mariner 9* was able to take close-up photographs of Mars in the early 1970s, it was possible to determine the coordinates of surface features with much higher accuracy. At that time, while matching the 0-degree longitude system of the old telescopic method as much as possible, the center of a small (500-meter-wide) crater named Airy-0 was chosen to define Mars' prime meridian. Using a single object (a crater in this case) to make such a definition corresponds to the situation in the late 19th and early 20th centuries, when Earth's prime meridian was defined by the position of the Airy transit circle in Greenwich, England.

For planets with no solid surface, such as Jupiter and Saturn, or for the Sun, planetary coordinates are defined in two possible ways. One method entails first determining an approximate rotation rate by timing the passage of some reasonably long-lived atmospheric feature. This feature is then assigned an arbitrary longitude value, and the rotation rate is assumed constant. Using such a starting point and rotation rate allows longitude to be defined anywhere on the body in the future, even if the atmospheric features slowly drift away from their original coordinates.

A second method of defining coordinates is by timing variations in the radio emission from a particular body, thus determining the rotation rate of its magnetic field and core. Again, selecting an arbitrary starting point in time and assuming the derived rotation rate to be constant allows longitude to be defined in the future. Of course, atmospheric features would also move relative to such a system.

Earth's case is special since longitude here is no longer defined by a single surface feature (like the Airy transit circle) but by a weighted average of the positions of modern instruments that constantly measure our planet's orientation and its position in space. These instruments include networks of radio telescopes, satellite and lunar laser ranging systems, and Global Positioning System satellite receivers. The International Earth Rotation Service based in Paris uses data from these instruments to define latitude and longitude on Earth, as well as coordinates in the sky and the difference between them, which is the orientation of Earth in space.

In the future we hope that a permanent network of landers and/or observatories will be operating on the surface of Mars. At that time the coordinates there may be redefined based on observations from those instruments.

—BRENT ARCHINAL,
United States Geological Survey

I think I remember reading that it actually rains diamonds on Neptune. Is that true? How?

—Dave Habershaw,
Warwick, Rhode Island

Yes, we think this is probably true, at least early in the planet's history and maybe still now. What we do know is that Neptune and Uranus contain methane, based on the spectra of their atmospheres as well as their densities and gravitational pull. Our observations suggest that each consists of a very deep, hot and dense layer of methane, water, and ammonia, which is beneath a thick atmosphere consisting mostly of hydrogen and helium. The conditions deep inside these planets are extreme: high pressures due to the weight of overlying material and high temperatures due to the gravitational energy of formation.

We can re-create such conditions in the laboratory by squeezing materials to pressures up to millions of times greater than Earth's atmosphere, in a device called a diamond-anvil cell. Basically, we apply mechanical pressure to a very small sample of a material placed between two diamonds. Keeping the sample under these high pressures, we can heat it to 2,000 to 5,000 degrees Kelvin (about 3,000 to 8,000 degrees Fahrenheit) using an infrared laser.

When we subject methane (CH_4) to such extreme conditions in the laboratory, the CH_4 molecule breaks down, and pure carbon is formed as diamond, which is stable at high pressures and temperatures. Such results, predicted more than 20 years ago, were recently confirmed by our group at Berkeley, and others.

Diamonds are solid at these conditions and much denser than the surrounding liquid methane, water, and ammonia. If the reaction we've observed in the lab occurs in the methane making up the giant planets, the resulting diamonds would drop like rain or hail, or maybe more like sand sinking to the ocean floor.

Unfortunately, we don't yet have a very good sense of the planetary scale for this reaction. Has the reaction started yet? How quickly would it proceed? Was it completed long ago, leaving a diamond layer at the core? Would pebble- or boulder-size diamonds be formed? Is there any chemical or dynamic factor that would encourage or inhibit the diamond rain? We guess that the downward sinking of carbon may take place in a manner similar to the sinking of iron that formed the Earth's core, but we cannot be sure.

We expect the interiors of planets the size of Neptune and Uranus may be chemically and physically complex. It is possible that many other molecules may be formed from the basic building blocks of carbon, nitrogen, oxygen, and hydrogen. We still have a lot to learn about these icy giant planets.

—LAURA ROBIN BENEDETTI, *University of California, Berkeley*

Factinos

A team of scientists from Switzerland and Spain has uncovered convincing evidence that stars may eat their own planets. Using the 8.2-meter KUEYEN telescope on Chile's Paranal mountain, the researchers detected the telltale presence of the rare isotope lithium-6 in HD 82943. This star, which is slightly hotter and larger than our Sun, is known to have two giant planets. Garik Israelian and Rafael Rebolo, of Spain's Instituto de Astrofísica de Canarias, and Nuno Santos and Michel Mayor, of Switzerland's Geneva Observatory, say that any primordial lithium-6 would not have survived the early evolutionary stages of a metal-rich, solar-type star, meaning it must have been added later. The scientists' detailed spectral analysis of HD 82943 indicates that the star may have engulfed one (or more) additional planets, whose lithium-6 was then deposited in the star's atmosphere.

"Lithium-6 is extremely fragile," the scientists explain, and is destroyed by temperatures of "only 2 million degrees" Celsius (about 3.6 million degrees Fahrenheit)—compared with the fusion of hydrogen to helium, which takes place at 10 million degrees Celsius (about 18 million degrees Fahrenheit). But unlike stars, planets never reach temperatures high enough to burn up their initial content of lithium-6. Consequently, if a planet falls into a solar-type star like HD 82943, its lithium-6 will be preserved in the star's upper, cooler regions for some time.

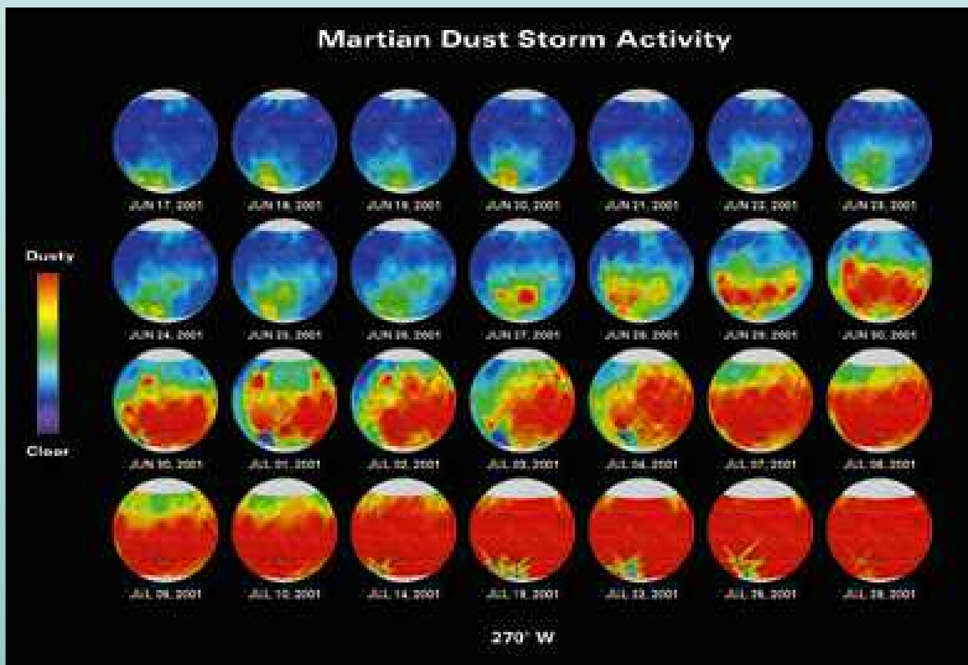
—from the European Southern Observatory

A region of "increased dust abundance," first detected by the *Mars Global Surveyor*'s (*MGS*'s) Thermal Emission Spectrometer (TES) on June 15, 2001 in Mars' Hellas basin, has grown (at the time of this writing) into a global storm of monumental proportions. This is the biggest, most intense dust storm observed during *MGS*'s mission. Also, it has come along early in the season. In the past an early-occurring dust storm on Mars was followed by more storms later in the year. TES scientists expect that this current storm will continue to grow, perhaps becoming a tempest similar in scale to those seen by *Mariner 9* and *Viking*.

TES has been mapping Mars' temperature and the amount of dust in its atmosphere for over a year (about two Earth years). These data are then used to create daily global images, or maps, of the planet's surface temperature and dust abundance (see image below). As the dust storm expanded, Mars' atmosphere has increased by more than 20 degrees Celsius (68 degrees Fahrenheit) over prestorm levels. The warming in the planet's southern hemisphere is due to direct heating of the dust as it absorbs sunlight.

To see moving images of the growing storm, go to *http://tes.la.asu.edu*.

—from Arizona State University



These globes depict the first month of Mars' recent dust storm. What started out as a couple of specks (see the color bar at left) in images of the Hellas basin on June 17, 2001 grew into a raging, planetwide storm by July 21.

To produce the globes, data from the Thermal Emission Spectrometer on* Mars Global Surveyor *(MGS) were colorized and draped over a shaded-relief representation of the topographic map derived from* MGS' *Mars Orbiter Laser Altimeter data.

Image: Arizona State University/NASA

Society News

New Board Member and Advisers Announced

The Society is delighted and honored that Maria Zuber of the Massachusetts Institute of Technology has joined our Board of Directors. Zuber is a planetary scientist with notable achievements on *Mars Global Surveyor* (*MGS*) and the *Near Earth Asteroid Rendezvous*. On *MGS* she led the laser altimeter team that produced topographic maps of the Martian surface. In addition, Zuber was a member of the blue-ribbon committee appointed by NASA Administrator Dan Goldin to investigate the failures of the *Mars Climate Orbiter* and *Mars Polar Lander*.

We are also pleased to announce three recent additions to the Advisory Council and a new Advisory Council Chair.

New to the Council is space artist, writer, and producer Jon Lomberg. Lomberg collaborated with Carl Sagan on *Cosmos* and other projects. A longtime friend of the Society, Lomberg designed our original logo and led the production of the *Visions of Mars* CD.

Risto Pellinen of the Finnish Meteorological Institute is another addition to the Council. Pellinen, a leader in Mars exploration, spearheaded the development of the small Mars lander that was to have flown on *Mars '96*. He works closely with European, Russian, and American space programs and has chaired space science advisory committees for the European Space Agency.

Kim Stanley Robinson, author of the noted trilogy *Red Mars*, *Green Mars*, *Blue Mars*, has also joined the Advisory Council. His work has garnered many awards, including the Nebula, Asimov, and Hugo Awards.

John Logsdon's term as Advisory Council Chair has ended, although he remains on the Board of Directors. Board member Christopher P. McKay has now assumed the position of Advisory Council Chair. McKay, a NASA scientist, is a leading astrobiologist with field experience from Antarctica to Siberia. He has authored theoretical papers on topics ranging from terrestrial planet Martian analogs to methods of terraforming Mars.
—Louis D. Friedman, Executive Director

SETI Construction Update

At the Oak Ridge Observatory in Massachusetts, work is proceeding on the new dedicated Optical SETI observatory, funded by The Planetary Society. Much has happened since the December 2000 groundbreaking.

Footings were put in place in February, the foundation was poured in March, and a steel frame went up in April. A movable roof on rollers was hoisted atop the frame in May, then taken down and reinstalled with an improved set of rollers in June. Meanwhile, wooden walls have sprung up, complete with windows and a door leading to a control room. Soon the physical structure will be complete and ready to receive the 72-inch (180-centimeter) telescope, which was built separately.

According to project director Paul Horowitz, the telescope will be set in place sometime this summer, and the rest of the year will be devoted to installing the electronic equipment. If all goes smoothly, the observatory will see "first light" early in 2002.

You can see pictures and follow the progress of the project on the SETI section of our website, *planetary.org*.

Meanwhile, not far away, the 84-foot (25-meter) radio telescope used in the Billion Channel Extraterrestrial Assay (BETA) is gearing up to resume operations. The giant dish suffered serious damage in a 1999 storm that broke its main shaft and left it out of commission.

Repairing the half-century-old mechanism turned out to be a real challenge. It seems that when the radio telescope was originally built in 1954, it was constructed around its operating mechanism. The motors, gearboxes, clutches, and brakes were never designed to be removed but instead were meant to remain in place for the lifetime of the dish. In order to extract the broken gearbox, which weighs over a ton, contractors had to break through four existing floors and lower the mechanism down through the gaping hole.

This was done in July of 2000, and the gearbox spent the next four months being rebuilt at Cone Gear Inc. in Michigan. It was shipped back in November, newly painted bright blue, and is now installed back inside the dish structure.

Much work, however, remains to be done, not the least of which is repairing the four broken floors. Horowitz estimates it will be early in 2002 before BETA is back online, scanning the sky for a signal from an alien civilization.

Once all the construction and repair work has been completed, Oak Ridge will be distinguished as the only research center in the world with three ongoing SETI projects: BETA, the new optical SETI sky survey, and the targeted optical SETI search, all three supported by The Planetary Society. If someone is hailing us from the vastness of space, the SETI group at Oak Ridge will be well placed to hear that distant call. *—Amir Alexander, Web Editor*

Thank You

We would like to gratefully acknowledge two recent bequests. Jonathan Kamin, a charter member of The Planetary Society, was particularly interested in Mars exploration. Robert Gibson had a lifelong fascination with space. We appreciate the gifts in their name.

Over the years, bequests have allowed The Planetary Society to fund special projects and pay for much-needed equipment. If you would like information about making a bequest to the Society, call Lu Coffing at 626-793-5100 or e-mail her at *lu.coffing@planetary.org.*
—Lu Coffing, Financial Manager

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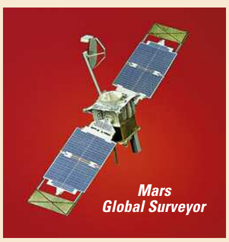

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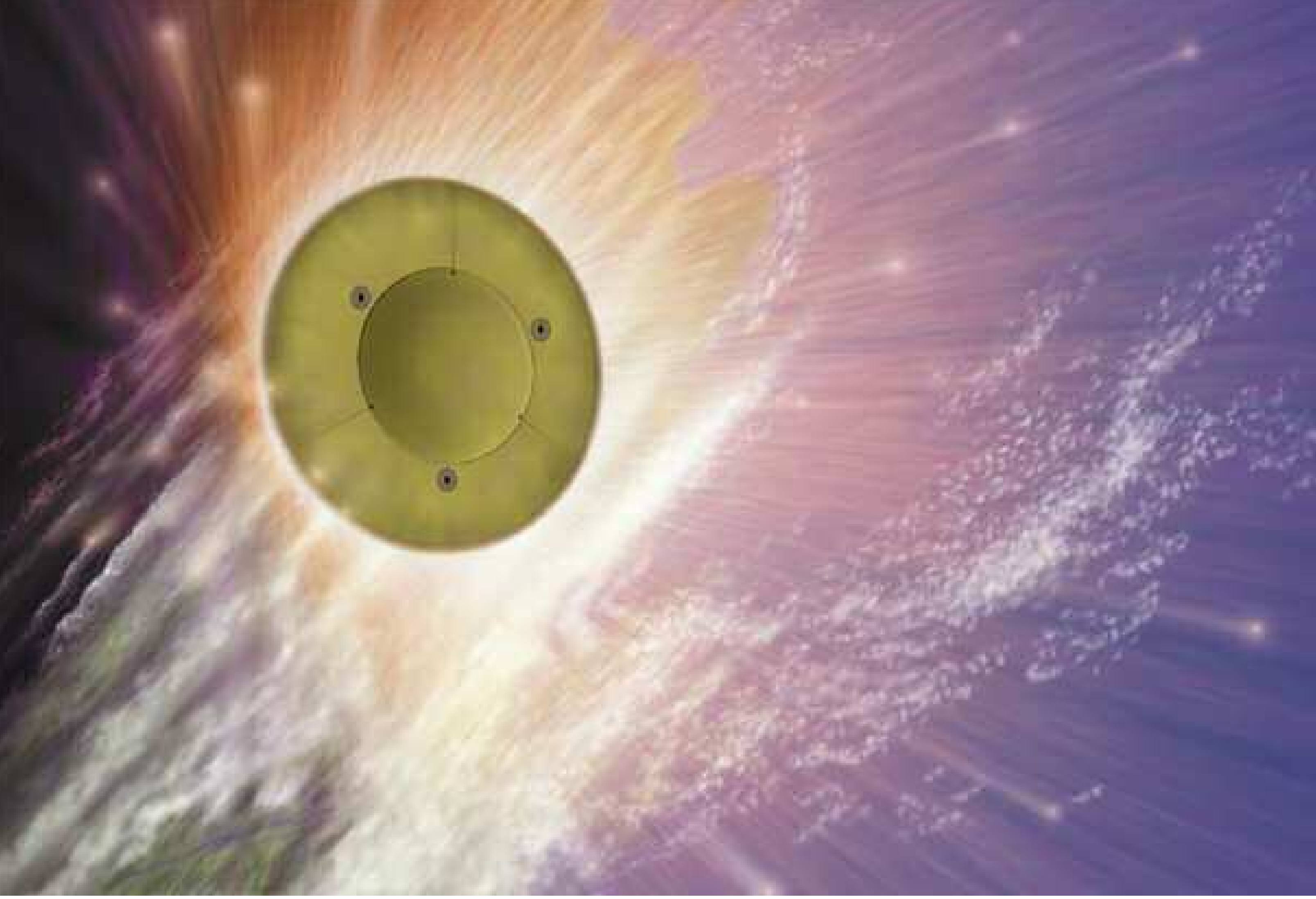

In *Precious Cargo* an aeroshell bringing the first samples from Mars streaks through Earth's atmosphere. The lightweight system has no thrusters to slow its entry, relying instead on a carefully planned entry trajectory and shock-absorbent housing unit to cushion the impact of landing. Perhaps, with fresh pieces of the Red Planet in hand, we can begin to solve the jigsaw puzzle that is Mars.

Pat Rawlings strives to make his space scenes as accurate as possible. After consulting with experts around the country, he uses hand-built and computer models, topographical maps, and family vacation and space photos to create his work. Rawlings lives and works in Houston, Texas.

THE PLANETARY SOCIETY
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