The PLANETARY REPORT

Volume XXX Number 2 March/April 2010

Spirit on Mars

From The Editor

"Transformation" is one of my favorite words. It's more mellifluous than "change" and also more positive, almost always implying something better to come. In this issue, we cover two transformations, one potential and one certain to occur.

NASA's human spaceflight program stands at the brink of transformation if the 2011 budget proposal survives its run through the U.S. Congress. It's inevitable that dreams of spaceflight are run through a federal process that grinds them into little bits for distribution among congressional districts. The process reminds us that "All politics is local." When the goal is to see humanity on its way to other worlds—the antithesis of "local"—the process can be exasperating.

Transformation is made harder when the agent of change—in this case, the U.S. presidential administration—fails to make plain its vision of the future that is intended to be born from the transformation. In an expanded "World Watch," Lou Friedman lays out the potential that The Planetary Society sees in this proposal and the reasons why the Society is supporting the administration's budget.

Speaking of Lou Friedman, he is the agent of the transformation that is certain to come—he is stepping down as executive director of The Planetary Society. The Society will now undergo its own transformation, with the nature of the new organization, in many ways, up to you and your fellow Members. Let us know, through communications channels such as Facebook, e-mail, and letters, your vision of a transformed Planetary Society. Together, we'll make it happen.

—Charlene M. Anderson

On the Cover:

Spirit is the small bright dot to the left of Mars' Home Plate in this image, taken July 16, 2009 by the High Resolution Imaging Science Experiment (HiRISE) on *Mars Reconnaissance Orbiter (MRO)*. If *Spirit* does not break free, it may rest there forever. The other bright areas around Home Plate are spots where the rover has churned up the soil. Image: NASA/JPL/University of Arizona

Background:

Mars' Nilosyrtis region was one of dozens of areas originally considered as a landing site for NASA's Mars Science Laboratory, scheduled to launch in fall 2011. Nilosyrtis, which lies just north of Syrtis Major, interests scientists because both *MRO* and *Mars Express* have detected phyllosilicate (clay) minerals there. These minerals are important in the search for evidence of microbial life. This view is part of a larger image taken by HiRISE on September 22, 2007. North is to the left.

Image: NASA/JPL/University of Arizona

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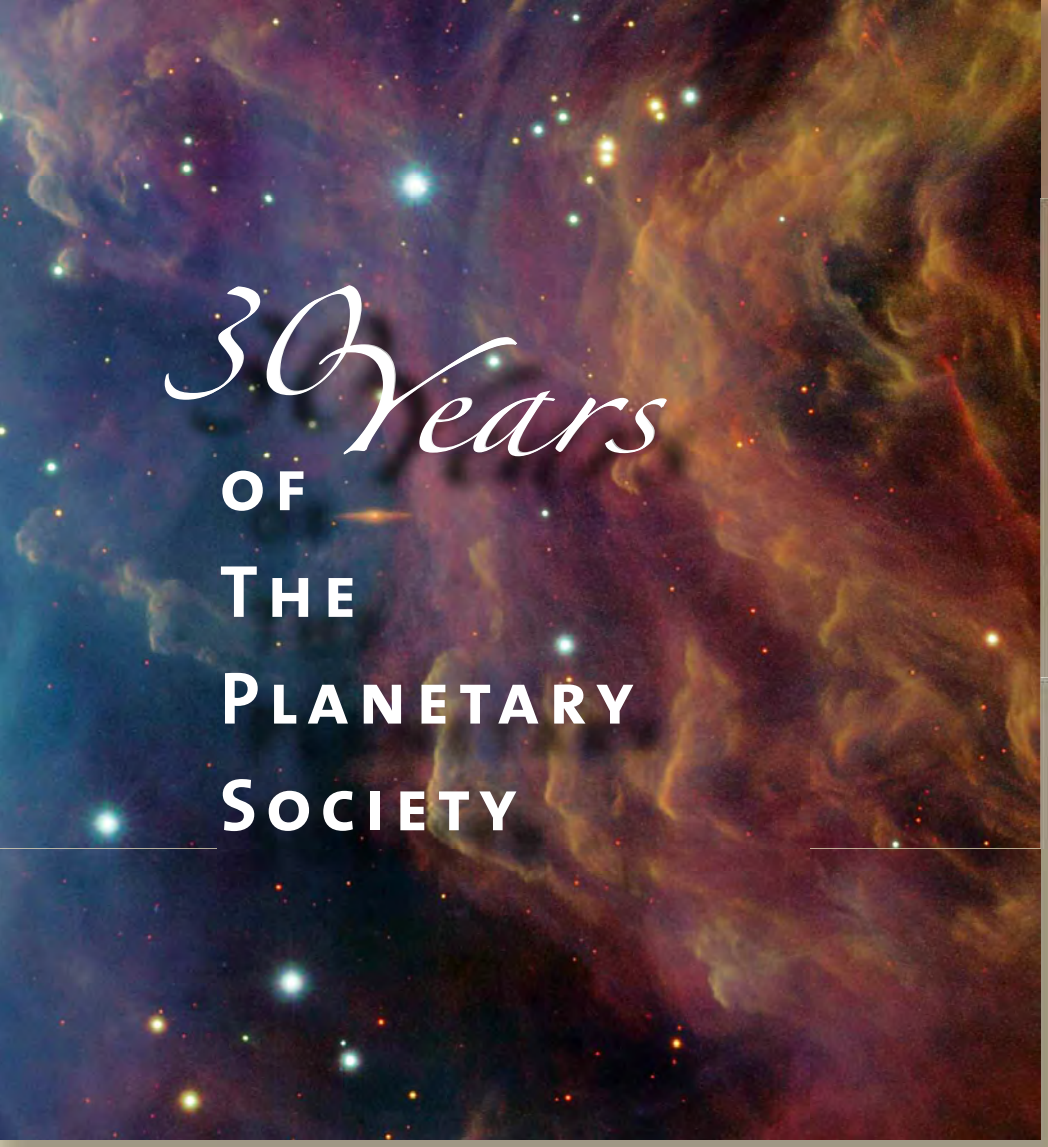


30 Years of The Planetary Society

Much has changed in the 30 years since The Planetary Society was founded. Those early days brought us many first-time views of the bodies in our own solar system; now, discoveries of extrasolar planets and kaleidoscopic views of deep space objects are part of our daily lives. This image, taken by the European Southern Observatory's Visible and Infrared Survey Telescope for Astronomy (VISTA), reveals a region near the center of the Orion nebula. Here, the fierce ultraviolet light from the Trapezium cluster sculpts gas clouds into wavy shapes. A distant, edge-on galaxy is visible shining through the nebula.
Image: ESO/J. Emerson/VISTA, Cambridge Astronomical Survey Unit

BY LOUIS D. FRIEDMAN

Space exploration is—in its essence—about the future. For 30 years now, I've served as executive director of The Planetary Society and directed my energy to helping create a future for humanity among the planets—exploring new worlds, seeking life on other worlds, and deepening our understanding of our home world. It's been quite a ride.

In 1979, Bruce Murray called me to his office on the top floor of the administration building at the Jet Propulsion Laboratory. Carl Sagan and he had been discussing the best way to preserve planetary exploration, which was then threatened in the United States by government budget mavens who thought no one would care if missions such as *Voyager* and *Galileo* quietly went away. Bruce and Carl had decided to form an organization with tens of thousands of members to demonstrate that people wanted space exploration to continue, and they asked me to lead it. Obviously, I agreed. In 1980, The Planetary Society started operations, and I am mighty proud of what we did.

Looking Back and Looking Ahead

Right now, I have no interest in looking back—the future is too exciting. We've entered a time of huge and profound change. The U.S. president has just proposed a seismic shift in the way NASA will pursue space exploration, a shift that I believe will lead more quickly to the future we once envisioned, a future that includes human explorers walking on Mars.

As the U.S. space agency changes, new players are entering the game, with China and India joining Russia, Europe, and the United States as spacefaring nations. Other nations, such as South Korea, Israel, Brazil, and Iran, are launching their own satellites, and others will follow. Competition still drives many space endeavors, but we've seen the International Space Station become a shining example of what cooperation can do in space. I believe that as humanity reaches beyond the Moon to Mars, we will undertake this great adventure as a planet, not as racing nations.

On the scientific front, we moved from getting our first glimpses of neighboring worlds in the solar system to pondering the possibilities of life in other star systems on new worlds we are discovering every day. Closer to home, we now know for certain that water once flowed across the plains of Mars, and we've discovered an ocean of liquid water on Europa and water geysers on Enceladus. Humankind may be only years from learning that we are not alone in the universe.

The greatest change I've seen in space exploration may well be the emergence of private companies and commercial industry in space exploration. I used to think it would be a century before they became major-league players in space, but now I see it might happen in less than a decade. The Obama plan proposes to engage that new industry in human space exploration. I hope it will bring new resources and new opportunities.

The Role of The Planetary Society

In addition to the external changes affecting us, we continue to experience organizational change. When we started there was no Internet, and *The Planetary Report* was a unique source for information about planetary exploration. Now we operate a thriving website, host a radio show, and interact through social media. We've also found new ways to connect the public directly with space missions, leading

to hundreds of thousands of members and supporters seeing their names flown around the solar system.

Through SETI@home and Stardust@home, we've made it possible for anyone to participate in real space science. Our initial research projects were ground-based radio searches for signs of extraterrestrial intelligence and near-Earth asteroid discovery projects. Now we are sending payloads into space, such as our Phobos Living Interplanetary Flight Experiment (LIFE), and developing our own satellite and space mission, *LightSail-1*. When we started The Planetary Society, I would never have dared dream our organization would come so far.

Now, it's time to plan how The Planetary Society can go even farther and chart a course into the future. Our Board of Directors has initiated a strategic-planning process to look at our three principal functions: advocacy, education, and innovative projects. They will evaluate our potential contributions and what we will need to achieve them. They will consider this question: if we were creating a new space exploration organization, would it be the same as the one we created in 1980?

Our Board is deeply involved in answering this question, and we welcome your views. One easy way is to write to me at *louis.friedman@planetary.org*.

Changes to Come

At the same time, we are charging ahead with the Society's exciting and audacious solar sail project, *LightSail*. Undertaking this program with three missions is a huge task and is an impetus for us to find new ways of doing business and raising funds to achieve our shared ambitions.

Our other innovative projects, such as Phobos LIFE, a new Mars microphone, techniques for protecting Earth from threatening asteroids, and the search for extraterrestrial intelligence, have been a great source of vitality. In our strategic plan, we will consider how we can now better use them to stimulate even more private-sector innovation and public-private partnerships.

We are also making a physical change by moving out of our wonderful old Pasadena home into a more efficient and economical location. Maintaining an old architectural masterpiece is not the best use of our time and money, but the many members who made it possible for us to buy this Greene & Greene building and occupy it for 25 years should take great pride in knowing they made a good investment. We raised more than double our purchase price and are able to use the proceeds to further advance our innovative projects.

We anticipate moving to a new location in May. We are considering several candidates (all near Caltech and JPL) and plan to make a final decision just about the time this magazine goes to press.

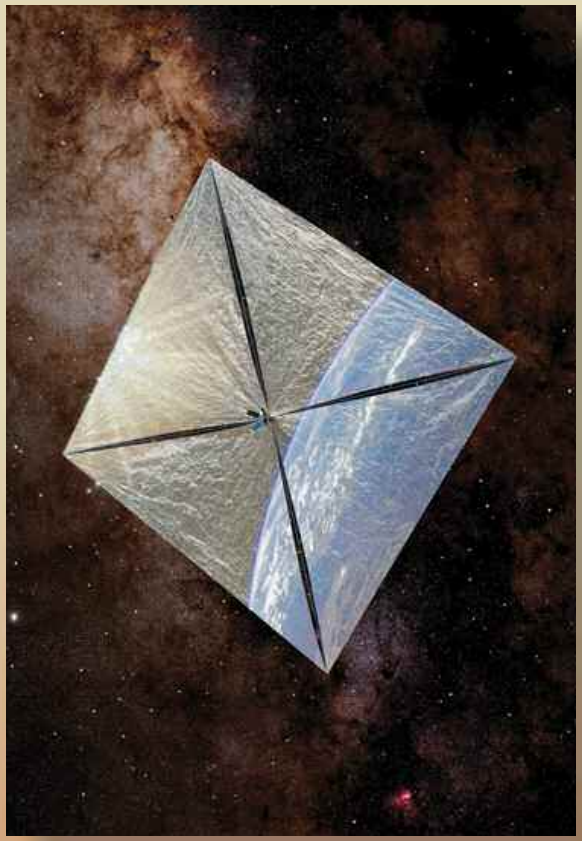
Change is afoot—new headquarters, new projects, new directions for NASA, and new international partners in space. One more change will come. For the past 30 years, I've been the sole executive director for the Society. Perhaps my single greatest task now is to ensure that the legacy of those years grows and thrives for many decades to come. As a result, I plan to step down from my day-to-day management responsibilities and to hand the reins over to a new leader. The Board of Directors and I are working to find that new leader and create a smooth transition.

I will remain on the Board of Directors and continue to contribute to our projects, particularly in our *LightSail* program and our leadership as advocates for planetary exploration. Later this year, I will introduce you to my successor and to future plans for the organization. You can be assured that the Society will pursue bigger and bolder ideas and projects while becoming a more effective advocate for the exploration of space.

Officially, I will be retiring, but I am not retreating. I will remain fully engaged with and in The Planetary Society through specific project and communication activities. The Society has provided me with a great ride through life—with all the great people I've met and the things we've accomplished together—and I have no intention of slowing down, let alone getting off the ride.

You're on this adventurous ride, too. Stay on board while we search for habitable planets, seek life elsewhere in our galaxy, explore unknown worlds, learn more about our own planet and its dynamic environment, and witness humankind venture farther out into the solar system and one day reach Mars. We're excited to continue this adventure for another 30 years and more.

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



The Planetary Society's new* LightSail *spacecraft will merge the ultralight technology of nanosats with the ultralarge technology of solar sails to set a course for the stars.

Illustration: Rick Sternbach, © The Planetary Society

A New Project: Microrovers for Assisting Humans

by Bruce Betts

Microrovers would likely be between the sizes of* Sojourner *(top) and* Muses-CN. *Photo: NASA/JPL

I am excited to share with you a new Planetary Society project. Cornell University and The Planetary Society have received a NASA grant to study "Microrovers Assisting Human Presence on the Moon and Mars." The Planetary Society, in general, and I, personally, have long been intrigued by the possibilities of microrovers—by which we mean rovers with a mass of a few kilograms. This study will give us an opportunity to better understand and define microrovers: what they could do, how they might be important, and what their designs should include.

Background

The story of this NASA grant program begins with a Planetary Society member, Ralph Steckler. He left a bequest to NASA—with The Planetary Society as the backup recipient if NASA couldn't take the money—"for the colonization of space because [he believed] this is for the betterment of mankind." NASA found a way to utilize the money by creating the Ralph Steckler/Space Grant Space Colonization Research and Technology Development Opportunity.

The program is open to proposals only from NASA Space Grant University leads—one in each state. Because of their rover expertise, we approached folks at Cornell University with the idea of using microrovers as assistants to human exploration. We started the discussion with Jim Bell, who is Planetary Society president, a Cornell professor, and Mars Exploration Rovers Pancam lead. Jim signed on as a co-investigator on the proposal, and the New York Space Grant director, Professor Yervant Terzian, agreed to head up the proposal to the Steckler grant program.

Our proposal was one of 18 selected by NASA to receive Phase 1 funding. The Planetary Society will manage and coordinate all technical studies and input, as well as work on various aspects of the project. In addition, NASA requires us to match a significant portion of the funding.

The Planetary Society has a long history with planetary rovers. It carried out rover testing in the early 1990s in the Mojave Desert, which helped raise the profile of rovers and pave the way to what became *Sojourner* and, later, the Mars Exploration Rovers. By the way, all three Mars rovers—*Sojourner*, *Spirit*, and *Opportunity*—were named through contests run or co-run by The Planetary Society for NASA.

Why Microrovers?

NASA and other countries have studied large rovers designed to carry humans, medium-sized robotic rovers like those used now on Mars, and even a low-gravity "nanorover," but there is a largely unstudied niche of microrovers, which we loosely define as rovers with masses of one to a few kilograms. Even less studied is how they might work with humans on the Moon, Mars, or other bodies.

Because of their low cost and mass, several microrovers could be used at an outpost and would be easy to customize and deploy. Think how much easier it would be to include a few microrovers on a robotic precursor or on a human mission than to include a single rover with a mass of many hundreds of kilograms.

Microrovers could assist human explorers with basic tasks outside their habitat while humans remain safely inside, thus increasing efficiency and safety as well as helping to limit extravehicular activities to human-optimized tasks. Our project will address the capabilities that microrovers could and should have to assist humans, including facilities for inspection, science, and reconnaissance.

Also, let's face it—they're cool! That's not enough to motivate studying them, but it sure makes the project and the vision more fun. Imagine astronauts carrying a few of these intrepid explorers with them to a planetary surface. They would "release" them to do reconnaissance around the site so that when the astronauts went outside, which is always dangerous work, they could focus on the most promising discoveries already made by the micro-

rovers. The microrovers could be teleoperated (joysticked) by astronauts or from the ground, or they could operate autonomously. They also could explore areas considered too dangerous for astronauts to visit.

The Long-Term Vision

What we'd like to end up with after a multiphase project is the creation of a well-studied, Earth-tested, standardized microrover design that can be utilized with a variety of future payloads. Like the CubeSat model for spacecraft, a standardized microrover with built-in chassis, electronics, and driving abilities would enable competition among specific scientific and engineering payloads for a variety of applications. This would allow flexibility and encourage participation by a variety of types of people and institutions.

NASA's Phase 1 is intended to establish the scientific and technical merit and feasibility of the project. After Phase 1, groups submit proposals for Phases 2 and 3, which in our case would actually get into prototyping and field testing.

Here's what we'll do in Phase 1. We are gathering what microrover work has been done for rovers in space and on Earth. In preparing the proposal, it was clear that a central source for this type of information didn't exist. The Planetary Society will become this central source. Much has been done on larger rovers for space, but also for microrover-sized vehicles on Earth—from military microrovers to science and commercial microrovers. Although, clearly, some aspects of design won't be relevant, some will, and we don't want to reinvent the (rover) wheel.

We also will be focusing on studying microrover capabilities to assist humans and to carry out tasks to support human colonization and settlement. We'll learn what they can do to be useful and which roles really are optimized to be carried out by microrovers.

These desired roles will then motivate requirements for "Studies of Trade-Offs and Optimum Designs for Microrovers for Human Settlement and Colonization," a collaboration of a Cornell design class taught by Professor Mason Peck and a professional design group led by Tomas Svitek of Stellar Exploration, Inc., with whom we have worked on other projects such as Phobos LIFE and *LightSail-1*.

Another part of the project is to conduct public information and outreach activities, given that this is part of what The Planetary Society is intended to do: communicate with and inspire the public on matters concerning space exploration.

Besides myself and those already mentioned, others who also are formally involved with the project are former astronaut, planetary scientist, and Planetary Society Adviser Thomas Jones; former JPL engineer and advanced concepts manager Doug Stetson; and JPL rover engineer, designer, and manager Brian Wilcox. We're also engaging a number of students, both in the Cornell class and outside it. We have a great team and a great project, and we're rolling out on microrovers.

Bruce Betts is director of projects for The Planetary Society.

What's **Up?**

In the Sky—April and May

The early evening is rich with planets. Venus looks like an extremely bright star in the west after sunset. Dimmer Mercury is below and to Venus' right in the first half of April. Reddish Mars is bright but fading, high overhead moving from Cancer to Leo during April and May. Yellowish Saturn is high in the east in Virgo. See the Moon march across the sky while it goes from crescent to gibbous: next to Venus on May 15, Mars on May 19, and Saturn on May 22. In the predawn sky, extremely bright Jupiter will be low in the east, rising as the weeks pass. There is a partial eclipse of the Moon (about half eclipsed) on June 26, visible from most of the Americas, the Pacific Ocean, Eastern Asia, and Eastern Australia.

Random Space Fact

Mars' Olympus Mons is the highest mountain in the solar system, with a height above the average Mars surface level nearly three times the height of Mount Everest above sea level. Olympus Mons is also the size of the U.S. state of Arizona, so most of its slopes are very gentle: about 2 to 5 degrees.

Trivia Contest

Our September/October contest winner is Bobby Baum of Bethesda, Maryland. Congratulations!

The Question was: Who was the first person to spend more than one day in space?

The Answer is: Gherman Titov on *Vostok 2*.

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

Commonly used to assist in classification and characterization of stars, an H-R diagram is a plot of the temperature of many stars against their luminosities. What does H-R stand for?

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 June 1, 2010. The winner will be chosen by a random drawing from among all the correct entries received.

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*.

Winds of Change at NASA

The Obama administration's proposed NASA budget for fiscal year 2011 would cancel the Constellation program and take a new approach, using commercial providers—with additional funding—to launch humans into Earth orbit and beyond. These proposals have ignited a firestorm in the space community, and change is by no means certain to be implemented.

The struggle has just begun. Special interests involved in affected NASA programs started attacking the proposed budget before it was released. My opinion is shaped by one simple criterion: will this new policy get human explorers beyond low-Earth orbit more quickly than Constellation, or will it further delay our reaching this long-overdue goal?

Some say the budget will cause delays—Constellation was supposed to land humans on the Moon by 2020. Others say it will speed things up by bringing new resources to rocket development. Constellation was years behind schedule. Work had not started on the heavy-lift, deep-space rocket needed for human space exploration, and the goal of a Moon landing was estimated to be no earlier than 2028! Before considering the opinions, let's look at the specifics of the budget proposal now before the U.S. Congress.

First, the money. NASA gets an increase of 1.5 percent, for a record total of $19 billion, despite a proposed freeze on most federal discretionary spending. Over the next five years, NASA would get $100 billion total, an increase over projections. The budget would:

- Cancel Constellation.
- Extend operations and increase science use for the International Space Station. The previous plan was for NASA to abandon the station in 2015.
- Add $6 billion to engage private companies to develop launch vehicles so that the government can buy launch services through commercial contracts.
- Provide money for technology development for heavy-

Flexible Path

Although the proposed budget does not mention it, much of the new policy follows the "flexible path" suggested by the Review of U.S. Human Space Flight Plans Committee, known popularly as the Augustine Committee. The flexible path is remarkably similar to The Planetary Society's *Beyond the Moon: A New Roadmap for Human Space Exploration*.

The proposed plan has been criticized as having no destination. As pointed out by the Augustine Committee, however, "Mars is the ultimate destination." The flexible path is a way to get there that sets interim technical steps and provides a series of publicly interesting milestones, such as sending the first humans to a Lagrangian point or to a near-Earth asteroid. In this economic climate, to send Congress a plan for NASA that sets a human expedition to Mars as its goal would be a political mistake.

We believe the political situation will improve, and The Planetary Society will continue to push for human Mars exploration as a step forward on the path into the solar system.

—LDF

What Does "Commercial"

by William Pomerantz

President Obama's FY 2011 budget proposal marks a clear shift in NASA's attitude toward commercial industry. Facing a multiyear gap in its human spaceflight capacity, the administration has called for NASA to turn to private companies to reach orbit. This vision for NASA has spurred passionate responses, and no issue has been more controversial than this one. But what, exactly, does reliance on commercial launches entail?

First, let's look at the plan under the previous NASA administrator and U.S. president. Commercial launches were a core part of the Constellation program. NASA would have depended on the Russian Soyuz to launch astronauts to the International Space Station, with seats costing roughly $50 million. This would have been NASA's only access to the ISS between the retirement of the space shuttle, originally slated for late 2010, and the first crewed flights of the Ares/Orion system, not scheduled to occur until sometime between late 2014 and late 2017.

Second, NASA would purchase ISS cargo supply services from American companies under the Commercial Orbital Transportation Services (COTS) program, initiated in 2006. Companies were required to find private funds to match government investment to drive the development of these orbital lift vehicles. NASA also initiated the Commercial Resupply Services (CRS) program, which offered contracts for ISS

lift, deep-space rockets and other key technologies for human spaceflight, including in-space propulsion and in situ resource development.

- Support science. Planetary science would grow steadily, with full funding for Mars missions, added funding for near-Earth object research, and a restart of the advanced radioisotope thermoelectric generators for future space power. Both the James Webb Space Telescope and the Solar Probe mission would be funded.
- Strongly support Earth science, including a reflight of the ill-fated Orbiting Carbon Observatory. The Earth science budget would grow 60 percent over five years.
- Initiate a new class of robotic missions as precursors for human spaceflight, including missions to the Moon, Lagrangian points, and near-Earth asteroids.

The Planetary Society Board of Directors supports all these proposals.

It is sad that the Constellation program has to be canceled. Having gone through program cancellations myself in my JPL days, I sympathize with the dedicated and excellent workers of the Constellation team. It is not their fault the program was underbudgeted and inadequately supported.

Inevitably, there will be job losses and economic dislocations, but the new policy is intended to create a new launch services industry with new jobs. Although no one can guarantee the outcome, with change comes opportunity, if the space community is ready to seize it.

Six years ago, The Planetary Society strongly supported the Vision for Space Exploration. That program never got the money necessary to achieve its goals, and other worthy endeavors, such as science, had to be cut to save it. The vision narrowed to a permanently manned lunar base that never caught the public's interest. The Ares slipped behind schedule and held back the heavy-lift launch vehicle technology to land people on the Moon or send them to Mars.

Will hopes for the new plan be similarly dashed? I can't predict, but I believe that change was necessary and hope that the extra money, the use of international partners, and new technology development will work—and I will work hard to see it pay off.

At The Planetary Society, we plan to be closely involved in shaping the new program, and our efforts begin now. We will testify before Congress, lobby its members, build coalitions, and make it happen.

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

REALLY MEAN?

cargo delivery. These programs would allow NASA to avoid paying Russia for continued cargo deliveries after 2011.

President Obama altered this plan by expanding the COTS and CRS programs with a $6 billion Commercial Crew Program. This amounts to a multibillion-dollar investment in American businesses, spurring them to develop capabilities from both existing and new rockets. These groups will use rockets new and old, ranging from the venerable Atlas V (which just launched the $850 million *Solar Dynamics Observatory*) and Delta IV (which has launched numerous multibillion-dollar national security assets), to relative newcomers such as SpaceX's Falcon 9, scheduled for its maiden launch this spring. This could create new jobs and send new revenue flowing into the U.S. economy.

This plan is not without risk—but no multibillion-dollar space activity ever could be. Ensuring the safety of human crew members will continue to be extremely demanding. The companies are already working with NASA to more clearly codify the standards for "human-rating" these launch systems.

Commentators who say that NASA is abandoning human spaceflight and taking a totally new direction with commercial industry lack the proper context. Rather, NASA is fostering an entire industry that will provide vibrant human spaceflight capabilities.

William Pomerantz is senior director of Space Prizes for the X Prize Foundation.

WORKING WITH INTERNATIONAL PARTNERS

The Obama administration's budget presentation included many glowing words promising to engage international partners, with hints that this includes "non-traditional" partners, meaning China, India, and South Korea. The Constellation program also sought international partners, but only after its basic plans were laid out. Russia and Europe were never very much interested in landing on the Moon, and within days of the budget rollout, they commended the U.S. course change.

Some in Congress have tried to raise the specter of the United States "losing" the Moon to China or India, but both nations are at least a decade away from attempting to land people there. With the new efforts to engage world partners in a broader space program, it may be that any lunar plans will become more international. As our good friend and adviser Buzz Aldrin has put it, "If we want to use the Moon as a stepping-stone in the future, we'll have to join with our international partners for the effort. No more 'go it alone' space projects."
—LDF

Spirit: NOT DEAD YET

by Emily Stewart Lakdawalla and Jim Bell

Spirit ***(right) sits in a valley off the western shoulder of Home Plate in this visualization by Glen Nagle.*** **Spirit** ***captured the panoramic view of the Home Plate plateau on sol 743 (February 4, 2006) as the rover was driving southward, completing its descent of the Columbia Hills to reach the Inner Basin and Home Plate. Just beyond the plateau of Home Plate is a low, rock-capped peak named Von Braun, the target that*** **Spirit** ***'s drivers were attempting to reach when the rover became bogged down in soft sand at Troy.***
Credit: NASA/JPL/Cornell/(c) 2010 Glen Nagle

To borrow a line from Mark Twain, the reports of the Mars Exploration Rover *Spirit*'s death have been greatly exaggerated.

You could be forgiven if you had begun mourning *Spirit*'s death in January, when the rover was the subject of a press briefing. The director of NASA's Mars Exploration Program, Doug McCuistion, then stated, "It looks like *Spirit*'s current location on Mars will be its final resting place." Headlines in newspapers around the world announced that *Spirit*'s days were numbered; stuck in a sand trap on Mars, the former rover was now a stationary lander and would shut down over the coming Martian winter, never to be heard from again.

The true situation is serious, to be sure, but we certainly haven't heard the last from *Spirit*, nor have we seen the end of its roving.

The Story of Home Plate

How did *Spirit* come to its present crisis? The rover team drove *Spirit* to the Columbia Hills in the summer of 2004 and finally crested the summit of Husband Hill in the summer of 2005 (around sols 580–620; a sol is a Martian day). From there the team began a slow descent into the "Inner Basin" to the southeast of the summit, heading for a small, bright, enigmatic, circular patch that could be seen in the distance. In orbital pictures, the bright patch looked a bit like home plate on a baseball diamond, and the name stuck: Home Plate would be *Spirit*'s next destination.

Home Plate and its environs have turned out to be worth the long journey. *Spirit*'s most significant discoveries have been made there, during a lengthy science campaign lasting through 2006 and 2007. Home Plate itself is a layered, semicircular plateau about 90 meters across and rising 2–3 meters above the surrounding plains. *Spirit*'s two Earth years of study at Home Plate indicate that the edifice probably is a volcanic feature. Its many layers appear to have come from repeated explosive (pyroclastic) eruptions of an ancient volcanic vent, and this layered material subsequently was eroded and further shaped by the wind in the billions of years since the volcanic vent was last active. Although the ancient volcano was a fascinating find, it was not precisely the watery environment *Spirit* had been sent to Mars to find and study.

Meanwhile, shortly before *Spirit* arrived at Home Plate, the motor for the rover's right-front wheel stopped working. With a 1,500-to-1 gear ratio, a stuck motor means an immobile wheel, so the team was forced to drive the rover backward and drag that wheel behind it in order to continue toward Home Plate. In the process, what first seemed like a handicap for *Spirit* turned out to be the key to several

The images at the top and bottom corners of this page are from* Spirit*'s front and rear Hazard Avoidance Cameras (Hazcams), respectively, and were taken on sol 2,078 (November 7, 2009), after* Spirit *had been bogged down at Troy for nearly 200 sols. Over the next two right-hand pages are two more sets of front and rear Hazcam images from two milestone sols. You can flip the pages back and forth to compare* Spirit*'s progress between them. ***Images: NASA/JPL***

discoveries. The stuck wheel became a trenching tool and, to everyone's surprise, started digging up some bright whitish and yellowish soil deposits.

Here, at last, was evidence for ancient water on Mars, but in an unexpected context. The bright soils turned out to be loaded with hydrated sulfate minerals. The specific minerals have not yet been identified definitively, but a representative terrestrial example of a hydrated sulfate is epsomite (chemical formula $MgSO_4•N7H_2O$, the chief component of Epsom salts). A little farther on, *Spirit* started detecting hydrated silica minerals ($SiO_2•nH_2O$) as well.

This was a major discovery! Hydrated silica and sulfate minerals often form under hydrothermal conditions on Earth, in the mineral-rich groundwater near active or recently active volcanoes. The soils around the eroded volcanic deposits at Home Plate thus provide the best evidence yet found in *Spirit*'s mission for ancient watery environmental conditions.

Hydrothermal environments on Earth often support thriving microbial ecosystems. Although *Spirit*'s data haven't revealed any specific evidence of ancient microbes or biologic activity near Home Plate, the discovery of some key marker minerals points to the environment having been at least habitable, if not inhabited. If that right-front wheel hadn't failed, we might never have seen those exciting water-related mineral deposits.

A Sticky Situation

Home Plate was the subject of more than a full Martian year (nearly two Earth years) of study. As 2007 came to a close, *Spirit* was positioned off the northern edge of Home Plate to tilt the solar panels toward the winter Sun. *Spirit* spent most of 2008 parked as a stationary lander. As the springtime Sun returned, and with it solar power, the science team finished up their detailed investigation of the plateau and its interesting soil and rock deposits.

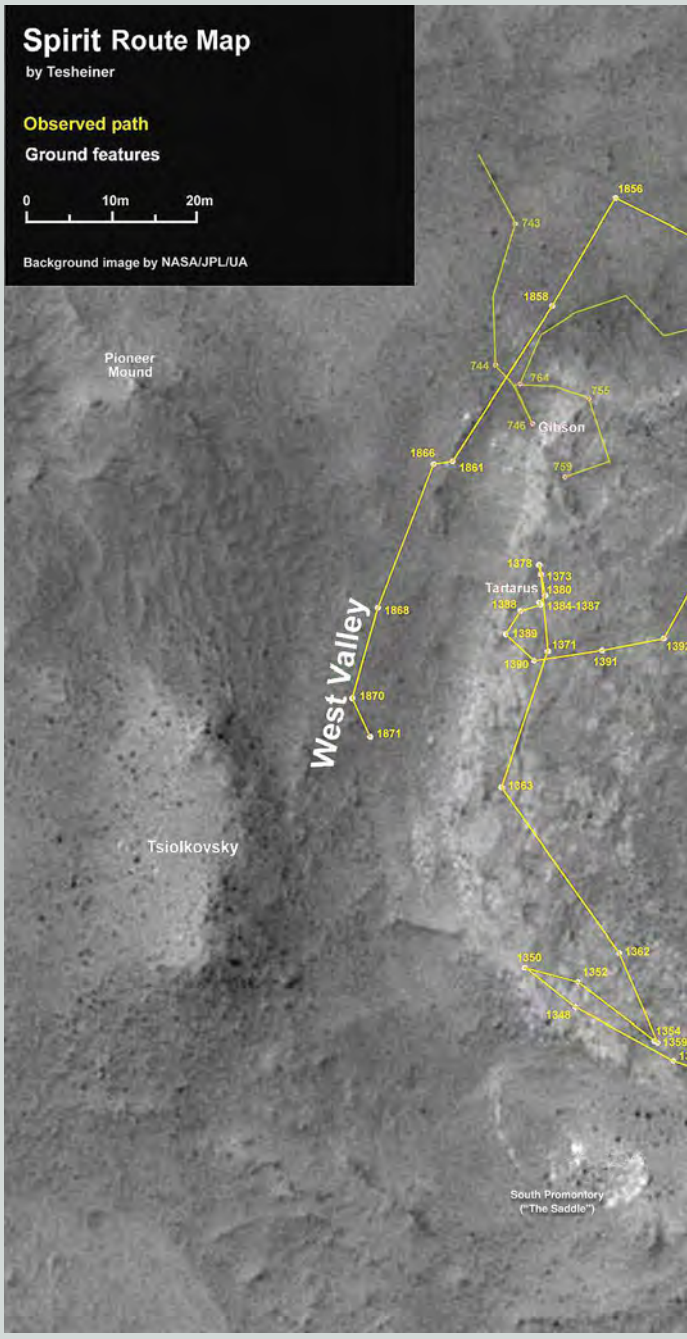
The team was ready to push *Spirit* southward, toward two mounds, named Von Braun and Goddard. First came months of attempts to drive *Spirit* back to the top of Home Plate, which offered an easy route across a rocky surface to points south. With the balky right-front wheel, however, the steep climb proved too much of a challenge.

In the front view (top), the immobile right-front wheel sits on the surface while the left-front wheel is nearly totally buried in a large pile of churned-up soil. In the rear view, the rover's two rear wheels should be visible, but both are buried to the rims in Martian soil.

Spirit Timeline

As a solar-powered vehicle located 10 degrees south of Mars' equator, *Spirit* finds its activities strongly dependent on the position of the Sun in the sky. Near southern solstice, the Sun is high overhead, days are long, and available power is at a maximum. Near winter solstice, the Sun is low in the northern sky, days are short, and *Spirit*'s activities are sharply curtailed.

Sol	Earth date	Activity
1	January 4, 2004	Landing
157	June 12, 2004	Begin ascending Columbia Hills
254	*September 20, 2004*	*First winter solstice*
577	*August 17, 2005*	*First summer solstice*
582	August 23, 2005	Reach crest of Husband Hill (highest point on climb)
589	August 29, 2005	Begin descent to Inner Basin and Home Plate
755	February 16, 2006	Ascend to top of Home Plate
779	March 13, 2006	Right-front wheel fails
805	April 9, 2006	Park at Low Ridge for winter
923	*August 8, 2006*	*Second winter solstice*
1,037	December 3, 2006	Begin spring science, exploring Silica Valley and drive to Home Plate
1,245	*July 5, 2007*	*Second summer solstice*
1,308	September 7, 2007	Reach top of Home Plate, begin clockwise trip around its rim
1,408	December 19, 2007	Park at northern rim of Home Plate for winter
1,592	*June 25, 2008*	*Third winter solstice*
1,709	October 23, 2008	Begin attempt to return to top of Home Plate
1,725	November 9, 2008	Power hits all-time low of 89 Watt-hours during major dust storm
1,850	March 17, 2009	Climbing attempts abandoned; new course set to Von Braun via West Valley
1,889	April 26, 2009	*Spirit* bogs down at Troy
1,914	*May 22, 2009*	*Third summer solstice*
2,078	November 6, 2009	Extrication efforts begin
2,156	January 26, 2010	*Spirit* declared stationary
2,260	*May 13, 2010*	*Fourth winter solstice*

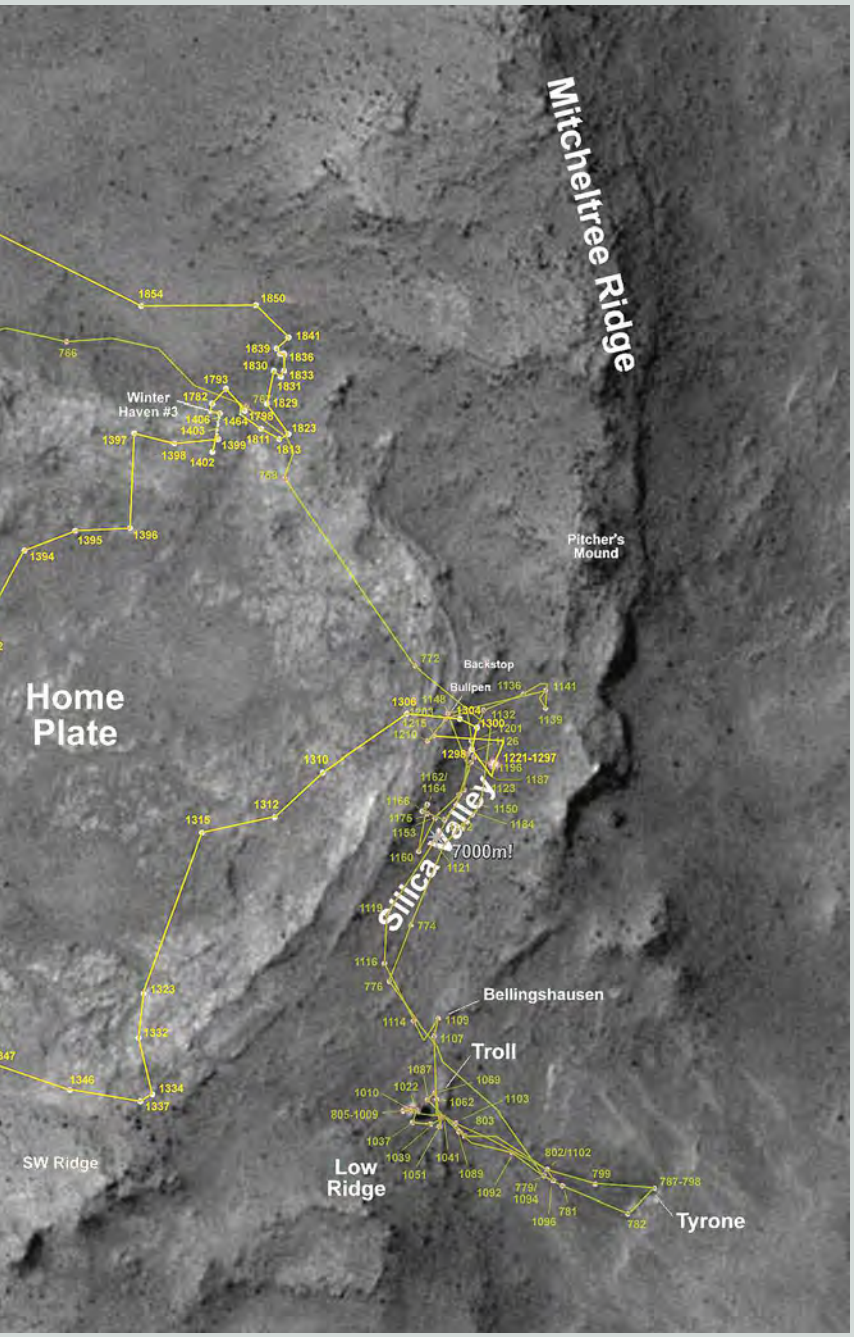


In March 2009, *Spirit* set off to drive counterclockwise around Home Plate, through terrain that the team had not yet seen. Suddenly, the rover was making tracks. It had to move quickly to cover the 300 meters or so to Von Braun by October, a deadline imposed by the short summer season, when *Spirit*'s dust-covered solar panels would be able to generate enough power to keep the wheels rolling. On some single days, *Spirit* logged more than 20 meters on the odometer on backward drives, with the right-front wheel dragging behind, digging trenches all the way.

On sol 1,889 (April 26, 2009), the wheels were rolling as usual for another long drive, but the pictures returned to Earth showed something disturbing: a churned area around the three functional corner wheels (the rovers have three wheels on each side) and a sudden cessation of forward progress. *Spirit* had hit a patch of some sort of soft soil. A few more attempts to drive *Spirit* out of the mess produced only further entrenchment, with five of the six wheels (all but the nonfunctional right-front wheel) deeply buried.

When the mission team stopped to analyze the situation, they found it worse than they had expected. Evidently, the left-side wheels had broken through a surface crust into an incredibly slippery, cohesionless sand that filled an unrecognized "ghost crater" beneath the soil. In addition, the rover had stopped with a pointy rock immediately underneath its belly. The rover's drivers, guided only by out-of-focus shots from the arm-mounted Microscopic Imager (an instrument never intended for use in engineering diagnostics), couldn't tell if the rover was actually touching Belly Rock, possibly leaving it high-centered.

Spirit was stuck. Really stuck.



In these Hazcam views after sol 2,154 (January 24, 2010),* Spirit *sat immobile while NASA announced that the rover was now a stationary lander. In the front view (top), the right-front wheel has remained more or less stationary, acting as a pivot, while the left-front wheel has churned soil as the rover moved. In the rear view (bottom), the two wheels are visible again, though still partially buried.

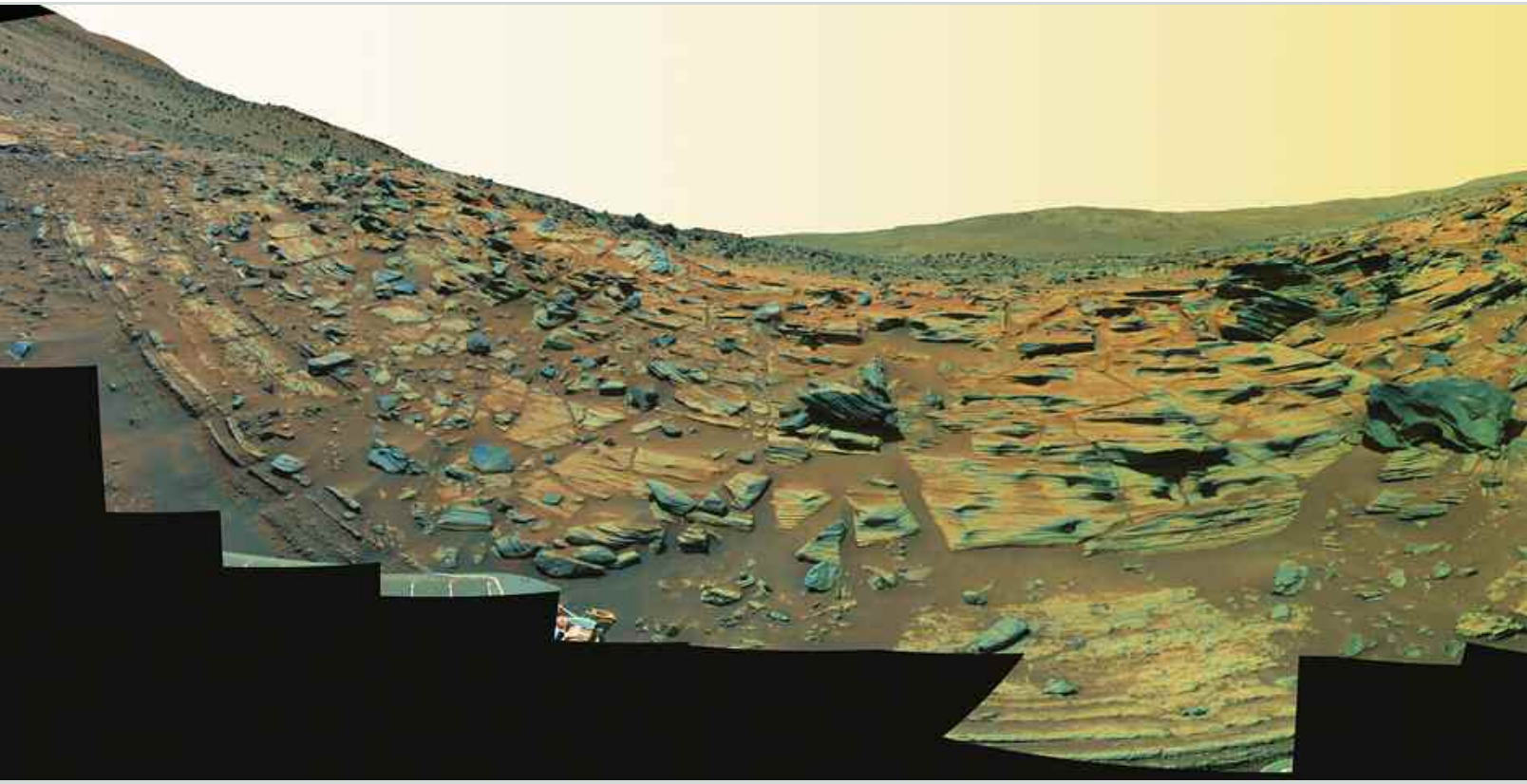
Left:* Spirit*'s peregrinations around Home Plate are mapped here with yellow lines and dots. Each dot represents a driving sol. The base image was taken by HiRISE while* Spirit *was parked for its second winter on Mars. The rover itself is visible under the dot for sols 805–1009. Compare this map with the cover image, which was taken almost three years later. The cover image shows numerous locations where* Spirit*'s dragging right-front wheel exposed bright white soils.

Map: NASA/JPL/University of Arizona/Eduardo Tesheiner, Unmanned Spaceflight

Free *Spirit*

The effort to free *Spirit* shifted from Mars to Earth. As they had done in 2005 when *Opportunity* got stuck in a sand dune, the mission's engineers at the Jet Propulsion Laboratory constructed a replica of *Spirit*'s sand trap and, with the help of the science team, began performing methodical experiments with two models of the rover. One, the engineering model (otherwise known as the Surface System TestBed, or SSTB), is a close copy of the rovers on Mars, having nearly identical mass and systems (though not, of course, wear and tear). The other, the SSTB-Lite, has only the mobility system—without arm, mast, or science instruments—and consequently weighs as much on Earth as the real rovers do on Mars, under 38 percent Earth gravity.

The tests did not immediately produce an obvious solution for how to extract *Spirit* from its predicament. Months



dragged on as testing continued. Meanwhile, back on Mars, *Spirit* wasn't idle; the team gathered a full-color, high-resolution panorama from its parking spot, now dubbed Troy, and performed more detailed analyses of the rocks and soil that the rover could reach with its robotic arm.

The soils in which *Spirit* is trapped appear to contain the same kind of sulfur- and silica-rich hydrated minerals as those discovered earlier on the other side of Home Plate. This indicates that the hydrothermal environment was regional, not just at one or two points.

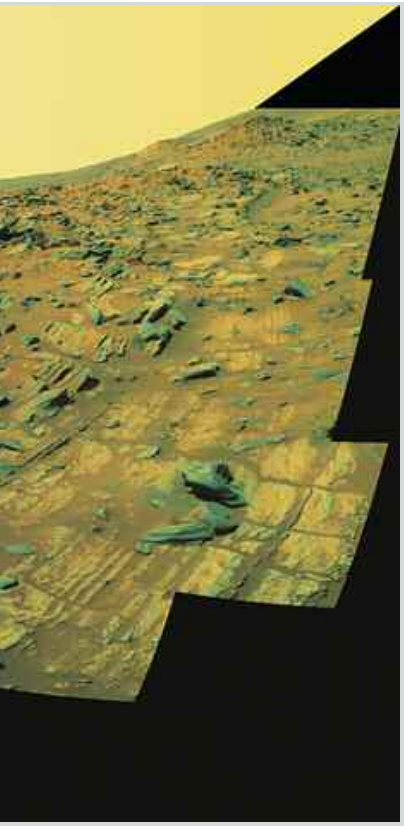
With the extra time provided by the rover's forced halt, the scientists have been able to do soil experiments that weren't possible when the exploration was faster-paced. For example, they've been able to make multiple measurements of the chemistry of the soils along profiles covering different terrains. They've also been able to spend more time taking individual measurements (more *integration time*, in scientific parlance), getting better and more robust estimates of the chemistry and mineralogy. Even though the wait to try to get out of the sand trap has been agonizing, at least the scientific results at Troy have continued to be rewarding. It's turned out to be a pretty good place to get stuck.

Mars was kind to *Spirit* during the wait. The valley in which *Spirit* sat acts like a funnel for Martian winds. On many occasions, wind gusts blew dust off the solar panels, to the point that *Spirit* was generating as much as or more power than just a few months after landing. More power meant more science, and, just as important, it meant more time to solve the problem of *Spirit*'s entrapment. The team would no longer have to cease rover activities for the winter in October; *Spirit* conceivably could roll wheels through November, December, or even January.

On sol 2,078 (November 6, 2009), *Spirit* was issued the first driving commands in nearly five months. The drivers had developed a library of extrication strategies and would proceed from simpler to more complex efforts. The first attempts involved steering the wheels straight and driving the rover forward (that is, in the direction from which it had come, since it previously had been driving backward).

Driving back out the way the rover came in didn't work. New problems also cropped up: stalls of the deeply buried right-middle and right-rear wheels. In fact, after a few sols worth of driving efforts, the right-rear wheel failed completely. The engineers quickly went back to the testbed to determine how much of a difference the stuck right-rear wheel would make. They found that the rover was still capable of driving, even with only four functional wheels, so extrication efforts continued. They also attempted driving the long-dead right-front wheel and were shocked to discover that it actually rolled, sometimes. Little progress was being made, however, and time was running out.

The engineers switched to backward driving, which was similarly unsuccessful, so they attempted more creative solutions. Their most productive strategy, one developed during the months of work in the testbed, involved "breaststroking" through the soil as they drove the rover backward. This involved steering the wheels outward (even the stuck wheels; the motors to steer the wheels are distinct from the ones used to spin them), rotated them half a revolution to pack the soil in place, rotated them back to straight, commanded 2 to 5 meters worth of wheel rotations, and then repeated the process up to 20 times per sol. These drives were the most fruitful yet, resulting in as much as 7.4 centimeters of progress in one sol's driving.



Spirit*'s Pancam gathered the images for the "Gibson" panorama, over sols 748–751 (February 9–12, 2006), while the rover was parked close to the rim of Home Plate. The intricately layered exposures of rock at the edge of Home Plate are clearly visible in this false-color image. Because the rover was perched at a 27-degree upward angle while this panorama was taken, the resulting mosaic has a "U" shape. See the map on pages 12–13 to locate this region.*

Image: NASA/JPL/USGS/Cornell University

***In these Hazcam views, after sol 2,169 (February 8, 2010),* Spirit *was finally forced to stop driving before winter. In the final two weeks of driving, engineers managed to pop the rear wheels almost entirely free of the soil. A few more centimeters of rearward progress will carry the wheels over a small ridge onto firmer ground. Pretty good for a "stationary lander."**

The Coming Cold of Winter

Alas, it was too little, too late. Winter approached inexorably, and as the Sun drifted north, *Spirit*'s available power ebbed. As had been done in winters past, *Spirit* needed to be parked with its solar panels tilted toward the north to maximize the panels' ability to eke power out of the short winter days. The mission was forced to stop attempting to escape the trap and instead confront the necessity of winter survival.

The announcement that extrication efforts would cease and winter survival work begin was made during a press briefing on January 26, 2010. NASA actually went a step further and stated that the mission would no longer attempt to extricate *Spirit* from its sandy trap at all. *Spirit* not only would stay at Troy for the coming winter but also would, NASA said, never rove again. The press release stated:

After six years of unprecedented exploration of the Red Planet, NASA's Mars Exploration Rover Spirit *no longer will be a fully mobile robot. NASA has designated the once-roving scientific explorer a stationary science platform after efforts during the past several months to free it from a sand trap have been unsuccessful.*

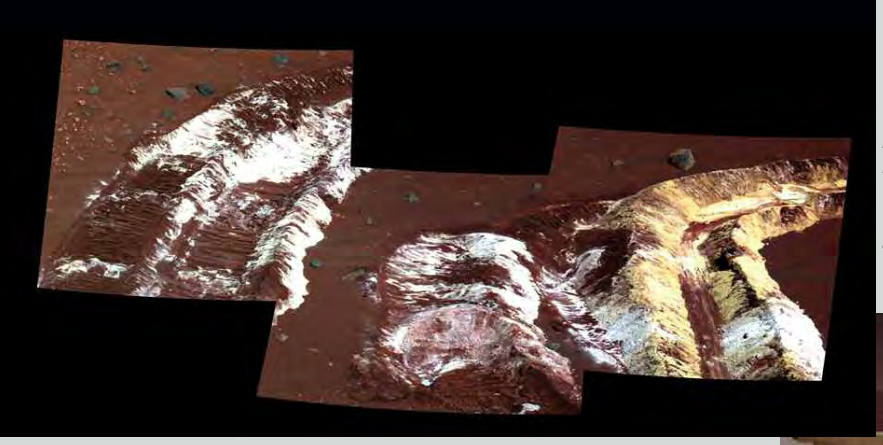
The venerable robot's primary task in the next few weeks will be to position itself to combat the severe Martian winter. If Spirit *survives, it will continue conducting significant new science from its final location. The rover's mission could continue for several months to years.*

*"*Spirit *is not dead; it has just entered another phase of its long life," said Doug McCuistion, director of the Mars Exploration Program at NASA Headquarters in Washington. "We told the world last year that attempts to set the beloved robot free may not be successful. It looks like* Spirit*'s current location on Mars will be its final resting place."*

The very next day of driving, however, belied the claim that *Spirit* was stationary. In fact, continued "breaststroking" efforts designed to increase the northward tilt of *Spirit*'s solar panels saw *Spirit* make many centimeters of rearward progress in one sol. The rear wheels, which were almost completely buried, are now nearly out of the deep soil, tantalizingly close to firmer ground. There is no reason to think that *Spirit* could not continue making such progress in the spring.

Unfortunately, the efforts to improve the northward tilt did not pan out; *Spirit* currently tilts not quite 10 degrees to the south. With this unfavorable orientation, it is very likely that at some point during 2010, the rover's batteries will drop below a minimum state of charge, triggering a low-power fault in the rover's electronics. It's impossible to predict exactly when this will happen, but it could be any day.

In low-power fault mode, the rover shuts down almost completely. The solar panels continue to function, trickling what power they can generate into the batteries. Other than that, only a master clock buried within the rover's brain remains active, patiently counting time. Periodically, a preset



Left:* Spirit *took the images in this mosaic on sol 788 (March 22, 2006), after its wheels excavated large deposits of light-toned soil at a place called* Tyrone. *This material has a salty chemistry, dominated by iron-bearing sulfates similar to soils disturbed elsewhere by* Spirit. *The distance between wheel tracks is about 1.5 meters in this false-color view. *Image: NASA/JPL/Cornell University*

Right: On July 9, 2009, Mars Exploration Rover Team members performed part of a series of tests of the best way to get* Spirit*'s wheels out of Troy's soft soil. The test setup, a box that holds a powdery mix of about 2.7 tons of diatomaceous earth and fire clay, simulates the soil and the situation at Troy. Clockwise from top are team members Scott Maxwell, Pauline Hwang, and Kim Lichtenberg. *Photo: NASA/JPL-Caltech*

timer expires and the rover briefly wakes up to check the state of charge on the batteries. If the batteries are charged enough, *Spirit* will attempt contact with Earth. If they are not, the rover will return to sleep.

This state of hibernation could continue for months, through Mars' southern winter solstice on May 13, most likely into July, August, or even later. During that time, there might be no communication at all from *Spirit*. One day, the rover will operate normally; the next, it might simply not show up for a planned communication session. Back on Earth, the engineers, scientists, and devoted followers will simply have to wait and wonder whether we'll hear from *Spirit* again on the other side of winter.

What are the odds? A lot depends on the balance between dust from Mars' atmosphere that settles on the solar panels and dust that is whisked away by wind gusts. If *Spirit* does not get too cold (the electronics are designed to cope with temperatures as low as –55 degrees Celsius, or –67 degrees Fahrenheit, and the rover is not expected to get that cold at Troy), and if no critical electronics break down during hibernation, the rover could very well ride out the winter just fine and come back on line for full-time work in the spring.

Stationary Science

Spirit's science team has already developed a long to-do list for a stationary *Spirit* that is alive and awake in the Martian spring. The most exciting activity for scientists is one that puts the rover's immobility to good use. Fixed to the ground, *Spirit* will act as a radio "tag" for one spot on the surface of Mars, which can be tracked to centimeter precision from Earth.

The position of *Spirit*'s radio beacon depends on the motion of Mars as it rotates on its axis and revolves in its orbit around the Sun. These motions are well understood. Superimposed on these motions are tiny wobbles excited by the gravitational pull of Mars' tiny moons and distant giant planets. How much wobble those gravitational tugs excite depends on whether Mars is solid from crust to center, or instead contains an internal liquid layer, as Earth does in its outer core. Six months of precise radio tracking of *Spirit*'s signals should enable geophysicists to determine whether or not Mars has a liquid center. The experiment was impossible to perform with *Viking* (which used longer-wavelength S-band rather than the X-band radio systems *Spirit* has; the shorter wavelength is necessary for the tracking method). It was attempted with *Pathfinder*, but that mission lasted only 80 days, not long enough for conclusive results. An immobile but operational *Spirit* therefore provides a unique science opportunity.

A Rover Again?

If the rover team can get *Spirit* through this most difficult of winters, and if six months of stationary science are completed with *Spirit* still functional, what then? Mars Exploration Rover scientists and engineers have every expectation that with the returning springtime sunshine will come renewed hope for extracting the rover and driving again. The significant progress made during the last few weeks before the winter power levels got too low for driving has the team heartened and optimistic. Besides, has anyone ever won a bet against either of the Mars rovers?

First, though, the team and the rover will need to settle in for a long winter of occasional science and frequent napping. To sleep, perchance to dream of roving once more . . .

Emily Stewart Lakdawalla writes for The Planetary Society's blog at planetary.org/blog *and is a regular contributor to Planetary Radio. Jim Bell, president of The Planetary Society, is an author of several space-related photography books and a professor of astronomy at Cornell University. Jim also is the lead scientist in charge of the rovers' Pancam color camera systems.*

Annual Report to Our Members

Dear Planetary Society Members, Donors, and Friends,

What a great year 2009 was for The Planetary Society.

Like any space mission, it shimmered with tension, excitement, and heartache, sweetened by the thrill of discovery and the elixir of success.

As you and I look back on The Planetary Society in fiscal year 2009 (October 1, 2008 through September 30, 2009), I hope that you will take pride in your Planetary Society and in the accomplishments that are now propelling us to success in 2010, our 30th anniversary year.

Today, you and your fellow Members worldwide stand together, passionate and strong as ever, determined to forge a positive future for space exploration.

You are essential to humanity's biggest, boldest, most daring adventure: to explore the frontiers of space, to seek life beyond our own pale blue dot of a world, and to better know and understand the cosmos and our own Earth.

On behalf of the Board of Directors, I thank you for your commitment to our programs of advocacy, education, and exploration.

Thank you for being part of this journey. The best lies ahead, and you will be a vital part of our future success.

You Are Shaping the Road of Exploration

Perhaps fittingly, our work as space advocates has come full circle from last year to now. In fall 2008, we turned to our Members, asking you how best to shape our future in space.

You responded with a profound desire to craft a vibrant course for exploration. We took your answers and those gleaned from a workshop the Society cosponsored with Stanford University, "Examining the Vision: Balancing Science and Exploration," and outlined a new approach to space exploration.

The resulting document, *Beyond the Moon: A New Roadmap for Human Space Exploration in the 21st Century*, created a stir.

We called upon the presidential administration and Congress to create an inspiring, flexible, and economically sustainable space program based on international partnerships, a program that looks both toward Mars as an ultimate human destination and back at our own fragile planet to ensure its survival.

We waged a campaign to promote this approach, applauding the conclusions of the Augustine Committee and rallying our Members and space activists around the world to support them as well. We never let up on the pressure.

Today, as NASA works out a new plan of exploration and discovery, setting its sights beyond the Moon, we know with certainty that you and your fellow Members have made and will continue to make an impact. Decision makers listen to The Planetary Society, specifically to its Members—to your voice.

You Make an Impact

Your donations also helped maintain the momentum of important research programs, including our searches for Earthlike planets outside our solar system, for signs of extraterrestrial intelligence, and for near-Earth asteroids and comets.

To help keep track of the action in the intense search for exoplanets—other worlds orbiting faraway stars—we created a "Catalog of Exoplanets," which can be found on our website at *planetary.org/exoplanets/list.php*.

We have also teamed up with planet hunters Debra Fischer of Yale University and Geoff Marcy of the University of California at Berkeley on a unique project called FINDS Exo-Earths (Fiberoptic Improved Next-generation Doppler Search for Exo-Earths). This uses the 3-meter telescope at Lick Observatory to search for smaller exoplanets and to verify Earth-sized planet candidates identified by the Kepler mission.

During 2009, you gave generously to SETI projects in both hemispheres: the Planetary Society Optical SETI telescope in the United States, which searches for laser signals beamed across the vastness of space, and our radio search in Argentina, which sifts through nature's random noise for beacons from other civilizations in the heart of our galaxy. When we detect a signal, you'll be listening.

Your donations also helped to keep on track our Phobos LIFE (Living Interplanetary Flight Experiment) project, which would test the viability of living organisms during travel to and from the Martian moon Phobos. We were disappointed to learn that the mission on which LIFE was to hitch a ride, *Phobos-Grunt*, has been delayed until 2011. We'll use this extra time on the ground to get data to help us better anticipate and interpret results from our eventual spaceflight. When LIFE does launch, what an exciting three-year journey that will be for all of us.

With You, We'll Keep Our Planet Safe

When my colleague, Planetary Society President Jim Bell, asked what aspect of interplanetary exploration most concerned you, the answer came back loud and clear: "protecting our planet from near-Earth asteroids and comets."

Planetary protection is indeed high on our list. The Society's Gene Shoemaker Near Earth Objects Grants program awarded three grants totaling $18,300. The recipients will, respectively, triple the productivity of

a NEO photometry program, engage hundreds of students internationally in measuring NEOs, and conduct work that will both rediscover the orbits of NEOs of which the space community has lost track and follow up on new discoveries.

Just this past year, two former Shoemaker Grant recipients, from China and Tahiti, made news as they tracked startlingly close comets.

That's not all. Google Corporation joined our Members in providing funds for a follow-up to our Apophis Mission Design competition to advance our ability to travel to asteroids that we know are headed our way. We also are campaigning for a global protocol for responding to asteroids that are on a collision course with Earth.

Can You Hear Us?

We welcomed the International Year of Astronomy in 2009 as an opportunity to interest and involve more of the world's public in planetary exploration. We have extended our reach, getting the word out in all the ways you've told us you value: The Planetary Society blog, our website, *The Planetary Report* (now available through electronic subscription), and Planetary Radio. We're delighted that so many of you follow us on Twitter or have made The Planetary Society a friend on Facebook.

Setting Sail for the Stars

Last year, we received much attention when Thomas Mallon recounted the story in *The Atlantic* of the Society's

Balance Sheet

For the Fiscal Years Ended September 30, 2005, 2006, 2007, 2008, and 2009 in thousands of dollars

Total All Funds:

Assets	**FY2009**	**FY2008**	**FY2007**	**FY2006**	**FY2005**
Current Assets					
Cash and Cash Equivalents and Investments	2.636	1,316	1,612	1,304	1,511
Membership Dues and Misc. Receivables	41	29	32	206	277
Inventories	28	39	42	50	64
Prepaid Expenses	64	39	37	26	49
Total Current Assets	**2,769**	**1,423**	**1,723**	**1,586**	**1,901**
Land, Building, and Equipment	**583**	**618**	**617**	**655**	**683**
Total Assets	**3,352**	**2,041**	**2,340**	**2,241**	**2,584**

Liabilities	**FY2009**	**FY2008**	**FY2007**	**FY2006**	**FY2005**
Accounts Payable and Accrued Expenses	141	154	286	195	206
Deferred Dues and Grant Revenue*	1,606	1,115	1,134	1,065	1,147
Total Liabilities	**1,747**	**1,269**	**1,420**	**1,260**	**1,353**

Net Assets (Deficits)	**FY2009**	**FY2008**	**FY2007**	**FY2006**	**FY2005**
Unrestricted	226	192	389	633	844
Temporarily Unrestricted	1,377	578	529	346	385
Permanently Restricted	2	2	2	2	2
Total Net Assets	**1,605**	**772**	**920**	**981**	**1,231**
Total Liabilities and Net Assets (Fund Balances)	**3,352**	**2,041**	**2,340**	**2,241**	**2,584**

Revenues	**FY2009**	**FY2008**	**FY2007**	**FY2006**	**FY2005**
Membership Dues	1,101	1,207	1,212	1,299	1,366
Donations/Grants	2,208	1,613	1,835	1,180	1,610
Bequests	277	170	3	37	72
Other **	144	184	205	396	208
Total	**3,730**	**3,174**	**3,255**	**2,912**	**3,256**

Expenses	**FY2009**	**FY2008**	**FY2007**	**FY2006**	**FY2005**
Member Development and Fundraising	380	556	534	443	421
Publications: Print and Web	621	552	467	535	554
Education and Information	155	184	228	182	117
Programs ***	172	353	364	432	418
Member Services	375	271	345	338	343
Administration	317	304	305	317	312
Projects	647	899	805	798	579
Special Solar Sail Expenses	230	202	267	117	428
Total	**2,897**	**3,321**	**3,315**	**3,162**	**3,172**

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

attempts to fly a solar sail. Soon after, one of your fellow Members made a gift to The Planetary Society of $1 million, challenging other Members to help raise the remainder needed for the first of three *LightSail* solar sail missions.

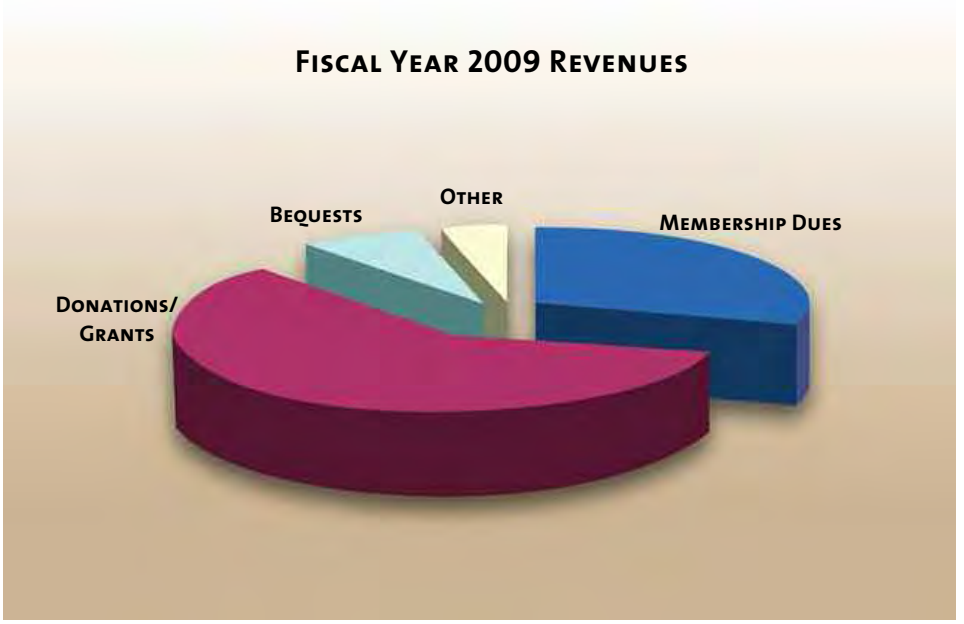
To date, we have nearly reached our goal, and we are on track to be ready for launch by the end of 2010.

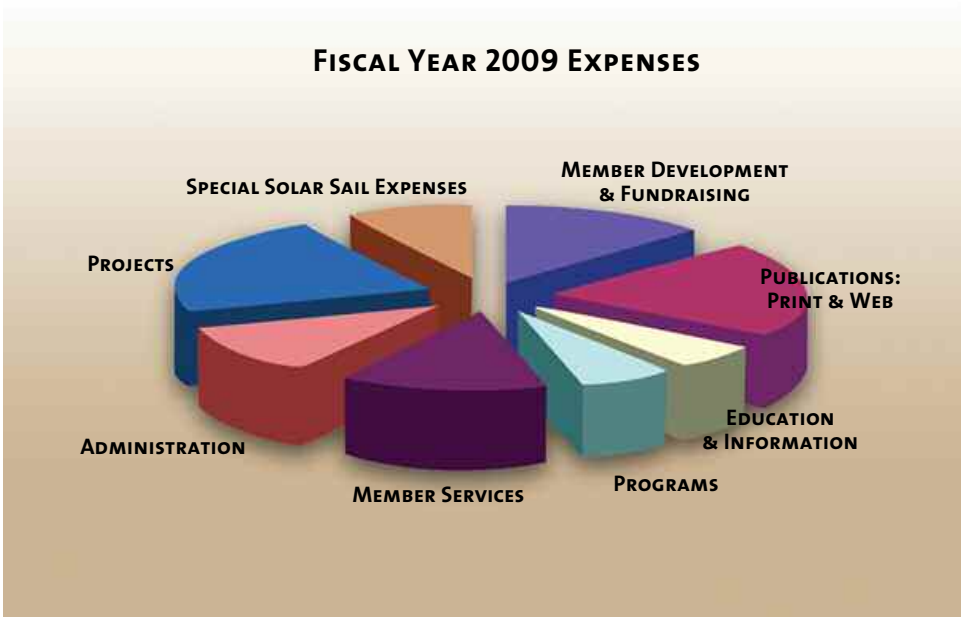
Full Speed Ahead—Your Investment Is Paying Off

Without you, The Planetary Society cannot exist. It's that simple. And it's more important than ever to have your support.

Whether you are a Charter Member or a more recent Member, whether you choose to support the Society as a Member of the New Millennium Committee or the Discovery Team, or name The Planetary Society in your will—your support is vital to every project, advocacy campaign, and outreach activity.

You can see your impact as you review our balance sheet. Even in a globally difficult economy, your generosity shone: you took advantage of our advanced renewal offer, many of you joining for decades to come; you donated to support projects as well as the unglamorous but necessary day-to-day work; you gave of your time and expertise; and your bequests provided vital funds as we weathered a challenging membership cycle and cut our expenses overall.





You Are Part of an Incredible Journey

Today, 30 years after Carl Sagan, Bruce Murray, and Louis Friedman founded the Society, you and I have the opportunity to invent the future—our future—of space exploration.

Please introduce a friend, relative, or coworker to The Planetary Society; give memberships to the young people in your life; make a generous gift of cash, securities, matching gifts, or time and expertise; or create your legacy with a planned gift. Take pride in what you have accomplished as part of The Planetary Society.

Those who are less informed may not understand the importance of space exploration and its impact on humanity's future. But those of us who make up The Planetary Society do, and we need to spread the word, increase membership, and ensure that ours is a legacy that future generations will value and appreciate.

We have a lot of work left to do. Let's do it together.

Sincerely yours,

Dan Geraci
Chair, The Planetary Society Board of Directors

Dan Geraci is also a member of the Society's New Millennium Committee. He is co-CEO and founder of DDG Financial Solutions, Inc., a management and strategic marketing company.

Questions and Answers

How would astronomers, looking at our solar system from 100 light-years away, be able to tell that there are four gas giants (or eight or nine planets) from effects these bodies have on our Sun's motion? With a solar system of eight or nine planets, there would seem to be a large number of perturbations to the star from many directions.
—Craig Daly
Canberra, Australia

Astronomers could use any of three methods: direct imaging, radial velocity (RV), and astrometry (the precise measurement of star positions). These methods all have potential for detecting gas giant planets from a distance of 100 light-years. Direct imaging looks for the actual positions of the planets as they orbit the parent star over time. RV and astrometry make use of the tiny motion of the parent star caused by the motions of its planets.

A star and its planets all orbit the center of mass of their system; the planets make large orbits and the star makes a small orbit. Imagine spinning a barbell with different weights on the two ends. The heavier end still makes a small revolution (orbit) off center from the weight's geometric center, while the lighter end spins out a much larger revolution. An animation of the effect of the planets on the motion of our Sun is at *planetquest.jpl.nasa.gov/SIM/images/SolarWobbleBlackSmall.mov.* There, the motion of the Sun—caused by all the planets—is illustrated for a 30-year period as seen from "above" the solar system at a distance of 33 light-years. The loops of the Sun's motion, if sized the same, would close on themselves in about 12 years (close to Jupiter's orbital period). The sizes of the loops (that is, the Sun's distance from the center of the coordinate system) and their durations vary, depending on the positions of Saturn, Uranus, and Neptune relative to Jupiter during the period. They push and pull Jupiter and the Sun with their gravity.

Factinos

Scientists may, for the first time, have pictures showing evidence of a collision between two asteroids. A mysterious X-shaped pattern and trailing streamers of dust in images recently taken by the Hubble Space Telescope (HST) suggest a head-on collision between the bodies. Observers first discovered the cometlike object, called P/2010 A2, through the Lincoln Near-Earth Asteroid Research (LINEAR) sky survey on January 6, 2010. The new Hubble images, taken on January 25 and 29, show a complex X pattern of filamentary structures near the nucleus (see images below).

"This is quite different from the smooth dust envelopes of normal comets," said Principal Investigator David Jewitt of the University of California at Los Angeles. "The filaments are made of dust and gravel, presumably recently thrown out of the nucleus. Some are swept back by radiation pressure from sunlight to create straight dust streaks. Embedded in the filaments are co-moving blobs of dust that likely originated from tiny unseen parent bodies." The Hubble images show that the main nucleus of P/2010 A2 lies outside its own halo of dust—something that has never been seen before in a cometlike object. The nucleus appears to be about 140 meters in diameter.

The main nucleus of cometlike P/2010 A2 (white spot at left) lies outside its halo of dust. The nucleus is the only surviving remnant of a collision that scientists believe took place between two asteroids. These Hubble Space Telescope images were generated with the new Wide Field Camera (WFC3), taken when the object was about 290 million kilometers (180 million miles) from the Sun and 145 million kilometers (90 million miles) from Earth.
Image: NASA/ESA/David Jewitt, UCLA

Because it orbits in the warm, inner regions of the asteroid belt with rocky bodies containing no volatile materials, P/2010 A2 may have an origin different from that of normal comets in our solar system. That leaves open the possibility that the complex debris tail is the result of a collision between two objects rather than ice melting from a parent body.

"If this interpretation is correct, two small and previously unknown asteroids recently collided, creating a shower of debris that is being swept back into a tail from the collision site by the pressure of sunlight," Jewitt said.
—from the Jet Propulsion Laboratory

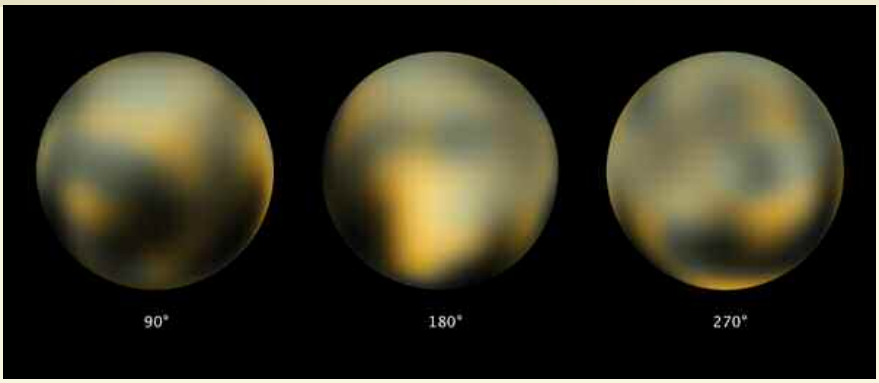
Direct imaging has shown us a handful of large planets much more distant from their parent stars than our system's gas giants are from the Sun. Instruments that could directly image our solar system's gas giants are more than a decade away from operation, and they still might have significant difficulties searching from a distance of 100 light-years. The angular separation of the planets from the Sun would be tiny, and the sunlight they reflect would be much diminished by the distance.

RV observations measure the tiny blue and red Doppler shift that is visible when a star moves toward and away from the viewer as its planets travel around their orbits. Numerous individual planets and multiple-planet systems at distances from 15 to more than 1,000 light-years from their sun have been discovered by observing this small "wobble" in the star's motion. Most of these planets are much closer to their parent stars than Jupiter, Saturn, Uranus, and Neptune are to the Sun. Uranus and Neptune might be significantly harder to find because of their slow orbital speeds and great distances from the Sun. RV measurements do not reveal planets' masses. Also, because exoplanets' orbital geometries are unknown, scientists assume minimum values for their masses. They could be much more massive.

Space-based astrometric instrumentation could be in operation in less than a decade to make detections. This method makes it possible to measure the position of the parent star over time, as illustrated in the animation mentioned earlier. From measurements of the parent star's position, the orbits and masses of planets orbiting it can be determined unambiguously. The European Space Agency's *Gaia* spacecraft is expected to discover thousands of exo-Jupiters when it is launched in a few years. It may find lower-mass planets as well, if they are close enough to their parent stars. NASA's SIM Lite Astrometric Observatory includes plans for an extensive campaign to discover massive planets around stars out to large distances from the Sun, and even exo-Earths in the habitable zones of their parent stars at distances as large as 33 light-years and beyond.

Time is the limitation, unmentioned so far, for all these search techniques. From 100 light-years away, one would have great difficulty, using RV and astrometry, finding the Sun's gas giants because of their long orbital periods. Direct imaging might pick them up but then would still need a long time to confirm they were moving planets and not background stars. Ideally, to be sure a planet is orbiting a star, it should be observed through one complete revolution around the star. For Jupiter that is 11.8 years, for Saturn it is 29.3 years, for Uranus it is 84.4 years, and for Neptune it is 165.8 years. Accumulating enough data to confirm all the Sun's giant planets would take a long time from 100 light-years.

—STEPHEN EDBERG,
Jet Propulsion Laboratory



These new Hubble Space Telescope pictures were generated from images taken with the Advanced Camera for Surveys over 2002 and 2003. They will remain our sharpest views of Pluto until* New Horizons *is six months from its 2015 flyby of the distant world. The images will be invaluable in helping the* New Horizons *team choose which hemisphere the probe will image.

Image: NASA/ESA/Marc Buie, Southwest Research Institute

The Hubble Space Telescope has returned the most detailed images yet of Pluto (above), showing that it is a dynamic world undergoing dramatic atmospheric changes. The new pictures show an icy, mottled world experiencing seasonal changes in surface color and brightness. Pluto has become significantly redder, while its illuminated northern hemisphere is getting brighter.

These changes probably are the result of surface ice melting on the sunlit pole and then refreezing on the other pole as the dwarf planet heads into the next phase of its 248-year-long seasonal cycle. Unlike Earth, whose tilt alone drives the seasons, Pluto's seasons are asymmetric because of its elliptical orbit. The dynamic changes on Pluto are propelled as much by its elliptical orbit as by its axial tilt.

Ground-based observations of Pluto taken in 1988 and 2002 reveal that the mass of the atmosphere doubled during that time—possibly because of the warming and melting of nitrogen ice. When scientists compare Hubble pictures from 1994 with images captured in 2002 and 2003, they see evidence that Pluto's northern polar region has gotten brighter, while its southern hemisphere has grown darker. These changes hint at very complex processes affecting the surface.

"The Hubble observations are the key to tying together these and other diverse constraints on Pluto and showing how it all makes sense by providing a context based on weather and seasonal changes, which opens other new lines of investigation," said Principal Investigator Marc Buie of the Southwest Research Institute in Boulder, Colorado.

—from the Space Telescope Science Institute

Members' Dialogue

A Note of Thanks

Thank you [Louis Friedman] and The Planetary Society's board of directors for presenting the Cosmos Award for Outstanding Public Presentation of Science to Stephen Hawking at Cambridge University on February 27, 2010. I found the meeting to be very moving and stimulating—particularly the impassioned debate about funding of humans in space (or not). I brought my 18-year-old son along as a guest. He is about to go to university, and he described the event as one of the most memorable of his life.

Professor Hawking is an amazing individual, not necessarily for his mathematical insights into the cosmos but for his spirit of life and delight in the mysteries of nature. The members of the panel also displayed this enthusiasm—albeit with very strongly held and divergent views, all eloquently expressed.

Best wishes to you all with your continuing efforts in the Society.
—MICHAEL J. WALKER,
Kenilworth, Warwickshire, England

NASA's Roots

At this time, when NASA's mission is not well defined and the place of human spaceflight is being debated, I advocate that technology development is as important, and as appropriate, for NASA as is science. NASA should return to its roots and reintroduce the sorts of programs accomplished by its predecessor, the National Advisory Council for Aeronautics (NACA). NACA was founded in 1915 "to supervise and direct the scientific study of the problems of flight with a view to their practical solution, to determine the problems which should be experimentally attacked, and to discuss their solution and their application to practical questions."

In 1958, NACA was abolished and its facilities incorporated into NASA. NACA was instrumental in the rapid development of aeronautical engineering. When *2001: A Space Odyssey* was released in 1968, it seemed completely credible to me that the technology portrayed would be in place by 2001. Apparently, Arthur C. Clarke thought so as well, since he did not title the story *2101*.

My expectation of rapid technological progress in space was based on my knowledge of the history of flight. By late 1905, the Wright Flyer was capable of a 24-mile flight at 38 miles per hour. In 50 years, we went from a cloth-and-wire contraption to the Boeing 707, and [at any one time] there are about half a million people suspended in the air.

What are the technological advancements made in spaceflight during the last 40 years? Comparatively none. Payload heavy-lift capability has actually decreased. There are no significant increases in vehicle speed. Most disturbing is that we are still burning kerosene or hydrogen and liquid oxygen. I do not think spending decades on a Moon or Mars mission using archaic technology makes sense. In the way that ever more powerful engines allowed engineers to design more sophisticated airframes, NASA should focus considerable effort (and budget) on developing advanced propulsion.

Regardless of the ultimate designs of the engine and spacecraft, NASA must remember its roots and understand that its mission is also engineering and pushing the envelope. This is a view that The Planetary Society should advocate. Those concerned about science should remember that the tools to do the science have to be built by engineers.
—ROBERT KAUFMAN,
Sherman Oaks, California

Focus on Space

In response to several recent letters advocating more focus on global climate change, I fervently believe The Planetary Society's focus should remain on exploration of our solar system and galaxy. Uncounted governmental and private agencies are already devoting tremendous efforts to understanding climate change here on Earth. Humanity's survival ultimately depends upon its ability to reach the stars and establish outposts where humankind can continue to develop and evolve. It would be a tragic mistake for the Society to turn inward and away from our ultimate destiny, which is to explore the universe.
—JIM SMITH,
Kansas City, Missouri

Dinosaurs' Demise

I enjoyed reading the January/February 2010 issue of *The Planetary Report* and think it is important that the impact threat is being taken seriously. It is a very real danger that must be dealt with. However, your description of the dinosaur extinction at the end of the Cretaceous period gives the impression that the dinosaurs were happily roaming the Earth when suddenly an asteroid hit and made them extinct.

Although the subject is still a source of much debate, fossil evidence shows that dinosaur diversity had been in decline for millions of years before the impact. This makes it much likelier that the impact *finished off* the dinosaurs rather than initiating their demise. I think it is important to recognize this distinction. At the very least, we should remember that there still is not a definite answer to what caused this and previous extinctions.
—FREDRIK JONSSON,
Bunkeflostrand, Sweden

Erratum

On page 11 of the January/February 2010 issue, the name of asteroid Ida's moon was mistakenly given as Gaspra. The moon's name is Dactyl.
—Editors

Please send your letters to
Members' Dialogue
The Planetary Society
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Pasadena, CA 91106-2301
or e-mail: *tps.des@planetary.org*

Society News

Become a Discovery Team Member!

Want to be a force in planetary exploration? When you sign on as a member of the Discovery Team—The Planetary Society's monthly giving program—your donations ensure that, with you, we can move quickly to shape space exploration.

Thank you to the more than 400 current members of The Planetary Society's Discovery Team. If you are not already part of the Team, we'd love to welcome you as the newest member.

As a member of the Team, you choose how much you can afford to give each month—$10, $15, and $25 are common amounts—and you can choose to increase your gift or stop at any time.

Ensuring our future in space—exploring other worlds, understanding our own, and seeking life elsewhere—is a long-term and innovative process. To be successful, we rely on steady, predictable funding from passionate space explorers like you.

Plus, as a Discovery Team member, you help The Planetary Society reduce fund-raising expenses by eliminating renewal notices (your membership automatically renews), and you take us a step further in going "green" as we eliminate more paper from our day-to-day operations. You can sign up online at *discoveryteam.planetary.org* or call us at (626) 793-5100 with your information. Then, each month, we will debit your credit card or bank account automatically for the donation amount you have chosen.

The Planetary Society uses a secure server for processing your monthly contributions, and we do not keep your credit card information.

Do you have questions about being a force in planetary exploration? Call Andrea Carroll, director of development, at (626) 793-5100, extension 214, or e-mail me at *andrea.carroll@planetary.org* to learn more about the Discovery Team or other ways you can support The Planetary Society.

—Andrea Carroll, Director of Development

Check Out Our New Online Store!

www.cafepress.com/planetaryshop

Help us celebrate our 30th anniversary with our special products commemorating 30 years of bringing space exploration to the public!

Your Gift Planning Today Can Shape Tomorrow's Future in Space

For 30 years, The Planetary Society has led the world in championing space exploration—for you and for all of Earth's people. You, as a Member, are integral to that success.

By planning your gift today—naming The Planetary Society as a beneficiary in your will or estate plan—you can make a significant gift for space exploration in the future.

Your will mirrors what you value deeply and is a way to extend your commitment to The Planetary Society.

A planned gift in your will helps ensure the long-term success of our projects, whether it's searching for life on other worlds, embarking on innovative missions like *LightSail*, understanding and protecting our own planet, or advocating for a strong and effective space program.

As someone who cares about our planet and those beyond, you can make a bequest to The Planetary Society that will help ensure that we can meet new challenges and opportunities.

You will play a part in shaping the future of space exploration, and in many countries, you will also receive tax benefits. In every case, you will be providing a legacy that will make a meaningful difference for future explorers like yourself.

Thank you to all of you who have already named The Planetary Society in your will or estate plan.

Please call Andrea Carroll, director of development, at (626) 793-5100, extension 214, or e-mail me at *andrea.carroll@planetary.org* if you would like information on including The Planetary Society in your will or estate plan.

—AC

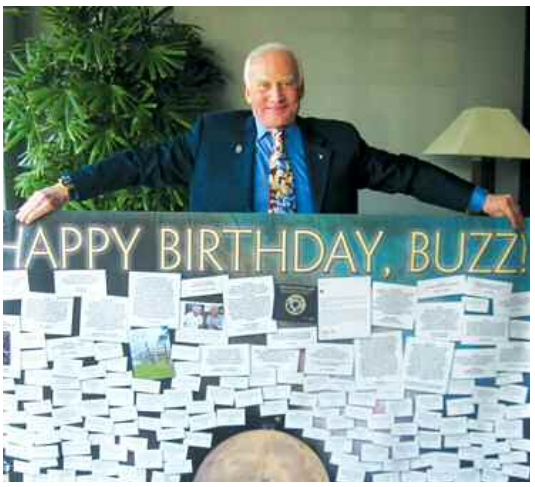
Happy Birthday, Buzz!

Thank you for helping us celebrate the 80th birthday of our good friend Buzz Aldrin.

With your help, we presented Buzz with more than 8,000 birthday greetings from all over the world. Your heartfelt good wishes were inspirational, moving, and some even quite funny. Buzz appreciated each and every one!

Buzz Aldrin is an astronaut, explorer, hero, and tireless advocate for space exploration. The Planetary Society is honored to have him serve on our Advisory Council and work with us to guide the future of space exploration.

—Louis D. Friedman, Executive Director



Astronaut Buzz Aldrin holding his giant card filled with messages from The Planetary Society.
Photo: The Planetary Society

Annual Audit Completed

The firm of Hensiek & Caron has completed its yearly audit of The Planetary Society. The firm determined that the Society's 2009 financial statement was in conformity with generally accepted accounting principles.

Copies of the financial statement are available upon request.

—Lu Coffing, Financial Manager

THE PLANETARY SOCIETY
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It may look like Mars, but it (most likely) does not smell or taste like Mars. This ruddy Red Planet landscape is sculpted from a big pile of paprika, cinnamon, chili powder, thyme, and charcoal. Matthew Albanese uses a variety of everyday materials to construct meticulously detailed, emotive landscapes. Using photographic techniques such as depth of field, white balance, lighting, and scale, he is able to drastically alter the appearance of his materials. "One day I knocked over a tub of paprika," he said. "As I was cleaning up the mess, I began to day-dream and found I was playing with the paprika more than cleaning it up. I thought it was a great shade of red, and it reminded me of Mars."

Matthew Albanese, a fine artist specializing in photography, began making models (this is his first) in 2008. He lives and works in Lincoln Park, New Jersey. To see more of his Strange Worlds series, visit *matthewalbanese.com*.