The PLANETARY REPORT

Volume XXIV Number 2 March/April 2004

Mars' Watery Past

A PUBLICATION OF THE PLANETARY SOCIETY

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From The Editor

Next year, The Planetary Society will celebrate its 25th anniversary. Over that quarter century, we've witnessed and celebrated many stupendous missions of discovery throughout our solar system. We've also experienced long years of drought, when no new spacecraft were launched and the future of planetary exploration itself was sometimes in doubt.

This is not one of those years. Right now there are five spacecraft exploring Mars. *Stardust* is on its way back to Earth with samples of a comet. In May, *MESSENGER* is scheduled to launch to Mercury. In June, *Cassini-Huygens* will reach Saturn. In September, *Genesis* will return samples of the solar wind to Earth.

Finally, if our schedule holds, this fall *Cosmos 1* will become the first solar sail and the first space mission flown by a membership organization.

This extraordinary roster of missions is being flown by NASA and ESA with the cooperation of a host of nations (not to mention The Planetary Society). This flowering of scientific discovery is due, in part, to the great public support for space exploration demonstrated over and over again by our members.

In a very real sense, over the past 25 years you have helped keep the dream of exploration alive. We have a lot to celebrate—and even more to look forward to.

—Charlene M. Anderson

On the Cover:

This false-color composite image, taken by *Opportunity* in a region close to its landing site dubbed "Opportunity Ledge," shows finely layered sediments that have been accentuated by erosion. The sphere-like grains, or "blueberries," distributed throughout the outcrop are geologic features called *concretions* that form in preexisting wet sediments. This image was taken by *Opportunity*'s panoramic camera on the 50th Martian day, or sol, of the mission. Image: NASA/JPL/Cornell

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Members' **Dialogue**

Wild About Mars

I would like to thank The Planetary Society for the excellent Wild About Mars conference. In my hometown I typically found myself as one of the few people truly interested in spaceflight. It was a wonderful change to see the live video from the Jet Propulsion Laboratory and *Spirit*'s new images with over 2,000 people instead of by myself at home!

I would also like to thank Mat Kaplan, Bruce Betts, and Emily Lakdawalla for all the work they put into Planetary Radio. Their commercials for Wild About Mars and subsequent discussions of it sold me on making the trip from New Hampshire to Pasadena!

After the *Columbia* accident, the desire for a new direction in manned spaceflight led me to several space societies, including The Planetary Society, the National Space Society, and the Mars Society. Each has slightly different goals, and different strengths, and I am a member of each. On a day-to-day basis, however, I find the most new information, support, projects, and hard work toward making a difference from The Planetary Society, and I want to thank everybody there for that.

—RYAN CARON,
Amherst, New Hampshire

My heart and my temples were pounding as I watched the NASA feed over my computer as *Spirit* landed on Mars. Hearing the voices of the technicians becoming more intense and focused as the moment was at hand, seeing the looks of concern on those faces, watching the drama of the whole event as years of work came down to 6 minutes of hell. Finally, there was the eruption of cheers and hugs as the rover performed its maneuvers in picture-perfect fashion and beeped a clear and present C note to signal "I'm here."

I have been a member of The Planetary Society since its inception in 1980. I have read the articles on space exploration triumphs and tragedies in *The Planetary Report* and on the website. But never have I felt so proud and full of myself for being a member at this moment. I just wish Carl were here to see this.

—BILL CAMPBELL,
Calgary, Alberta, Canada

Save the Hubble

It has been announced that the Hubble Space Telescope will not receive the maintenance necessary for its survival, the reason being that safety considerations won't allow for another shuttle visit. While safety must always be given the highest priority, I disagree with the logic behind allowing the Hubble program to end. Presumably, when the shuttle flies again, its safety will be well improved.

The Bush administration and NASA have announced plans to send a human flight to Mars. Safety will be far more compromised in such an enterprise, but I can't think of anyone who understands the importance of space exploration who would consider the physical risks not worth it. It has been explained many times that the reasons for spaceflight and the subsequent deadly risks are to seek knowledge and to learn about ourselves and our role in the universe. There is no more profound question in science, and we must be willing to take the risks.

No other program has influenced our understanding of the universe as profoundly as the Hubble Space Telescope. It has changed the way we view the universe and influenced the way millions of people consider our very existence. Hubble images have become iconic, representing everything from simple wonder to creation itself. Isn't this the desired outcome of space exploration?

—JACK SHAW,
Mount Shasta, California

We at The Planetary Society believe that the Hubble Space Telescope has been of enormous public and scientific value, and we encourage any action to prolong its productivity until it is replaced. We believe that the actions taken by NASA and the US Congress for independent review are the correct course to determine if NASA's decision to terminate the planned maintenance mission is in the best interest of the safety of the astronauts and the future of space astronomy.

—Wesley T. Huntress, Jr., President

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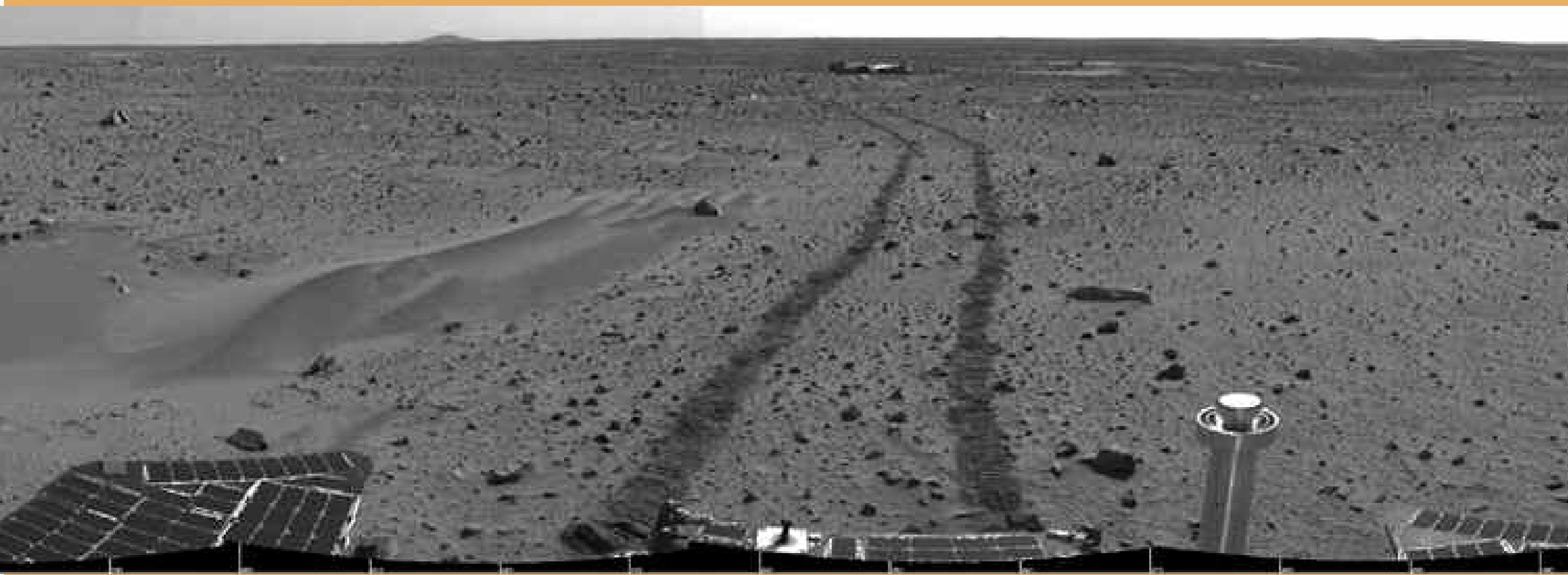
We Make It **Happen!**

by Bruce Betts

The Planetary Society on Mars!



She's leaving home: In this navigation camera, or Navcam, image, Spirit *looks back at its own tracks and the lander that got it safely to the Martian surface. The MarsDial is visible in the middle foreground, on the back of the rover's solar panels. On that lander in the distance is The Planetary Society's DVD carrying the names of 4 million Earthlings, including those of our members. By this time, intrepid Astrobot Biff Starling has left the DVD and hopped onto the rover for a fun and righteous ride.* Image: JPL/NASA

Wow! We really have made it happen. Not only did the world witness the arrival of three very successful new spacecraft at Mars and a successful comet fly-through, but The Planetary Society also had success beyond our wildest expectations. We set a string of firsts, involved the public in this remarkable time of space exploration, and brought 16 exceptional students to the Jet Propulsion Laboratory (JPL) to work on the Mars Exploration Rover mission and promote the future of Mars exploration.

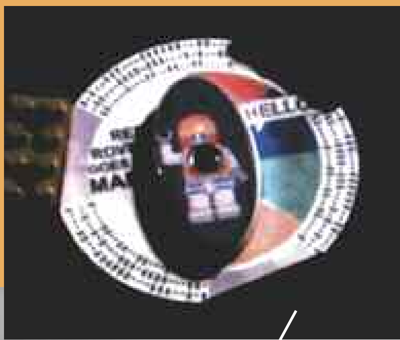
As you've read here (most recently in the November/December 2003 and January/February 2004 issues of *The Planetary Report*), The Planetary Society's Red Rover Goes to Mars project—conducted in partnership with the LEGO Company—is an official part of the Mars Exploration Rover mission. Our participation represents no small feat as the first education experiment on a planetary spacecraft. Let's review what turned out to be one of our most successful projects ever, and show a small sampling of the intriguing images being returned by *Spirit* and *Opportunity.*

Q: *What Do You Get When You Mix . . .* 4 Million People, All Our Members, and Two Astrobots?

A: A very special DVD now on the surface of Mars (times 2)! The identical DVDs (one on the lander that carried *Spirit* and the other on *Opportunity*'s lander) are only the second and third pieces of privately funded hardware ever to fly on a planetary spacecraft (the first was The Planetary Society's Mars Microphone on the failed *Mars Polar Lander*).

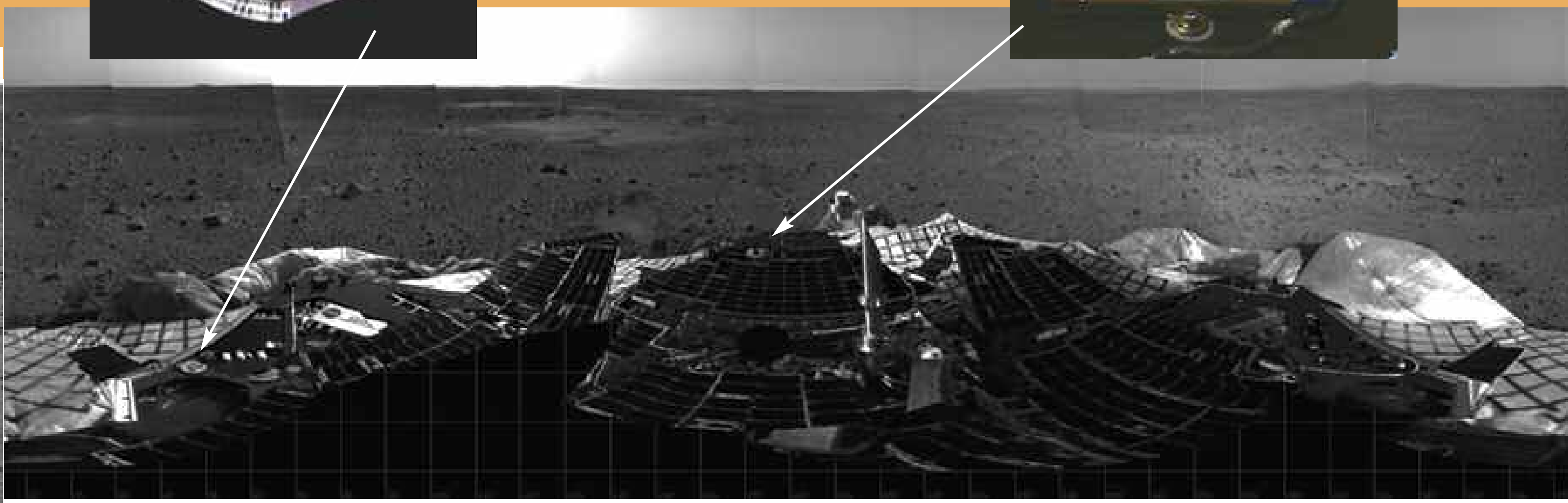
The Planetary Society provided the mini-DVDs to each spacecraft. Each DVD contains the names of almost 4 million Earthlings—the names of all Planetary Society members as of October 2002, and those of the general public who signed up via a NASA website to send their names to Mars—thus giving themselves a piece of the future and some ownership in the mission. These ultra-durable silica glass DVDs can last as long as 500 years!

Each DVD also carries unique engagement tools to teach, entertain, and inspire. The label on each disc has



Below: This was the first visual demonstration of the success of the Mars Exploration Rovers—the first panorama of *Spirit's* landing site in Gusev Crater. At the time of *Spirit's* landing, this Navcam panorama came through and was enjoyed by all in attendance at Wild About Mars and by everyone else following along on the Web. This image showed the first evidence that The Planetary Society was on Mars—the color insets show close-ups of The Planetary Society's DVD and the MarsDial that were taken by the panoramic camera, or Pancam. On the DVD, you can see Astrobot Biff Starling in the middle and a secret code around the outside edge.

Panorama: JPL/NASA, insets: JPL/NASA Cornell University



a secret message encoded around the outside rim—two different messages and two different codes. We now have images back from Mars showing both DVDs, and we challenge kids and the general public to look at the images and decode these messages. To try to crack the codes or just learn about them, or to find a link to print a certificate that your name is on Mars, go to *redrovergoestomars.org/dvd.html*.

Each DVD also has on it an Astrobot, a representation of a LEGO mini-figure suited up for space. Biff Starling became the first Astrobot on Mars with *Spirit* and Sandy Moondust the second with *Opportunity*. After Biff safely touched down on Mars, he had this to say: "This is one very tiny step for a tiny robot, and, well, one somewhat larger step for dudes and dudettes everywhere." Since then, he has chronicled his adventures at Gusev Crater in his unique and endearing Biff way. The usually stoic Sandy has had a change of attitude since being run over by the *Opportunity* rover. She's been appreciating the beauty of her new home and learning to have fun. You can read their entertaining and educational first-person accounts of their journey, their landing, and their Martian explorations on our website at *planetary.org/astrobots*.

Each Astrobot has three magnets built into its body. These magnets are designed to collect magnetic dust as part of a collaboration with the Mars Exploration Rover magnet team, who have a number of magnets on the rovers. The Astrobot magnets have indeed shown accumulation of dust, details of which are still under analysis at the time of this writing.

Q: *What Do You Get When You Mix* . . . a Stick, a Circle, Mars, and Bill Nye the Science Guy?

A: A MarsDial on each rover. When Planetary Society Director Bill Nye looked at the Pancam camera calibration targets on board each rover, he saw a shadow-casting stick and a circle—a sundial. Nye and a cast of characters including the Society's Louis Friedman developed a plan to make a MarsDial (see

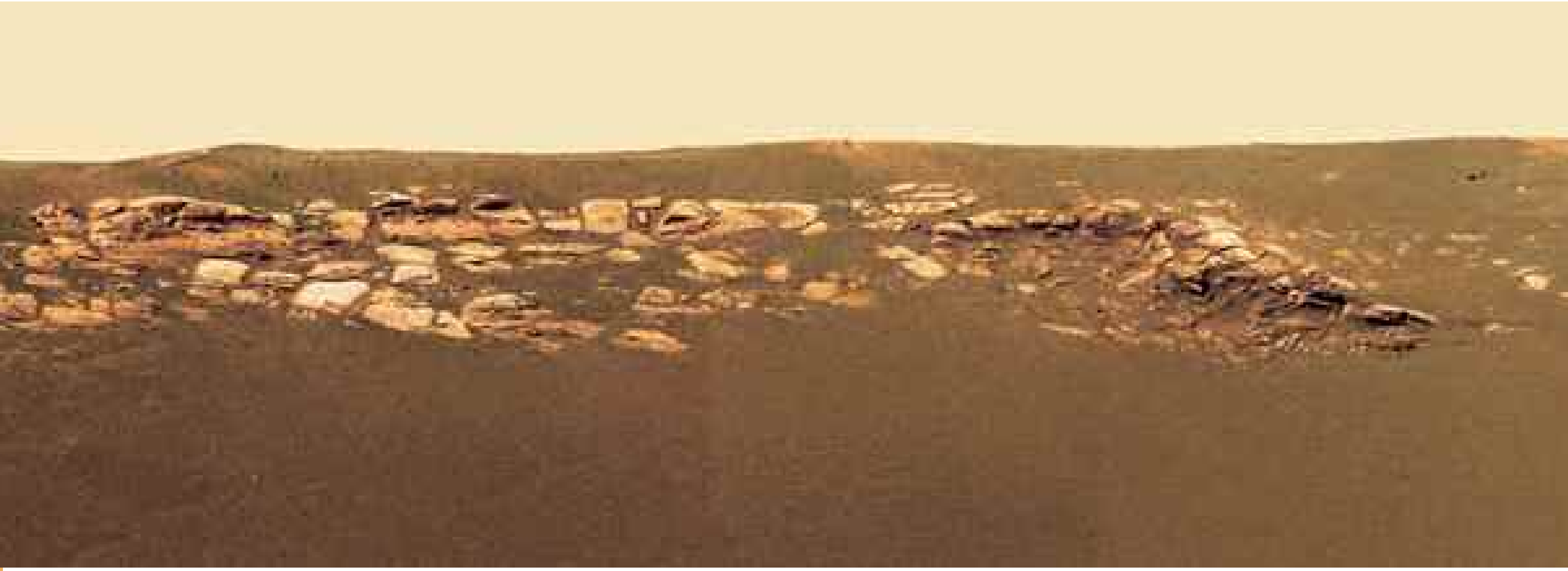
This image of the MarsDial on *Spirit* was taken on January 14, 2004 at 07:44:47 Universal Time (similar to Greenwich Mean Time). Student Astronauts Abby and Shih-Han used image analysis software to determine that the center of the sphere's shadow corresponds to a time on Mars (at the Gusev Crater site) of 11:01 a.m. on sol 11 of the mission. The shadow also indicates that at the site it is about halfway between the summer solstice and autumnal equinox (for Mars' Southern Hemisphere). The Red Planet's southern summer solstice occurred on September 29, 2003, and its southern autumnal equinox took place on March 5, 2004. Therefore, it is 107 sols past the summer solstice and 49 sols until the autumnal equinox in this image. Image: JPL/NASA/Cornell

Opportunity, which touched down successfully on Meridiani Planum, returned this panorama of its landing site. This location was chosen because coarse-grained hematite has been detected there by spacecraft in orbit around Mars. On Earth, this mineral usually forms in the presence of liquid water. Opportunity *confirmed that the gray material spread around on the surface was indeed the coarse-grained hematite. The spacecraft happened to land inside a 20-meter crater, which was great news for the mission because the crater exposed the bedrock outcrop shown in this image.* Opportunity *spent weeks studying this outcrop, the first ever visited on Mars. Results haven't been disappointing. A range of evidence adds up to this location having been soaked by liquid water in Mars' past—just the thing the rovers were designed to find. Liquid water isn't stable on the surface of Mars now, and it is one of the only things that all life on Earth requires. Its Martian history is therefore of great interest to scientists for geologic and astrobiologic reasons. You'll get more detail on* Opportunity*'s water discoveries in future issues of* The Planetary Report, *as well as on our website.* *Image: JPL/NASA/Cornell*

Right: Stardust *was the other big star of Wild About Mars. The* Stardust *mission successfully flew through comet Wild 2 on January 2, 2004, the day before Wild About Mars. Here Project Manager Tom Duxbury from JPL presents to the Wild About Mars crowd brand new images from the fly-through that occurred the day before. In January 2006,* Stardust *will return to Earth samples collected from the comet.* *Photo: Donna Stevens*

Below: The giant screen at Wild About Mars allowed everyone to witness the ecstatic mayhem in Mission Control during the moments the first images from Spirit *were coming down.*

Below right: When Spirit *landed successfully, the crowd went wild at Wild About Mars!* *Photos: Donna Stevens*



the January/February 2004 issue of *The Planetary Report*).

On a moving platform such as a Mars Rover, you can't have the hour marks drawn on your sundial. To solve that problem, the calibration target images have been processed by The Planetary Society's Student Astronauts to add hour marks using software developed at Cornell University in collaboration with University of Washington's Woody Sullivan. These MarsDial images appear on our website in an effort to connect one of Earth's oldest science devices with one of our newest—all on another planet.

Q: *What Do You Get When You Mix . . .* 16 Sleep-Deprived Students from 12 Countries?

A: The Student Astronauts (see the November/December 2003 issue of *The Planetary Report*). This group of 13- to 17-year-olds performed spectacularly in mission operations, working side by side with the scientists and engineers behind the success of these extraordinary rovers. The students worked in teams of two, each pair spending about one week at JPL during the first two months of the Mars Exploration Rover mission. They worked on Mars time (which means sometimes they were working overnight), and they were there to witness the excitement of landing and egress and to take part in daily science team meetings.

The students also processed images of the MarsDials, worked on other image-processing tasks including science analysis of the variation in atmospheric dust, and collaborated with the magnet team. Their biggest job—to communicate out to the world what it is like inside mission operations—continues. While at JPL, they did countless interviews and chronicled their daily experiences on our website, and they continue to talk to the US and international press as well as their peers, schools, communities, and, in some cases, even their nations' leaders. These enthusiastic young people are now acting as ambassadors—promoting the future of space exploration and inspiring the next generation of explorers.

Q: *What Do You Get When You Mix . . .* Mars, a Comet, a Solar Sail, and Thousands of People?

A: An unforgettable party weekend. How does one celebrate the first successful landing on Mars in seven years, the first-ever sample collection fly-through of a comet, the first education experiment on a planetary mission, and the first Astrobots on Mars? The Planetary Society did it with Wild About Mars, a two-day celebration held at the Pasadena Convention Center on January 3–4, 2004.

On the night of January 3, a sellout crowd anxiously awaited news that *Spirit* had landed successfully. As soon as mission control had confirmation that *Spirit* was on the surface, the crowd erupted in excitement—clapping, cheering, hugging, some even crying. A similar scene played out when JPL received *Spirit*'s first image (the MarsDial). The evening was exhilarating—truly a great way to witness history in the making.

Earlier in the evening, before the landing events, the *Stardust* team gave a stunning presentation about their fly-through of comet Wild 2 the day before. Our special guest, Ray Bradbury, also spoke to the crowd and watched as noted stage and screen actors John Rhys-Davies (Gimli the Dwarf in *Lord of the Rings*), Bob Picardo (*Star Trek: Voyager*), and Lisa Pelikan performed readings of Bradbury's works.

On January 4, numerous special guests appeared on stage, including key Mars Exploration Rover players Rob Manning, Mark Adler, and Jim Bell. At one point, we had on stage Ed Weiler (NASA's current head of space science), Society President Wes Huntress (NASA's former head of space science), Charles Elachi (current director of JPL), and Society Chairman of the Board Bruce Murray (former director of JPL).

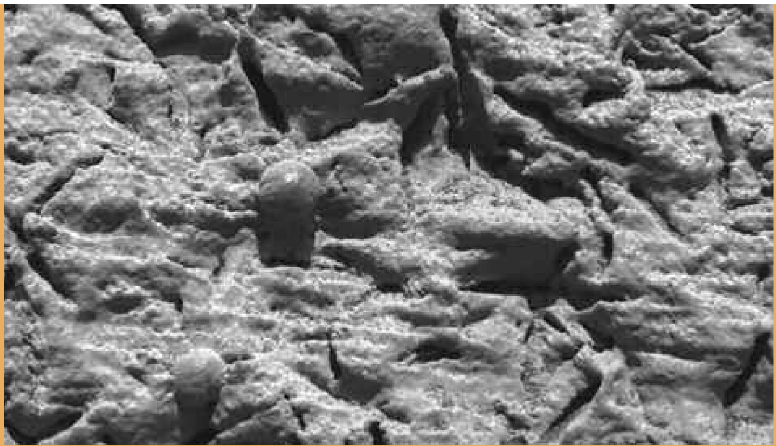
The experience was one that I and others who were there will never forget. The event was of a type unique to The Planetary Society, bringing together key players from science and entertainment with the public, both in person and via the Web. You can see

Opportunity looks ahead in this Pancam image of the area surrounding the crater in which it landed. Note how vastly different this region looks from the landing sites of Spirit, Pathfinder, *and* Vikings 1 *and* 2*. The dark material covering the "plains" is coarse-grained, gray hematite. Notice the small, 5-meter crater in the middle, and in the distance the 160-meter-diameter crater nicknamed Endurance. Note also the sunlit far rim of Endurance. The mission team plans to send* Opportunity *to Endurance once it finishes nosing around the crater it landed in. Stay tuned for many more discoveries from both rovers.* Image: JPL/NASA

more images from Wild About Mars on our website, where you can also get regular updates on the Mars Exploration Rover and *Stardust* missions. We also have audio excerpts from Wild About Mars and interviews with key members of the Mars Exploration Rover and *Stardust* teams in our Planetary Radio section at *planetary.org/radio.*

Q: *What Do You Get When You Mix . . .* The Planetary Society, the LEGO Company, and Our Members?

A: Pure success. Success in involving the public in new, innovative ways in planetary exploration. Success in inspiring kids. Success measured by enormous Web traffic to our many activities, press coverage, member and public feedback, and warm, fuzzy feelings. Thank you to LEGO, a company with a commitment to education and to inspiring kids. The company stuck with us through the cancellation of the 2001 lander, knowing the risks of planetary exploration. Thank you as well to Planetary Society members. I say it a lot in this column, but you really make these things happen, and you really have something to be proud of. The first educational experiment on a planetary mission; the first, second, and third privately funded pieces of hardware flown on planetary spacecraft; 4 million people paying more attention to space exploration than they would have; and countless people around the world who played a part in this extraordinary endeavor of space exploration.



Opportunity*'s microscopic imager took this close-up of a part of the outcrop called Guadalupe shown in the picture at the top of page 6. The spacecraft found chemical evidence that pointed to past liquid water, such as various salts and high concentrations of sulfur including sulfates. It also found the physical evidence shown here. The "slots" appear to be what are called vugs by geologists. These are holes left behind when a mineral (for example, gypsum) forms within the rock from salty water, then the mineral is eroded away, either by other water or by another process. Also, note the spherule—the ball-shaped object. Many of these are seen at the* Opportunity *landing site and have been nicknamed "blueberries" by the science team. They appear to be concretions, spherical deposits that form when minerals in water flowing through the rock "grow" around a point.*

Opportunity*'s navigation camera took this picture of the layered rocks in the "El Capitan" area near its landing site in Mars' Meridiani Planum on March 1, 2004. Two holes ground by the rover's rock abrasion tool (RAT) are visible here, as well as* Opportunity*'s wheel tracks at right and bottom left. Once the RAT did its job, the rover's microscopic imager and two spectrometers looked beyond the veil of dust and coatings on the rocks to get the best insights into the chemical composition of the area. The data they gathered indicate that the rocks include large quantities of sulfate that could have been created only by the presence of liquid water.*
Images JPL/NASA

What's Up

In the Sky

(Exact locations of planets will vary somewhat depending on your latitude, but this guide will get you close.)

Mercury: Visible in late March and early April at lower right of Venus near horizon just after sunset.
Venus: Looks like the brightest star in the sky for more than three hours after sunset in the West.
Mars: Reddish-orange bright "star" in evening sky at upper left of Venus.
Saturn: High in the sky after sunset, between Mars and Jupiter. Yellowish and fairly bright.
Jupiter: Very bright (only Venus is brighter right now) in the East after sunset, rising higher as evening progresses.

Random Space Fact

The surface atmospheric pressure on Venus is approximately 100 times that on Earth, equivalent to the pressure approximately 1 kilometer (3,000 feet) under the surface of the Earth's oceans.

Trivia Contest

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

Which planet in our solar system has the lowest average density?

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

Submissions must be received by May 15, 2004. The winner will be chosen by a random drawing from among all the correct entries received. The winner will be notified in May 2004 and will have his or her name published in the July/August 2004 issue of *The Planetary Report*.

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

Bruce Betts is director of projects at The Planetary Society.

World Watch

by Louis D. Friedman

Mars, via Darmstadt and Pasadena—In December and January, people all over the world joined in the exploration of a new world as *Mars Express* and the Mars Exploration Rovers began their work at the Red Planet. Unfortunately, two of their "colleagues," *Nozomi* from Japan and *Beagle 2* from the United Kingdom, failed to reach their goals.

The European Space Agency's *Mars Express* entered orbit in December. (This was only Europe's second interplanetary mission; ESA's *Giotto* flew by Halley's Comet in 1986.) After a couple of weeks spent adjusting its orbit, the spacecraft began sending brilliant new three-dimensional color images of the Martian surface back to Earth. As we go to press, we await the first-ever results from below the Martian surface from a combined US-European radar experiment.

The January landings of *Spirit* and *Opportunity* on Mars proved wildly popular, and NASA broke all records for Internet traffic, recording many millions of hits per day throughout the month. International news media covered the drama and the science progress daily. The political implications of the enormous public interest were not lost on Washington: Just one week after *Spirit*'s successful landing, President Bush announced a new US space policy with a goal of sending humans to Mars.

Unfortunately, the *Beagle 2* lander was never heard from after it separated from *Mars Express*. The mission was financed by a combination of private and public funds in Great Britain and was developed by Open University scientists and EADS Astrium. This was their first attempt at a planetary mission, and they had chosen difficult science and engineering objectives for the attempt.

Japan failed in its second interplanetary mission. Like ESA, it had succeeded in 1986 with a mission to Halley's Comet, but this time, it could not rescue its troubled *Nozomi* spacecraft. The mission suffered several setbacks on the journey to Mars, first with the incorrect injection into the Earth-Mars trajectory and later when a cosmic ray strike damaged the spacecraft's electronics. Up to three weeks before the craft reached the vicinity of Mars, the Japanese space agency made several heroic attempts to overcome the problems. Ultimately, it could not control the spacecraft well enough to send it into orbit, so it flew past Mars. The mission did return good data from fields and particles measurements in interplanetary space—but nothing from Mars.

With all the new arrivals at Mars, we can't forget the terrific jobs being done by *Mars Global Surveyor* (launched in 1996) and *Odyssey* (launched in 2001), both still orbiting the planet. They have been sending back beautiful scientific information to support the rover missions, as well as serving as communication relays.

We send congratulations to all those involved in these missions. Even those missions that failed have been tremendous efforts. And now we look forward to an exciting year of exploration.

Washington, DC—President Bush announced a new National Space Policy Directive, dramatically changing the purposes of the US human spaceflight program and setting a new course to Mars. After 30 years of policy drift, with no goal for human flight beyond Earth orbit, the new policy redirected all developments in the human spaceflight program to the goal of sending people back to the Moon—and then to Mars.

Specific elements of the policy include retiring the space shuttles as soon as the International Space Station basic assembly is complete, redirecting US objectives on the space station to prepare for human flight to Mars, developing a new crew-carrying vehicle for exploring the Moon and preparing for the transportation elements that will be needed to get to Mars, and launching more robotic missions to the Moon and Mars to prepare the way for humans.

These are key policies that The Planetary Society has been advocating for decades, and we regard the new policy directive as a tremendous victory for us. We have not specifically called for returning humans to the Moon, but doing so to prepare to send humans to Mars, as the new policy specifies, does not conflict with our position.

Although the new policy deals primarily with human spaceflight, it specifically supports science and robotic exploration—not just for the Moon and Mars but also for "understanding the history of the solar system." We interpret that as strong backing for outer planet missions, including both a *Jupiter Icy Moons Orbiter* and the *New Horizons* mission to Pluto and the Kuiper Belt.

The policy proposal endorsed international cooperation, recognizing existing commitments in the space station program and being open to new ones. In another major policy shift, the Bush administration showed strong willingness to consider more non-American launches after the shuttle is retired.

On February 3, the administration released its proposed fiscal year 2005 budget. The proposal calls for a 5.3 percent increase in NASA funding, an addition that will face a difficult time in Congress. The new exploration policy was given a total budget of $12 billion over five years, with most of the money coming from reallocations within NASA. Only $1 billion in new money is allocated to the proposal.

Already, debates are raging over whether the new exploration policy is realistic and adequately funded. Some criticize it as a new spending program at a time of enormous US budget deficits. Others attack it as providing too little funding for such a bold objective. The administration believes the first steps in this new course will fit in the planned budget, and later steps will be affordable because of the technological progress, robotic precursor efforts, and experience gained in new missions.

Supporters of the new policy also have been reminding debaters that the NASA budget totals only 0.7 percent of the federal budget, and the increase proposed is less than 0.2 percent of the annual proposed tax cut.

The Society supports the interim milestone approach—as long as it is focused on the Mars goal and doesn't get bogged down or take detours. The focus on humanity extending its presence to other worlds and exploring the conditions for life in the universe has long been our objective. We are delighted to now see it as official policy.

The International Space Station partners—Europe, Japan, and Russia—will have to consider the new policy and how it affects their plans for the space station and future human spaceflight. Europe has plotted a similar path in its Aurora program for Mars, and Russia has long touted its interest in, and still considerable capability to support, human missions to Mars. The Russians have an approved but not fully funded robotic Phobos sample return mission on the books for 2009.

The Planetary Society actively urges international participation in the new Moon and Mars missions outlined in the US plan.

The proposed budget for NASA is now being considered by the US Congress. This process will take several months, and Society members can follow its progress on our website, *planetary.org*.

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

Your **Membership Dollars** at Work

According to surveys of Planetary Society members, advocacy is one of the chief reasons people join the Society. This magazine, our website, our exciting projects—including the *Cosmos 1* Solar Sail, SETI (the search for extraterrestrial intelligence), and Red Rover Goes to Mars—also are mentioned, but political advocacy in making space exploration happen is always cited as a principal reason for membership.

We are doing a good job as advocates. Those campaigns in which you sent letters, faxes, and e-mails to the White House and Congress have saved the Pluto-Kuiper Belt mission from extinction. They prompted Congress to add money for the robotic Mars programs in almost every year in the past decade. We helped make the US Mars program happen, with missions every two years.

But the recent change in US space policy directing human explorers to Mars is perhaps our biggest victory. Members faxed the White House. Society officers were all active in Washington testifying to Congress, giving background briefings, visiting the White House, and advising NASA. Our Board of Directors is deeply involved with the questions of human spaceflight, and we benefited greatly from John Logsdon on the Columbia Accident Investigation Board and Neil deGrasse Tyson on the National Aerospace Commission. Now, Tyson and Maria Zuber have been asked to serve on the commission to oversee the implementation of the new space policy directive.

The Society isn't active only in the United States. This past year, we were involved in a European effort to support the *Rosetta* mission to explore a comet. We've been involved in Russia, Australia, Canada, and elsewhere, and we are active as a nongovernmental organization in the United Nations Committee on Peaceful Uses of Outer Space, as well as in the International Astronautical Federation.

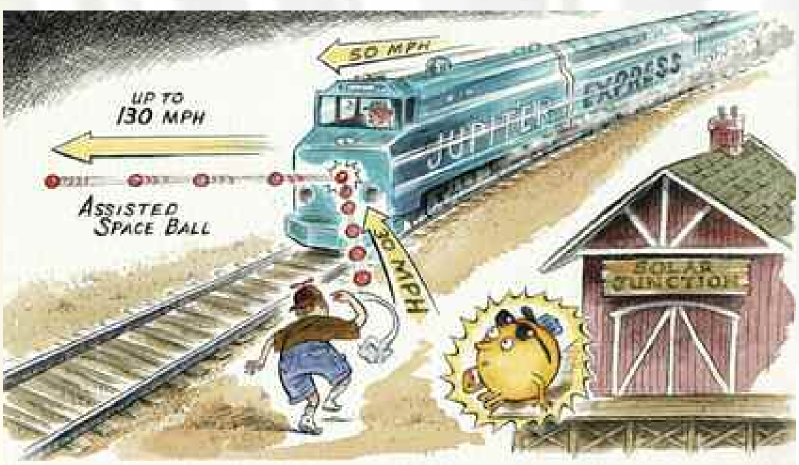
We can all take pride that the new American policy so closely followed Society recommendations made over the past few years. Influence is hard to measure. Whether we were the cause of these changes or just prescient in our advocacy, we made a difference.

But we can't ease up. There are battles still to come in Congress in the months ahead. *—LDF*

More than six years have passed since I dashed from the control center to watch *Cassini-Huygens*' perfect launch from Cape Canaveral at 4:43 a.m. EDT on October 15, 1997. The ensuing journey has been a long one, given the need to set up four gravity assists en route—two from Venus, one from Earth, and one from Jupiter. Even with the mighty Titan-4B/Centaur expendable launch vehicle, one does not send a 5,550-kilogram (12,235-pound) spacecraft directly to Saturn. Instead, it must be forced to gain a total of 21 kilometers (13 miles) per second from four clever slingshot maneuvers, robbing each of the assisting planets of minuscule amounts of its own speed about the Sun. Insertion into Saturn orbit is scheduled for June 30, 2004 (PDT). With the NASA/JPL *Cassini* spacecraft orbiter and its attached European Space Agency (ESA) *Huygens* Titan probe in excellent health, we anticipate an exciting four-year tour of Saturn, its great rings, and its many moons.

I had joined the NASA/JPL *Mariner Mark II* (*MMII*) team half time after the *Voyager 2* encounter with Uranus in 1986, becoming full time in late 1989 following the epic flybys of Neptune and its large moon Triton. At the time, the *MMII* program consisted of two missions—one to Saturn and Titan (known initially as SOTP, or Saturn Orbiter Titan Probe) and another to an asteroid and a comet (CRAF, or Comet Rendezvous Asteroid Flyby). Under the umbrella of the *MMII* program, these missions were to use as much common hardware as possible to keep costs down. Unfortunately, this was not the way the federal budget office saw matters, and CRAF was canceled in late January 1992. Several months later, Dan Goldin became NASA administrator and resolved to usher in a new era of "faster, better, cheaper," threatening to cancel *Cassini-Huygens* as well in late 1993.

With many countries participating in this great mission, none of us could imagine Goldin taking this drastic step and damaging our country's relationship with the Europeans. To our joy, on June 14, 1994, Jean-Marie Luton (then director general of ESA) sent a powerful letter to Vice President Al Gore, with copies to the US secretary of state, key office directors, and of course Dan Goldin. It did the job in saving *Cassini-Huygens,* particularly through its penultimate paragraph, which read, "Europe therefore views any prospect of a unilateral withdrawal from the cooperation on the part of the United States as totally unacceptable. Such an action would call into question the reliability of the U.S. as a partner in any future major scientific and technological cooperation." Goldin allowed *Cassini-Huygens* to remain on schedule.



In this down-to-Earth analogy, the tennis ball plays the role of the spacecraft, the moving train that of the assisting planet, with the Sun fixed on the station platform. The train engineer sees the ball approach and leave at a relative speed of roughly 130 kilometers, or 80 miles, per hour (for a head-on throw and a perfectly elastic collision). The Sun sees the ball initially traveling at 48 kilometers (30 miles) per hour, only to bounce off the train at an amazing 210 kilometers (130 miles) per hour! The big gain in speed relative to a fixed observer is achieved by a minuscule reduction in the train's speed. Were the assisting body at rest, there would be no net speed gain after the encounter.

Illustration: Gary Hovland, based on a concept by the author

Left: This image of Saturn from 111 million kilometers (about 69 million miles) was taken by Cassini*'s narrow-angle camera on November 9, 2003. Exposures through different spectral filters were combined to yield the natural color seen. In addition to faint banding in Saturn's atmosphere, the planet's shadow on the rings also may be seen. As the spacecraft closes in on the planet, pictures will become much more detailed and will show storms, wave patterns, and spots. Five of Saturn's icy moons were also detected. Fourteen camera-team scientists from the United States and Europe will use the two* Cassini *cameras to investigate many features of Saturn, its moons, and its rings.* Photo: JPL/NASA/CICLOPS

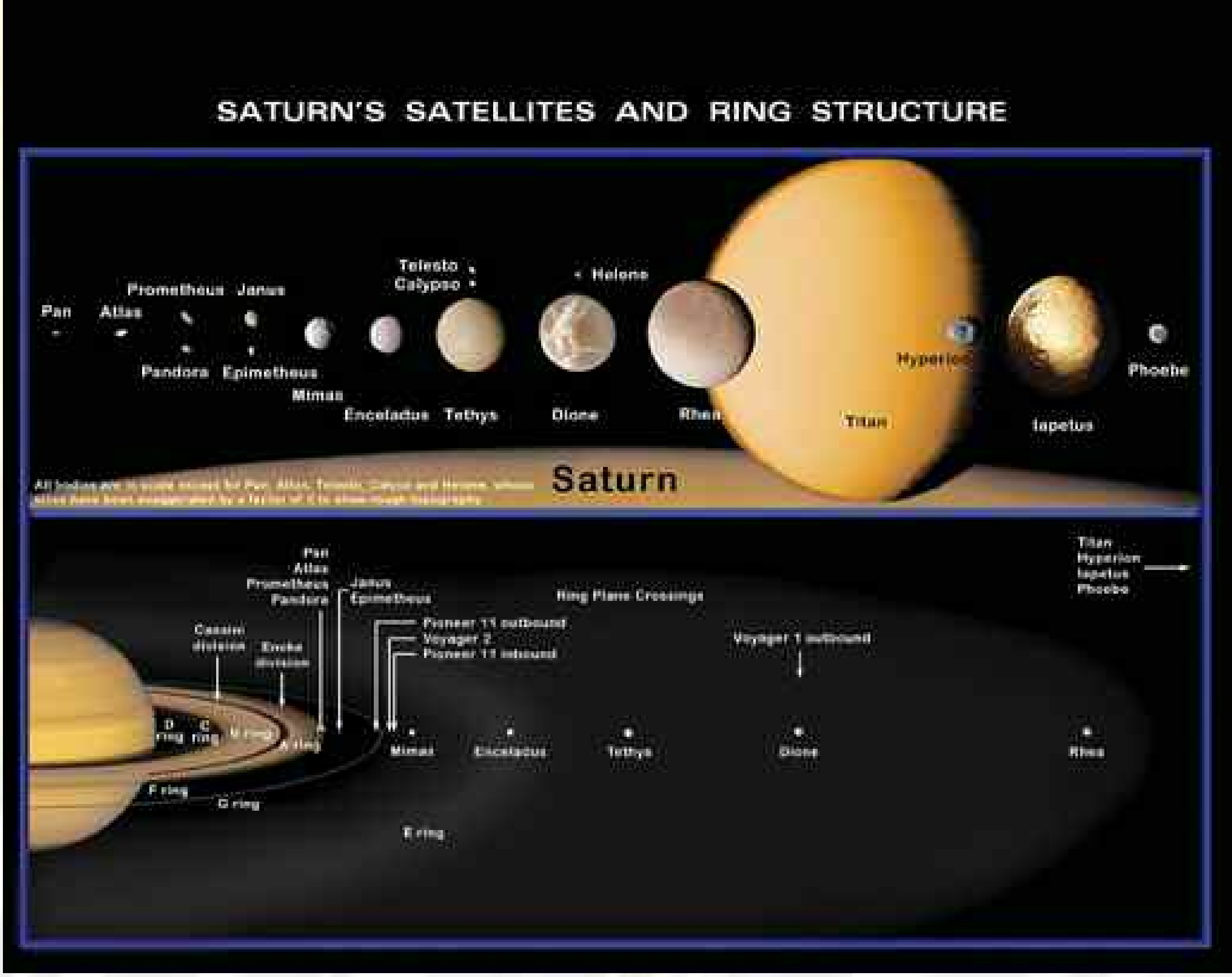
The flight spacecraft, nearly 7 meters tall, in the JPL solar thermal vacuum test chamber. When loaded with more than 3,100 kilograms (about 6,830 pounds) of propellant, its total launch mass was roughly 5,550 kilograms (about 12,235 pounds). Also seen in this photo are the 4-meter-diameter high-gain antenna (top of photo) and the attached 2.7-meter-diameter Huygens *Titan probe (in gold-colored thermal blanket wrap at photo center). Many of the 12 scientific instruments aboard the* Cassini *orbiter appear below the antenna, with the 6 instruments aboard the* Huygens *probe inside the probe payload behind the blanket-covered heat shield.* Photo: JP/NASA

The *Cassini-Huygens* international mission has been undertaken by NASA, ESA, the Italian Space Agency, and numerous academic and industrial partners—peaking at nearly 5,000 people before launch, scattered in 18 countries and 32 US states. The orbiter is named in honor of the French-Italian astronomer Jean-Dominique Cassini, who discovered the prominent gap in Saturn's main rings as well as several icy moons. The probe is named for Dutch scientist Christiaan Huygens, born into a prominent family deeply involved in the sciences, literature, and music. Huygens discovered the large moon Titan in 1655 and four years later found that the strange "arms" around Saturn noted decades earlier by Galileo were actually a set of rings.

GRAVITY ASSIST PAR EXCELLENCE

Launch energies to go directly from Earth to Saturn are great, so JPL mission designers had to devise alternate routes. Normally, one would simply use the powerful gravity assist from Jupiter, as did the *Voyager*s in 1979. The Earth-Jupiter-Saturn gravity-assist alignments occur roughly every 20 years, so 1997 was promising. Unfortunately, the heavy *Cassini-Huygens* spacecraft could not be launched to Jupiter with the largest expendable launch vehicle available, so other tricks were needed. This usually calls for swingbys first of Venus and Earth to pick up the speed needed to coast to Jupiter. JPL's Roger Diehl had previously masterminded *Galileo*'s great feat of interplanetary billiards to reach Jupiter, ultimately flying a Venus-Earth-Earth-Gravity-Assist.

Roger combined his formidable talents with those of Chen-Wan Yen to allow *Cassini-Huygens* to reach Saturn by using a Venus-Venus-Earth-Gravity-Assist. This resulted in Sun-relative "delta-Vs" of about 6, 7, 6, and 2 kilometers per second for the en route swingbys, respectively. The small gain at Jupiter (normally many times greater) resulted from the delay in reaching Jupiter and consequent need to fly past at a much greater range to avoid being deflected too much inside and ahead of Saturn's orbital position. This trip plan will cause *Cassini-Huygens* to arrive at Saturn around 7:38 p.m. on June 30, 2004 (PDT at the spacecraft)



Saturn's system of moons and rings is vast, with rings labeled in order of discovery. The faint but far-reaching E ring is thousands of kilometers thick but composed mostly of micron-sized particles that do not pose a threat to the* Cassini *orbiter. The currently known 31 moons exceed the number shown. Most of the more recent discoveries are relatively small, distant, irregular bodies.

Photo: JP/NASA

after firing its main engine for 97 minutes to brake into a loose capture orbit. Never at a loss for seizing opportunities, mission designers have planned a close 2,000-kilometer flyby of distant Phoebe nearly three weeks earlier on June 11.

The *Huygens* probe will be released on December 24, 2004, and after a coast of three weeks, it will enter Titan's atmosphere on January 14, 2005. Originally, the probe was to have arrived at Titan several weeks earlier, but a problem in the probe's receiver aboard the orbiter required a later, more distant flyby to reduce the Doppler shift between the orbiter and probe during the relay link. After recovery and playback of the probe data, the orbiter will continue on its tour, making a total of 75 orbits about the planet by nominal end of mission on July 1, 2008. During the tour, the orbiter will use precision navigation to achieve 45 close encounters of Titan; 3 close flybys of Enceladus; 1 close flyby each of Hyperion, Dione, Rhea, and Iapetus; and several more distant flybys of other moons. Flyby altitudes will be as close as 950 kilometers (590 miles) for Titan and 500 kilometers (310 miles) for some of the targeted icy satellite flybys.

Gravity-assist gains from each Titan swingby are typically in the range of 600–850 meters per second (1,340– 1,900 miles per hour), with the total gain of 33 kilometers (20 miles) per second from the 45 Titan swingbys exceeding that of the four cruise-phase planetary swingbys by 57 percent! Through the use of Titan gravity assists, with Saturn as the central body, *Cassini*'s orbits will be varied to permit excellent viewing of equatorial and polar zones, including the huge but invisible magnetosphere of energetic particles trapped by Saturn's magnetic field. Because scan platforms were eliminated to reduce costs, the entire spacecraft must turn to point the cameras and other sensors at particular targets. More than half of each Earth day will be spent maneuvering to the desired pointing attitudes and collecting scientific data on the solid-state recorders. For the rest of the day, *Cassini* will point at Earth and play back the recorded data.

SATURN

Within our solar system, Saturn is second in size only to Jupiter, but it is considerably larger than Uranus and Neptune. With a diameter more than nine times that of Earth, it could enclose nearly 750 Earths if they were reshaped to fit without empty spaces. With a density less than that of water, however, the planet could float in a vast ocean. Unlike the inner planets, Saturn does not have a rocky surface but is made of gases. Hydrogen and helium predominate, with methane, ammonia, acetylene, propane, and phosphine also present. The gases become denser and hotter as one descends from the cloud tops to the interior. Near the equator, wind speeds reach 500 meters per second (1,100 miles per hour), mostly eastward, but slowing at higher latitudes and even alternating east and west poleward of about ±35 degrees.

We see Saturn as banded in pastel yellows and grays. Interestingly, the colors of the four gas giants differ, partly as a result of their varying distances from the Sun (and hence their temperatures). Jupiter's colors run toward tans and reds, and the more distant Uranus and Neptune appear as shades of pale blue where considerable amounts of methane absorb red light. Saturn radiates about 80 percent more energy than it receives from the Sun, with one explanation suggested by the less-than-expected amounts of helium in its outer atmosphere. Perhaps the missing helium, long ago condensed out of the cool upper atmosphere, has been sinking slowly toward the planet's interior, converting gravitational energy to heat when the fall of the helium raindrops is eventually stopped.

A SEA OF RINGS

The ring systems of Jupiter, Uranus, and Neptune pale in comparison with that of Saturn, so often depicted by space artists. Saturn's rings are a frigid cast of trillions of particles and icebergs ranging in size from that of fine dust to that of houses. They march in orbits around their captor in a vast sheet of amazing expanse and thinness. It is believed that the ring fragments are primarily loosely packed snowballs of water ice, but slight colorations suggest the presence of small amounts of rocky material, possibly even traces of rust (iron oxide). Although the distance from the inner edge of the C ring to the outer edge of the A ring is about 13 times the distance across the United States, the thickness of the ring disk is not more than a few tens of meters, with waves or "corrugations" in this sheet rising and falling by 1–2 kilometers.

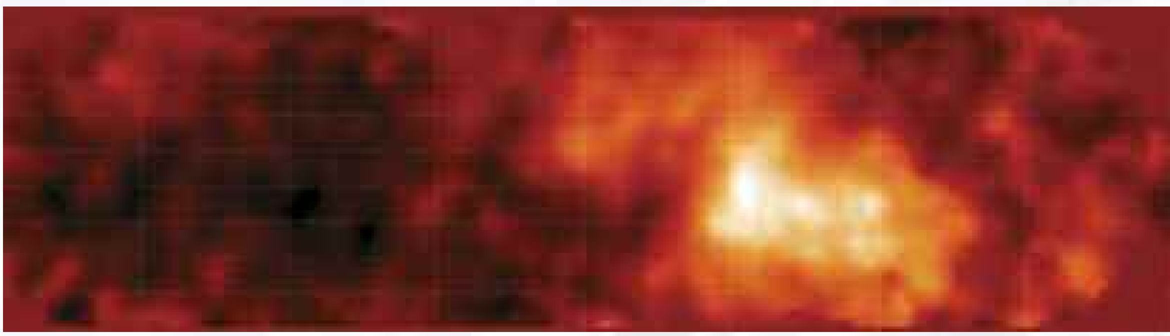
Numerous patterns, both simple and complex, are formed within this rotating sea of icy fragments. They are variously described as circular rings, eccentric rings, kinky rings, clumpy rings, resonance gaps, spokes, spiral density waves, bending waves, and shepherding moonlets. Within the ring sea may orbit tiny moonlets too small for the *Voyager* cameras to have detected. The elaborate choreography of this complex ring system is orchestrated by the combined gravitational tugs from Saturn and its moons that lie out beyond the ring sheet, as well as by the tiny tugs and gentle collisions between neighboring ring particles. The formation and dissipation of the amazing ring "spokes" has been explained by electromagnetic forces acting on charged dust grains dislodged from ring bergs when struck by meteoroids.

How did the rings form in the first place? If one could collect all the particles and icebergs into a single sphere, its diameter would not exceed about 300 kilometers (185 miles), roughly midway between the sizes of the moons Mimas and Phoebe. Are the rings simply leftover material that never formed into larger bodies when Saturn and its moons condensed eons ago? Or, as suggested by the *Voyager* data, are they the shattered debris of moons broken apart by meteoroid impacts? If the impact theory is valid, small orbiting ring moons may be awaiting that moment when they too will be struck and transformed into magnificent rings. Recent findings suggest that the ring system originated shortly after Saturn's formation, with the material in the rings gradually changing and being replenished.

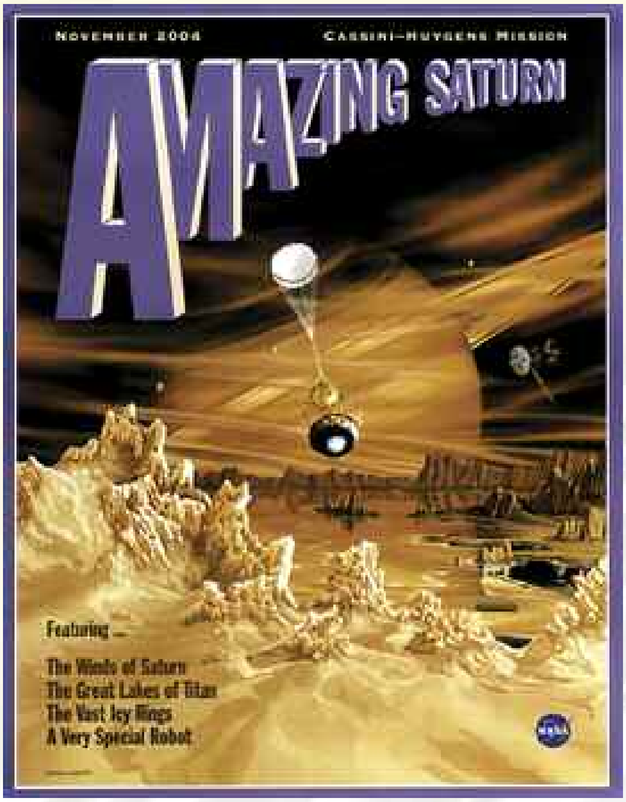
TITAN

Of Saturn's 31 known moons, Titan is not only the largest (bigger than Mercury and slightly smaller than Mars) but also the most intriguing. Its dense atmosphere hides a frigid landscape that may contain mixed-hydrocarbon oceans of liquid ethane and methane sprinkled over a thin veneer of frozen methane and frozen ammonia, which in turn probably overlies a mantle of frozen water ice. These are the latest scientific speculations arising from various hypotheses and from Hubble Space Telescope infrared images of Titan that show bright and dark regions possibly related to continents and oceans. Radar observations from Earth also hint at such a possibility. It could be that rains of ethane and methane, rather than water, fall on Titan's alien surface.

Scientists are fascinated by Titan's brownish-orange haze, which is believed to be made of complex organic (carbon-based) molecules. They are formed in Titan's atmosphere by the bombardment of nitrogen and methane molecules by ultraviolet radiation and high-energy particles. Further reactions can lead to such chemicals as acetylene, hydrogen cyanide, cyanogen, and longer molecular chains known as polymers. These organic polymers



A hydrocarbon-based smog in Titan's dense atmosphere hides the surface in photos taken in the visible spectrum. So in late 1994, Peter Smith of the University of Arizona and his colleagues used Hubble Space Telescope images in the near infrared to glimpse the surface (all longitudes, and latitudes from about 45 degrees South to 60 degrees North, with a newer map in publication to show more of the southern hemisphere). The bright and dark features may represent continents, impact craters, or perhaps oceans. The brightest areas may be highlands washed clean of organic sludge by methane rains, with the darkest areas possibly seas of liquid methane and ethane. Eons of organic chemistry make Titan a dramatic point of interest for the **Cassini-Huygens** ***mission.*** *Image: Peter Smith, University of Arizona/NASA*



A* Cassini *poster, fashioned after the* Amazing Stories *science fiction magazine, with the original idea by Mary Beth Murrill, the Titan-Saturn painting by artist Craig Attebery, and overall direction by the author. A designer always faces the tough balancing decision between scientific accuracy and artistic license. In this case, an inspirational impact was chosen, but with the Titan surface probably too spiky and the passing spacecraft too close for scientific precision . . . but very popular with schools and space fans.

Photo: JPL/NASA

would clump together into larger particles, raining slowly down on the unworldly surface below. If this process has been going on for a few billion years, the accumulated layer could be as deep as several hundred meters!

It is true that organic molecules provide basic building blocks for life, but they are not necessarily produced by life. Even though the Titan environment may resemble the chemical factory of primordial Earth, scientists expect it to be lifeless due to the extremely cold surface temperatures near –180 degrees Celsius (–292 degrees Fahrenheit). With the sensor-equipped probe's slow 2–2.5-hour descent through the atmosphere, as well as the orbiter's 45 flybys of this large and cloaked world, perhaps the findings will shed light on the chemistry of early Earth. Jean-Pierre Lebreton, the *Huygens* project scientist, is particularly excited about the possibility of landing in an ocean and floating upright long enough to analyze the liquids and transmit these tantalizing results to the orbiter before it disappears over the Titan horizon.

SATURN'S OTHER MOONS

Titan may be Saturn's most intriguing satellite, but several of the smaller moons have their own peculiar mysteries. The surface of Enceladus is coated with unusually pure water ice, with much of its surface smooth and uncratered. Could tidal stresses have heated the moon's interior and melted much of the surface, erasing most of the early impact craters? Saturn's distant E ring has an increased particle density in the vicinity of Enceladus' orbit. Could tidal stresses also have created geysers of water or water ice to feed the E ring?

Iapetus is equally interesting. As dark as asphalt on its leading face (as it orbits the planet) and as bright as snow on its trailing face, it perplexed early astronomers by disappearing on the left side (approaching the observer) of Saturn and reappearing on the right side. Arthur C. Clarke chose to feature this moon in his novel *2001: A Space Odyssey,* with its famous journey to the "eye of Iapetus," as it reminded him of a beacon. Has the dark material been swept up from the outside, or did it emerge from the moon's interior?

Many of the other Saturnian moons have their own telltale features, whether large impact craters (Mimas and Tethys), long trenches (Tethys), smaller moons in the same orbit (Tethys and Dione), or even the F-ring shepherding moonlets (Prometheus and Pandora). The "braids" in the F ring have been explained by the gravitational interactions with the shepherding moonlets.

S. S. Sheppard discovered the 31st moon in 2003. A team led by Brett Gladman of the Observatoire de la Cote d'Azur in Nice, France, discovered the prior dozen moons, classifying them as "irregulars," most smaller than 50 kilometers (30 miles). These irregular moons circle Saturn in distant, inclined, elliptical, often retrograde orbits, suggesting capture from the widespread icy debris in the young solar system. Like Hyperion and Phoebe, most of these probably are not in gravitational lock (same side facing Saturn) like the major moons. All in all, Saturn's icy moons are members of an interesting club that *Cassini* will explore with its broad array of sensors.*

THE *CASSINI* ORBITER

The orbiter is a large and sophisticated collection of high-quality hardware and software, integrated very carefully to meet a special challenge. It is three-axis stabilized with the primary purpose of carrying the many scientific sensors to the Saturn system and providing them with such essential services as power, attitude control and pointing, sequencing, environmental control, precision navigation, and data collection and broadcast to Earth.

The orbiter design is the result of years of brainstorming and performance trade-offs, subject of course to budget limitations. New technology is also folded in by way of such advances as solid-state data recorders with no moving parts, very high speed integrated circuit (VHSIC) chips, powerful application-specific integrated circuit (ASIC) parts for onboard computers, and reliable solid-state power switches to eliminate transients that usually occur with conventional power switches.

Cassini can provide some 700 watts of power from the output of its three RTGs (radioisotope thermoelectric generators) to its engineering and scientific subsystems. It can point its sensors to accuracies of a tenth of a degree and

*The author thanks his friend and colleague Ellis Miner for reviewing the scientific content of this article.

maintain stability levels ten times slower than the motion of a clock's hour hand. It can control subsystem temperature levels to 10–40 degrees Celsius (18–72 degrees Fahrenheit), navigate to accuracies of 10 kilometers (6 miles) or better, store some 4 billion binary bits of information, and broadcast data to Earth at rates as high as 165,900 bits per second. The 18 instruments aboard the *Cassini-Huygens* spacecraft support 27 different scientific investigations.

THE *HUYGENS* PROBE

The 2.7-meter-diameter probe will enter Titan's atmosphere at about 6 kilometers per second (13,400 miles per hour). It will use a silica-based, shuttle tile–like heat shield to dissipate a heat energy input of 35 kilowatt-hours in less than a minute, reaching peak deceleration levels of 12.6 Earth *g*s and temperatures on its ablative front surface as high as 1,800 degrees Celsius (3,270 degrees Fahrenheit) in the process.

Shortly thereafter, the main parachute, which is 8.5 meters in diameter, will be deployed at an altitude of 170 kilometers (105 miles), followed 30 seconds later by the release of the heat shield and its supporting structure. This will allow the central module of scientific sensors to descend slowly through the murky atmosphere. At an altitude near 110 kilometers (68 miles), the main chute will be released and a smaller drogue chute will provide stability for the remaining descent to the alien surface.

The probe carries accelerometers to measure drag forces in the upper stratosphere, as well as other sensors to measure temperature and pressure. It also carries an instrument to measure the structure and physical properties of the atmosphere, an aerosol collector and pyrolyzer to examine clouds and suspended particles, a gas chromatograph and mass spectrometer to measure the chemical composition of gases and particles in the atmosphere, a Doppler wind experiment to study the effects of winds on the probe, and a descent imager and spectral radiometer to take 1,100 pictures of Titan's clouds and surface in order to learn about aerosols, cloud structure, and the nature and composition of the atmosphere and surface.

The probe's primary mission will be conducted during its atmospheric descent of 2–2.5 hours, but there is always the chance that it might survive touchdown, given a landing speed of only 5 meters per second (about 11 miles per hour). If it doesn't tip over too far, and if it can continue to function on battery power until the orbiter flies over the horizon, it may be able to use the instruments in its surface science package to tell us more about that surface. Its tiltmeter can measure wave motion if it lands in an ocean, and another device will be able to measure the liquid's index of refraction, providing clues to the composition of the ocean. A sounder can even give readings of ocean depths of less than a kilometer.

For more information about *Cassini-Huygens*, visit *http://saturn.jpl.nasa.gov/index.cfm*

Charley Kohlhase was science and mission design manager for the Cassini-Huygens *mission from near inception through launch. He was awarded NASA's Distinguished Service Medal in 2003 for mission design contributions spanning 40 years. Besides part-time consulting for several NASA/JPL missions, he is active in wilderness preservation, photography, and digital artwork—of which samples may be seen at* http://artshow.com/kohlhase *and* http://homepage.mac.com/kohlhase.

This 12- by 20-foot canvas, painted in 1995 by eight East Los Angeles muralists from the Academia de Artes Yepes, ages 8 to 17, depicts the mythological god Saturn removing a veil to allow the* Cassini-Huygens *spacecraft to explore the Saturnian realm in 2004–2008. The mural has been on display at several major museums throughout the United States, including the Kennedy Space Center.

Photo: JPL/NASA

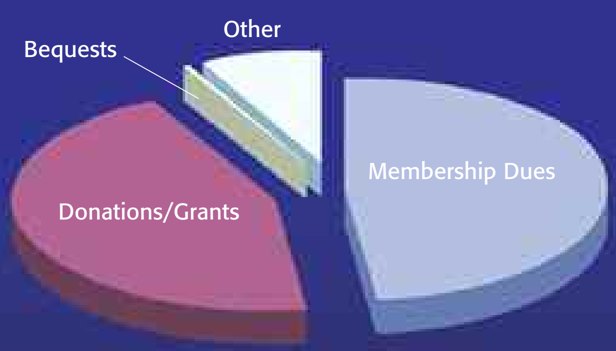
Annual Report to Our Members

Dear Planetary Society Members, Donors, and Friends:

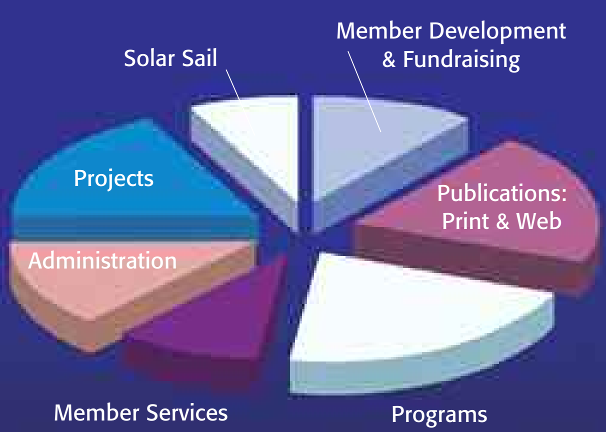
What a fantastic time for space exploration—we witness the rovers *Spirit* and *Opportunity* on Mars; *Mars Express*, *Mars Global Surveyor*, and *Mars Odyssey* orbiting above; fascinating new images and information about the Red Planet; *Stardust*'s exciting capture of particles from comet Wild 2; China's first manned space mission; and the United States' new and inspiring national space policy directive to extend human presence across the solar system.

You—Members and Supporters of The Planetary Society in more than 125 countries around the world—are leading the way with real exploration, science, and effective advocacy.

Fiscal Year 2003 Revenues



Fiscal Year 2003 Expenses



The following review of accomplishments over the past year and 5-year overview of our financial status are intended to give you a sense of your Society. A look back at 2003 and our many innovative projects shows clearly that with you, we are shaping the future of space exploration. Thank you!

- *Cosmos 1* Solar Sail mission, in partnership with Cosmos Studios, moved forward in its mission to test technologies that may one day pave the way for interstellar flight; hundreds of thousands of people viewed a sail blade displayed at New York City's Rockefeller Center.
- Red Rover Goes to Mars, a joint venture with LEGO on NASA's Mars Exploration Rovers, included several exciting components, some of them still under way: the first privately funded educational experiment to fly on a planetary mission; an international group of 16 stellar student "astronauts" who participated in the mission from inside Mission Operations at California's Jet Propulsion Laboratory; and Mars Stations around the world, including the Society's own Carl Sagan Memorial Mars Station.
- A Planetary Society contest, cosponsored by NASA and LEGO, named the rovers *Spirit* and *Opportunity.*
- The Gene Shoemaker Near Earth Objects grants funded amateur astronomers; our other scholarships helped high school and college students pursue planetary science studies.
- The Society's ongoing Search for Extraterrestrial Intelligence, including the remarkable SETI@home and other projects in both Northern and Southern hemispheres, continues to involve people around the world.
- Local events in communities around the world, including MarsWatch, which partnered the Society with museums, planetariums, science centers, and astronomy clubs from Hollywood to Vienna, and from Austria to the People's Republic of China, excited the public about Mars and the unusually nearby Mars opposition.
- We bade farewell to *Galileo* and celebrated the astronomer and the science team—Robert Picardo directed actors John Rhys-Davies and Linda Purl in a one-time reading of "An Evening with Galileo and His Daughter," written by *Galileo's Daughter* author Dava Sobel.
- Our Vulcanoids search exemplified your commitment to exploring the frontiers of space.
- Comprehensive and cutting-edge coverage on our website at *http://planetary.org* and via opt-in electronic newsletters kept you informed and excited, as they do today.
- Press around the world turned to the Society and its prestigious Board and Advisors for commentary and in-depth discussion about our projects and advocacy.
- The Society led with research and opinion, convening a workshop with the Association of Space Explorers and the American Astronautical Society to consider options for sending humans to Earth orbit and beyond.

Looking Ahead—The workshop's recommendations for human and robotic exploration throughout the solar system appear in the United States' new policy, which is a great victory for the Society. We are determined to realize the policy's goal and vision through building significant public, political, and international constituencies.

Your support, as Members and Supporters, is key to our success. Even in difficult economic times, you have maintained our financial strength. Major individual gifts and bequests have enabled us to undertake ambitious projects and advocate for exploration. We are making the most of this extraordinary time in space exploration by reaching out to new Members, especially to students, who are key to our future.

You make it possible to realize the vision with which Carl Sagan, Louis Friedman, and I founded The Planetary Society nearly 25 years ago: to inspire the people of Earth—through education, research, and public participation—to explore other worlds and seek other life.

With you, we will make it happen.

Sincerely,

Bruce Murray
Chairman of the Board

Balance Sheet

For the Fiscal Years Ended September 30, 1999, 2000, 2001, 2002, and 2003, in thousands of dollars.

	Total All Funds:				
Assets	FY2003	FY2002	FY2001	FY2000	FY1999
Current Assets					
Cash and Cash Equivalents and Investments	1,959	2,274	1,104	1,695	967
Membership Dues and Misc. Receivables	114	5	113	427	12
Inventories	47	49	45	43	43
Prepaid Expenses	21	20	42	16	75
Total Current Assets	**2,141**	**2,348**	**1,304**	**2,181**	**1,097**
Land, Building, and Equipment	**658**	**698**	**760**	**818**	**859**
Total Assets	**2,799**	**3,046**	**2,064**	**2,999**	**1,956**
Liabilities	FY2003	FY2002	FY2001	FY2000	FY1999
Liabilities					
Accounts Payable and Accrued Expenses	101	170	164	312	314
Deferred Dues and Grant Revenue*	1,420	1,864	1,614	2,020	1,753
Total Liabilities	**1,521**	**2,034**	**1,778**	**2,332**	**2,067**
Net Assets (Deficits)	FY2003	FY2002	FY2001	FY2000	FY1999
Unrestricted	60	28	(254)	(36)	(573)
Temporarily Unrestricted	1,217	983	540	703	462
Permanently Restricted	1	0	1	0	0
Total Net Assets	**1,278**	**1,012**	**286**	**667**	**(111)**
Total Liabilities and Net Assets (Fund Balances)	**2,799**	**3,046**	**2,064**	**2,999**	**1,956**
Revenues	FY2003	FY2002	FY2001	FY2000	FY1999
Membership Dues	1,636	1,703	1,780	1,994	2,030
Donations/Grants	1,495	1,285	1,797	1,885	1,077
Bequests	10	631	59	0	14
Other **	258	288	335	291	233
Solar Sail Grant	0	677	2,226	126	0
Total	**3,399**	**4,584**	**6,197**	**4,296**	**3,354**
Expenses	FY2003	FY2002	FY2001	FY2000	FY1999
Member Development & Fundraising	342	339	518	689	474
Publications: Print & Web	629	749	711	589	667
Programs ***	653	559	634	1223	735
Member Services	312	394	379	360	408
Administration	408	394	753	317	312
Projects	561	1,097	841	587	751
Solar Sail	228	326	2369	126	0
Total	**3,133**	**3,858**	**6,205**	**3,891**	**3,347**

* Income received but not yet recognized
** Admissions, events, interest, net sales, royalties, etc.
*** Events, lectures, tours, expeditions, educational outreach

Questions and Answers

An article about* Voyager 1 *approaching the heliopause made me wonder, how is the exact position of a spacecraft in space calculated?
—Taylor Barnett, Boulder, Colorado

In theory, it is relatively easy to keep track of a spacecraft's position in space. Data are received from *Voyagers 1* and *2* on a semiregular basis. Years of tracking spacecraft—along with direct measurements—have given spacecraft navigators very accurate position information on the location of each tracking station in the Deep Space Network relative to the center of the Earth and to each other. Navigators also have remarkably precise measurements of Earth's rotation and of the position of our planet's center relative to the center of the Sun as these change with time. Without accurate information on the locations of these tracking stations (relative to the center of the Sun), determining the exact position of a spacecraft would be essentially impossible.

Tracking of a spacecraft also involves precision pointing of the tracking antenna or antennas—something accomplished in part by moving the antenna back and forth across the expected direction of the incoming signal until the strength of the signal from the spacecraft (in this case, *Voyager 1* or *2*) is maximized. When that maximum signal strength is achieved, it defines the direction in the sky where the spacecraft is (or at least where it was when the signal being received left the spacecraft).

Determining the distance of the spacecraft along that line of sight then involves something called *ranging*, in which a series of very short (or coded) radio signals is occasionally transmitted from the ground, received by the spacecraft, and transmitted virtually intact (except for a slight change in the wavelength, or frequency, of the transmitted signal) back to Earth. The total delay time from ground transmission to ground receipt, including an adjustment for the very brief interval required for the turnaround at the spacecraft, can be measured to an accuracy of nanoseconds. Multiplying that delay time by the speed of light and dividing by two yields the distance of the spacecraft. The combination of direction and distance reveals the instantaneous position of the spacecraft.

In practice, however, the determination of a spacecraft's position with time is much more complex and includes both measurement of the craft's velocity and accounting for all the forces acting on it. These forces include slight changes in spacecraft velocity

Factinos

Scientists observing a sunlike star 90 light-years from Earth have found evidence of an extraordinary role reversal. Whereas stars normally heat planets, in this case a planet seems to be heating its star.

Observations suggest that a planet that whips around a star called HD 179949 once every three days produces a hot spot in the star's atmosphere. Evgenya Shkolnik of the University of British Columbia and her team reported these findings at the January 2004 meeting of the American Astronomical Society in Atlanta.

The hot spot, she says, probably results from a magnetic interaction between the planet and the star. If correct, this discovery would provide the first evidence that an extrasolar planet has a magnetic field. In turn, the presence of a magnetic field could provide new information on how and where such planets form.

Shkolnik and her team used the Canada-France-Hawaii Telescope on Hawaii's Mauna Kea to look for evidence of the planet's effect on HD 179949. They found a hot spot that was just a few percent brighter, on average, than they would have expected if the star alone had generated it. The observations, taken over more than a year, show that the hot spot moves in sync with the planet.
—from R. Cowen in *Science News*

For the first time ever, oxygen and carbon have been detected in the atmosphere of a planet outside our solar system. Alfred Vidal-Madjar of the Institut d'Astrophysique de Paris (CNRS, France) and his team used the Hubble Space Telescope to make their discovery.

The oxygen and carbon are bleeding off a giant gas planet in a tight, 3.5-day orbit around the star HD 209458, which lies about 150 light-years from Earth. The oxygen exists naturally (as it does throughout the universe) and does not indicate the presence of any sort of life on the hot, gaseous world. Nevertheless, it is a promising demonstration that the chemical composition of atmospheres on planets many light-years away can be measured.
—from *hubblesite.org*

in reaction to firings of attitude control jets, the gravitational effects of planets and the Sun, and the effects of solar wind pressure on the spacecraft.

Keeping track of all these effects and providing data on the position and velocity of *Voyagers 1* and *2* is the job of the Voyager Navigation Team—a job they do very well.
—ELLIS D. MINER,
Jet Propulsion Laboratory

While reading about SETI, it occurred to me that the only thing missing is some form of "gravity wave SETI." There are gravity wave detectors being built in Washington state and Louisiana. Would we be able to detect an intelligent modulation of gravity waves if, by some unimaginable technology, an extraterrestrial civilization was broadcasting with them?
—Bill Hilsher,
Baltimore, Maryland

Although gravitational waves have been predicted by Einstein's theory of gravity, they have not yet been directly detected. They have, however, been indirectly detected by observing a pulsar orbiting another star. The pulsar's orbit shrinks by just the amount it ought to if it's emitting gravitational waves. (You can read about it at *http://astrosun2.astro.cornell.edu/academics/courses//astro201/psr1913.htm.*)

As you know, the Massachusetts and California Institutes of Technology have built gravitational wave detectors in Washington state and Louisiana—a project called the Laser Interferometer Gravitational Wave Observatory (LIGO). They began operation in 2002 and haven't yet detected any such waves.

It is theoretically possible that a vastly superior civilization might be able to use gravitational waves to signal—though from our present primitive understanding of physics, that seems like the hard way to do it. Radio and light signals are much easier to generate.

There's a good chance that LIGO will detect gravitational waves in the next few years. Should that happen, scientists will study those signals very carefully to deduce the kind of object that emitted them. If there is an artificial variation in the signals, they probably will see it.
—TOM McDONOUGH,
SETI Coordinator

On page 13 of the January/February 2004 issue of* The Planetary Report, *Melissa Lane, in her article about Mars, states, "the weathering effects of wind and time on the gray hematite may have worn down the original deposits."

I have read much about the weathering effects of wind on rock and soil, but I am curious as to what the weathering effects of time are. Can time alone, absent other sources of weathering such as wind, water, and gravity, have an effect on rock and soil?
—Donald H. Coleman,
Sonora, California

Time itself is not a true weathering agent. However, when considering weathering processes on Mars, time becomes quite relevant. On Earth, plate tectonics act to regenerate rocks and resurface the planet, but Mars does not have plate tectonics. Therefore, many surfaces on Mars are billions of years old (as determined from crater densities).

Long-term exposure to ultraviolet radiation, temperature cycling, and micrometeorites (as well as larger meteorites) can indeed affect the breakdown of the Martian surface without the aid of wind, water, or gravity.
—MELISSA LANE,
Planetary Science Institute

NASA's *Stardust* spacecraft has begun its two-year journey back home to Earth after surviving an out-of-this-world sandblasting by cometary particles. On January 2, 2004, *Stardust* successfully passed through the particle- and gas-laden coma surrounding comet Wild 2. During the hazardous traverse, *Stardust* flew within 240 kilometers (150 miles) of Wild 2, gathering samples of comet particles and snapping detailed pictures of its pockmarked surface (see image at right). "Things couldn't have worked better in a fairy tale," *Stardust* project manager Tom Duxbury said of the encounter.

The particles collected from Wild 2 are stowed in a sample return capsule on board the spacecraft and will be returned to Earth for in-depth analysis on January 15, 2006.

To read more about *Stardust*'s amazing encounter, go to *http://planetary.org/news/2004/stardust_success.html*

Stardust ***captured this image during its closest approach to comet Wild 2 on January 2, 2004. Although the comet's nucleus is roughly spherical, this distant side view—with one hemisphere in sunlight and the other in shadow—is more like a view of the quarter Moon. Wild 2 is about 5 kilometers (3 miles) in diameter.*** *Image: JPL/NASA*

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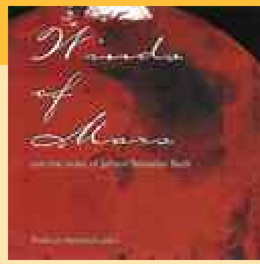

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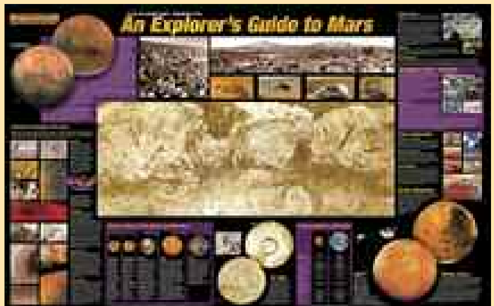

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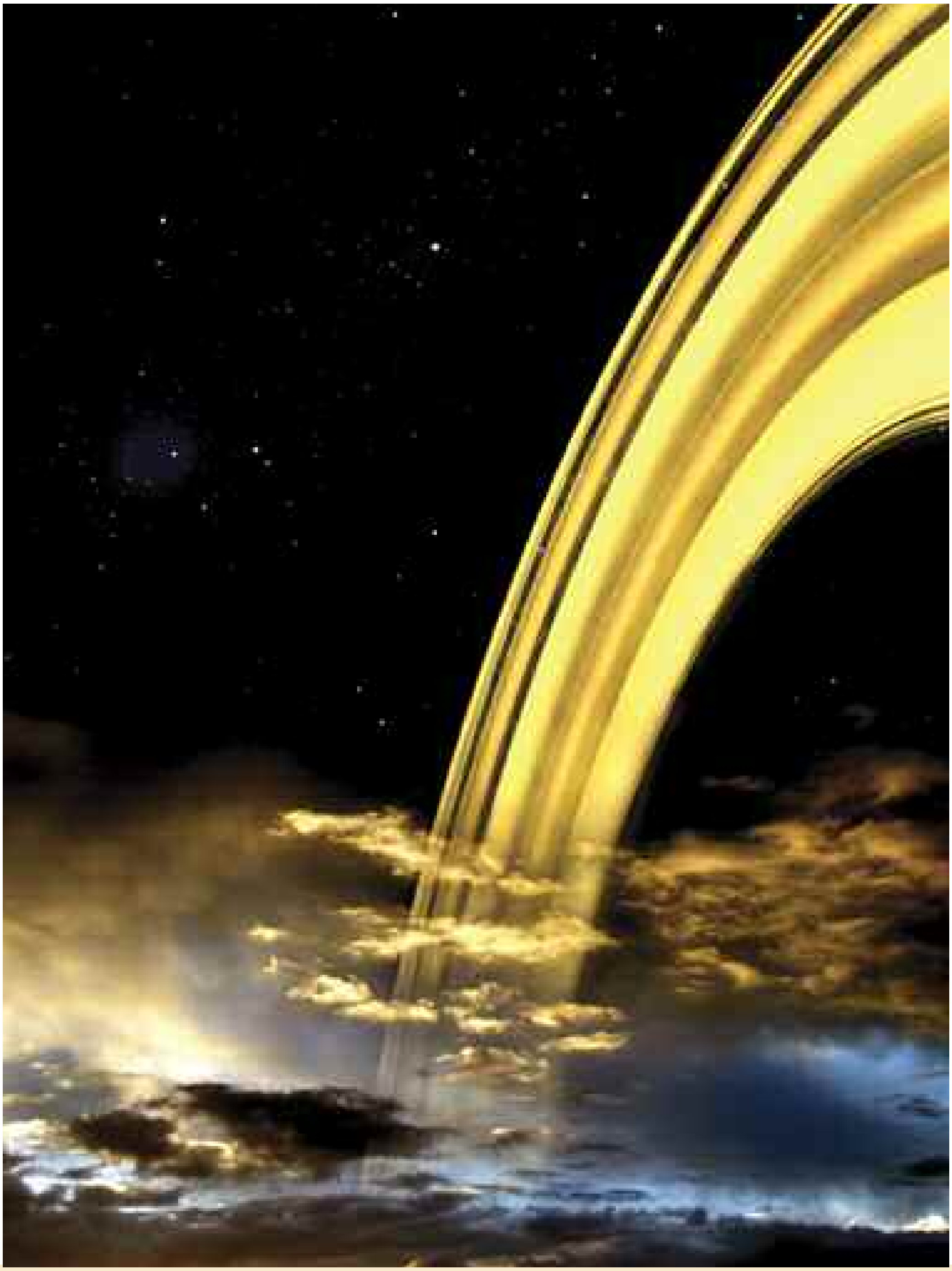

If a single structure in our solar system deserves to be called "planetary jewelry," it is the Saturnian ring system. These trillions of chunks and specks of ice and rock encircle and adorn the gas giant, setting it apart from all its planetary neighbors. In *Sunrise Over Saturn*, the rings shimmer like bands of gold over the planet's cloud tops.

Like so many others who have devoted their careers to space exploration or the depiction thereof, Frank Hettick experienced a defining moment in his young life when he acquired a copy of Willy Ley's *The Conquest of Space* with illustrations by Chesley Bonestell. Hettick, a member of the International Association of Astronomical Artists, lives and works in Crooked River Ranch, Oregon, where he owns and operates Sky High Galleries.

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