

# THE PLANETARY REPORT

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SOLSTICE **2011**

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[www.planetary.org](http://www.planetary.org)

SPECIAL  
MESSAGE FROM  
BILL NYE  
PAGE 4

NEW -  
KIDS' PULL-OUT  
SECTION IN THE  
MIDDLE!



## SHUTTLE LIFE

OUR TINY PASSENGERS HAVE RETURNED TO EARTH

## SNAPSHOTS FROM SPACE



**EMILY STEWART  
LAKDAWALLA** blogs at  
[planetary.org/blog](http://planetary.org/blog).

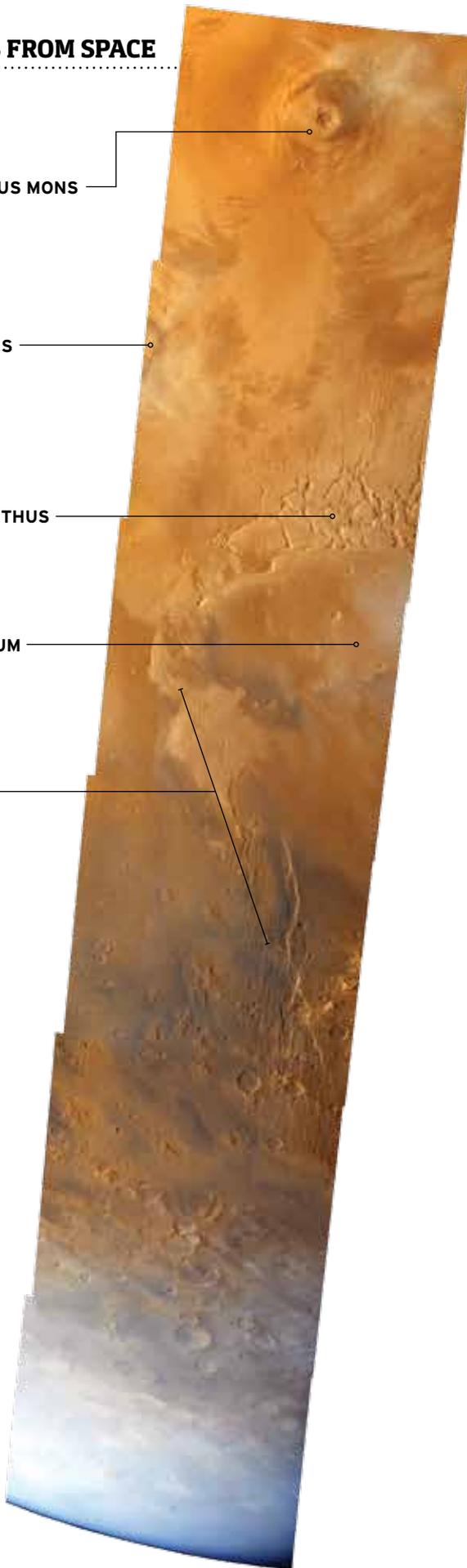
ASCRAEUS MONS

PAVONIS MONS

NOCTIS LABYRINTHUS

SYRIA PLANUM

CLARITAS FOSSAE



# Viking Redux

## New data from old images

**RECENT ORBITERS TO MARS** have revolutionized our view of the Red Planet, so you'd be forgiven for thinking that there's little of value in the collection of images snapped by the twin *Viking* orbiters from 1976 to 1980. But you'd be wrong. The two *Vikings* covered the entire planet through two color filters, red and violet, and these color data still form the basis for most global color views of Mars generated by both professionals and amateurs today. Not many people are keen on working with the *Viking* data to craft aesthetically beautiful images of Mars, because the data have lots of blemishes, including missing lines and a speckling effect from noise in data transmission, but the effort is worth it.

The view here was generated by Daniel Macháček, who brought out subtle color variations across Mars' southern hemisphere by synthesizing a green image from the red- and violet-filter data. At the northern end is Ascraeus Mons, one of the three great Tharsis volcanoes near Mars' equator. In the south is the cloudy, icy Martian pole, which was just sinking into the twilight of polar winter. In between, the image mosaic crosses Noctis Labyrinthus, a maze of collapsed pits and fissures that forms the western reach of Valles Marineris, and also Claritas Fossae, an area fractured by the stress imposed on Mars' crust by the lava deposits of the Tharsis volcanoes. 🐾

— Emily Stewart Lakdawalla

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**ON THE COVER:** They're back! This scanning electron microscope image, enlarged 450 times, shows the abdomen and legs of a tardigrade, or water bear. As precursors to the Planetary Society's Phobos LIFE (Living Interplanetary Flight Experiment) mission, a bunch of these seemingly indestructible little animals, along with a specialized group of microbial cohorts, flew into space as part of Shuttle LIFE. Launched on space shuttle *Endeavour's* final voyage, Shuttle LIFE (along with Phobos LIFE), will test the idea that living organisms can survive in space, potentially "seeding" one world with life from another. More than 1,000 species of water bears can be found in all regions of our planet. *Photo: Martin Kage, Peter Arnold Images*



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## YOUR PLACE IN SPACE



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# Contracting to Expand

## Looking forward to the Society's future

**AT THIS TIME OF YEAR, THE EARTH'S TILT** tips the Planetary Society headquarters in California toward the summer Sun. Along with the change in seasons this year come changes at your Planetary Society. You're holding our first Solstice Issue of *The Planetary Report*. Our plan now is to become a quarterly publication that will go out to you on the solstices and equinoxes of each year. For our Northern Hemisphere members, I hope this is the start of a great summer. To our many members south of the Earth's equator, I hope this issue brightens the shorter days.

### FROM SIX TO FOUR ISSUES

At the Planetary Society, we're busier than ever. As I write, we're making arrangements for our Shuttle LIFE spacefaring organisms to be analyzed, now that they're back here on Earth after their trip on *Endeavour*. We're aggressively testing the software and torquing the last few screws on our *LightSail-1* spacecraft, even while looking for a ride to space. Of course, we also continue in the fight for a measured and productive space policy that will push forward our shared dreams of exploration.

We're also devoting our energies to getting more information to you faster. The new communication channels open to you and me hold the promise of bringing us closer together and making us a more effective force for space exploration.

Fundamentally, because so much information is available on the Web these days, we have made the change from six issues per year to four. We've found ourselves putting the news of discoveries in space and space policies on our website, reserving the printed *Planetary Report* for in-depth stories, interviews, and insights. This change re-

flects the times; we're changing along with so much of our world, where information is accessible almost instantaneously and via so many channels.

### WE MADE SOME MOVES

The last couple of years have been tough on many of our colleagues, friends, and family members. The economy may be recovering, but many people have had to make some hard choices about their charitable contributions. Overall, the Society is in steady financial shape, thanks to you, our Members, and to the savvy sale last year of the house that held our headquarters. But we must be vigilant.

We moved to smaller offices, and we've cut back in what I feel are appropriate places. As you can imagine, the costs of printing our magazine and sending it to you through the mail are significant. While we're finding more efficient ways to keep you up to date, please make sure that you have given us your e-mail address. You can e-mail our office at [tps@planetary.org](mailto:tps@planetary.org), call our friendly staff at 626-793-5100, or go to our website and sign up for e-mails at [planetary.org/emailupdates](http://planetary.org/emailupdates).

I expect you have noticed the new look of your *Planetary Report*, prompted by our new designer, Loren Roberts. Our original designer, Barbara Smith, was part of our team for 31 years, but now she has chosen to retire. As a tribute to the iconic style she developed, and in keeping with what all of us seem to love about *The Planetary Report*, our cover will remain one beautiful, uncluttered image of some place in outer space or our own gorgeous planet Earth.

We will continue to feature in-depth articles, written by the world's experts in their fields. As you know, this is information that would be difficult to find anywhere else. We'll work to present the information you

like effectively, in a readable and engaging layout, so that despite fewer issues per year, the magazine will still be rich with accessible and valuable information.

Space exploration is a human endeavor of the highest aspiration. Science is a process by which we learn about nature and how we fit into the universe. In *The Planetary Report*, we have room and the inclination to capture the viewpoint of each author. We find out not only what authors are working on but also how they feel about their discoveries. As Carl Sagan often said, when you're in love, you want to tell the world. So it is with our authors. We'll give them room to share with you their love of space and science.

#### DOING IT FOR THE KIDS

I hope you also noticed the new kids' pages, which will be included right in the middle of the magazine. You can easily remove this section to share with your own children, grandchildren, or someone else's kids, or to experiment a bit yourself.

With a few important exceptions, everyone I've met who is excited about space today became interested when he or she was young—before leaving elementary school. To inspire the next generation of space explorers, we're working to provide material for them in each issue. We hope these pages will engage entire families in sharing and learning about space together.

As you may know, I have some small experience in this area. I'm in love with science, so I want to tell the world, especially the young world, as much as I can. We will have some wonderful facts in each kids' section, and we will have at least one demonstration or experiment that readers of any age can do at home, providing a chance to do some hands-on scientific work.



Along with kids in elementary and high school, we want to engage college students. We've established new college chapters at Georgia Tech and Arizona State University, both in the United States. We also are working with the international Students for the Development and Exploration of Space (SEDS). We hope soon to have a similar relationship with student chapters of the American Institute for Aeronautics and Astronautics (AIAA).

I also hope to develop closer ties to the International Space University (ISU), headquartered in France, which holds programs around the world. I look forward to seeing old friends and making new ones at the International Astronautical Congress (IAC) and at the young professionals' Space Generation Congress. The two events will be held back-to-back in Cape Town, South Africa later this year.

We want to help young people make contacts in the aerospace industry, and we especially want their ideas and their

*continued on next page...*

**ABOVE** We are proud to unveil the new look of *The Planetary Report*. We are working on ways to communicate even more effectively with you—our Members—online.

**THIS IS YOUR ORGANIZATION, AND I WANT TO HEAR FROM YOU.**

E-mail me at [tellbill@planetary.org](mailto:tellbill@planetary.org) or send a letter to Bill Nye at **The Planetary Society**  
**85 South Grand Ave.**  
**Pasadena, CA 91105**

Find more information at [planetary.org/yourplace](http://planetary.org/yourplace)

# What's Up?

By Bruce Betts

**IN THE SKY** Yellowish Saturn goes from high to low in the west as summer progresses. It is near Virgo's bright star Spica, and, on August 3, look for it next to the crescent Moon. In the predawn sky, very bright Jupiter is high in the east and dimmer, reddish Mars is far below it. Both get higher over the weeks. The Perseid meteor shower peaks on August 12 and 13, but increased activity can be seen from several days before to several days after. The Perseids typically are one of the best showers of the year, with an average of 60 meteors per hour from a dark site, but this year a full Moon near the peak will wash out the dimmer meteors.



**RANDOM SPACE FACT** When the Space Shuttle *Endeavour* completed its final flight on June 1, 2011, this youngest space shuttle orbiter had flown 25 missions, spent 299 days in space, orbited Earth 4,671 times, and traveled 122,883,151 miles, all since its first flight in 1992. The Planetary Society's Shuttle LIFE experiment flew on its final mission. Follow me on Twitter: @RandomSpaceFact

**TRIVIA CONTEST** Our November/December contest winner is João Matos of Setubal, Portugal. Congratulations!

The Question was: *In light-years, how far away is Proxima Centauri, the closest star to Earth besides the Sun?* The Answer: 4.22 light-years away.

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

**Mars' atmosphere is 95% carbon dioxide. What is the second most common gas in the Martian atmosphere?**

E-mail your answer to [planetaryreport@planetary.org](mailto:planetaryreport@planetary.org) or mail your answer to *The Planetary Report*, 85 South Grand Avenue, Pasadena, CA 91105. Make sure you include the answer and your name, mailing address, and e-mail address (if you have one). Submissions must be received by September 1, 2011. 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 quests, listen to Planetary Radio at [planetary.org/radio](http://planetary.org/radio).



**ABOVE** Our May 28, 2011 Planetary Radio Live show was a great success. Here we see guest Mike Brown, left, speaking with Planetary Radio host Mat Kaplan and Society Executive Director Bill Nye.

inherently fresh perspectives to help extend our species' reach into the solar system and beyond—a goal you and I share through our membership in the Planetary Society.

## ON THE AIR

During the last year, Planetary Radio became better and better, thanks in large part to the vision and professionalism of its producer and host, our own Mat Kaplan. We did a live show in May with a studio audience, who had a great time. Given that success, we hope to expand our live shows this year and take Planetary Radio to new heights ... or new horizons. Please keep an ear out for "Plan Rad," as Mat likes to call it. If you miss the show on your local radio station, catch it by podcast from [planetary.org/radio](http://planetary.org/radio). There, you can also peruse our archives, which go back to our first show, in November 2002. Give us 30 minutes; we'll give you the universe!

## THROUGH SOCIAL MEDIA

We humans love to be part of communities. Because we now can interact with one another from anywhere on Earth, we want the Planetary Society to be one of your com-

munities. Along with our podcasts, we are expanding and updating our presence on the Web, Facebook, and Twitter. As new social media emerge and augment or even supplant these current ones, we'll be there—sending information around the world at the speed of light. It's vital to any modern organization. In addition, face it (pun intended)—it's just fun.

## FINDING YOUR PLACE IN SPACE

Finally, as you hold this first Solstice Issue, I hope you feel, as I do, that the Planetary Society has taken the next step in our evolution. Our goal is to keep our important work going. We aim to foster a scientifically literate populace, one in which every citizen knows and appreciates other worlds as well as this one. We will strive to include people in every country on Earth, seeking and understanding other worlds and other forms of life for the betterment of all humankind.

Thanks for your support. Together, we can change the world. 🚀

  
Bill Nye



## Pasadena Volunteers Step Up

**CAN YOU IMAGINE KIDS, PARENTS, AND TEACHERS** getting together on a Friday night on purpose? In Pasadena, California at Longfellow Elementary School, the annual Stargazing Night gets bigger every year. This year, the Planetary Society was invited to participate in the festivities, and, thanks to our Pasadena Volunteers, we made quite a splash.

Geovanni Somoza manned his homemade telescope on the school playground, and on-lookers were treated to views of Jupiter and the Orion nebula. He could barely keep up with the long line of excited observers.

Meanwhile, Mary Brown and Chuck Dorn regaled waves of children and families with their display of light, prisms, and lasers.

The Planetary Society has been asked to return next year, and we had so much fun, we are looking forward to it!

Thanks, Pasadena Volunteers, for all you do to keep the local community enthused about space and exploration. Your passion makes a difference! 🌟

*Volunteer Spotlight shares the personal stories and achievements of Planetary Society volunteers. If you know a Planetary Society volunteer who is working hard in your community—or if you are that volunteer—we want to know about it. Please send a brief update and photo to [planetaryreport@planetary.org](mailto:planetaryreport@planetary.org) so we can share it here or on our website at*

[PLANETARY.ORG/SPOTLIGHT](http://PLANETARY.ORG/SPOTLIGHT).

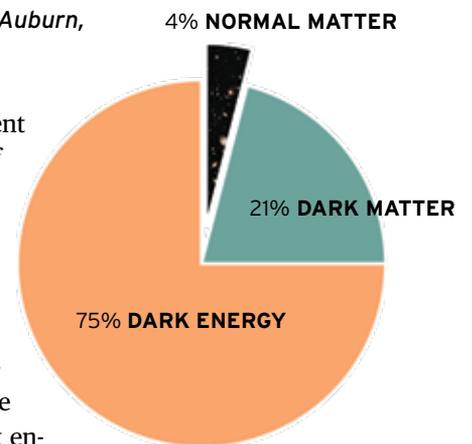
**Q** We know that dark matter and dark energy exist, although, as I understand it, we do not know much about them. Is it possible that dark matter and/or dark energy could be affecting the speed of light as we view it? Could a varying speed of light in space be affecting our perception of where things are in the universe? Also, could dark matter, dark energy, and forces associated with them be affecting our search for extraterrestrial life? —*Judith C. Enos, Auburn, California*

**A** As far as we know, no current measurements or theories of dark matter and dark energy change the SETI picture. The first reason is scale: dark matter might affect the movement of stars around the galaxy, but it has no effect in our neighborhood of a few thousand light-years, and only a minor effect across the 100,000 light-years of our galaxy. Dark energy affects only the universe as a whole, at billions of light-years, and has no effect within the nearest million or so galaxies, let alone inside our own galaxy.

Dark matter is so named because it doesn't interact with light, electricity, or magnetism. Even though gravitational observations lead us to believe that most of the mass in our galaxy is dark matter, researchers are hard at work trying to detect even a few particles of the stuff. The vast majority passes right through Earth without any effect.

With regard to the speed of light, dark matter and energy do affect the way light travels, but only in the way that Einstein's general theory of relativity predicts that everything with mass or energy does. In fact, it's through these effects that dark matter in other galaxies can be mapped out: light from a galaxy far away is bent and squeezed a bit by the dark matter in a galaxy in between. 🌟

—*Jason Gallicchio, Harvard University*



**ABOVE** In this chart, the slice labeled “normal matter” represents everything we see and know about in the cosmos to this point. The remaining 96 percent of the universe comprises elusive dark energy and dark matter. At present, these mysterious forces have no known effect on SETI measurements.

**ABOVE LEFT** Planetary Society volunteer Mary Brown excites kids about light at Longfellow Elementary School in Pasadena, California.



**BRUCE BETTS** is director of projects for the Planetary Society.

# Shuttle LIFE Organisms Return

## A Successful Test Run for Phobos

**IN THE MIDDLE OF THE NIGHT** of May 31, 2011, millions of passengers returned safely to Earth as part of the great conclusion to space shuttle *Endeavour's* final flight, STS-134.

periment) module that will launch this fall to Mars' moon Phobos and back.

Both Shuttle LIFE and Phobos LIFE will help us determine if life could

We took the first step toward answering these questions with Shuttle LIFE by testing the survivability of five kinds of hearty organisms in Earth orbit for 15 days. The opportunity to fly on *Endeavour* came up quickly, and thanks to you—our Members—we were able to jump at the chance to test our organisms on a short spaceflight before sending them off on a three-year journey.

We sealed the Shuttle LIFE organisms inside Delrin plastic tubes within argon (a gas that won't interact with the organisms). This is the same procedure we used to pack the organisms for Phobos LIFE. The Shuttle LIFE tubes then were loaded into a commercial experiment block from Nanoracks, LLC called CREST-1 (Commercial Reusable Experiments for Science & Technology).

I went to Florida for the loading of the tubes into CREST-1, and I was pleased to find our own Planetary Society Arizona Regional Volunteer Coordinator Veronica Ann Zabala-Aliberto as part of the team that was loading the tubes. The fully loaded CREST-1 then was loaded into the shuttle within two days of launch.

After *Endeavour* and

The majority of those passengers were part of the Planetary Society's Shuttle LIFE project.

Thanks to our Members' rapid response, we were able to fly five kinds of creatures from all three domains of life. The organisms were part of our Shuttle LIFE project, an outgrowth of our Phobos LIFE (Living Interplanetary Flight Ex-

periment) module that will launch this fall to Mars' moon Phobos and back. Both Shuttle LIFE and Phobos LIFE will help us determine if life could travel naturally between the planets. For instance, if a rock containing some form of life is ejected off one planet—say, Mars—and makes it to a second—say, Earth—could the life survive the journey? With our LIFE projects, we will go where no one ever has, to help determine the plausibility of the transport of life between planets, which is called *transpermia*.



**ABOVE** This image of the International Space Station and the docked space shuttle Endeavour was taken by Expedition 27 crew member Paolo Nespoli from the Soyuz TMA-20 following its undocking on May 23, 2011.

Image: NASA

## Meet the Microbes...

Water bears made the trip aboard Shuttle LIFE with four other microorganisms: Conan the Bacterium, Joe Bacteria, Old Salty, and the Fire Eaters. The organisms were packed into sample tubes, which were contained in wells inside a shuttle experiment payload.



**TARDIGRADES** (water bears) Members of the animal kingdom, water bears are “huge” microorganisms compared with the other LIFE travelers. Their bodies are composed of four segments, each with two legs ending in claws. Water bears are extremophiles, which means they can adapt to some pretty hostile environments—from about 150 degrees Celsius (about 302 degrees Fahrenheit, or hot enough to bake biscotti) to just a few degrees above absolute zero. Plus, they’re radiation resistant.



**CONAN THE BACTERIUM** This strain of bacterium is so hardy it has the nickname Conan the Bacterium. Whereas 10 Gy (Grays) of radiation would kill an average human, *Deinococcus radiodurans* can survive a whopping 5,000 Gy. More than one third of the cells will even survive a dose of 15,000 Gy! That’s an ideal trait for long journeys through the dangerous radiation of outer space.



**JOE BACTERIA** *Bacillus subtilis* is a “model organism,” a standard bacterium used over and over again in many different biological experiments. *Bacillus subtilis* is also quite radiation resistant and has a long history of space biology missions, going back to the days of *Apollo*. That will allow a good comparison point between Shuttle LIFE and some of the other spaceflights of this bacterium.



**OLD SALTY** *Haloarcula marismortui*—a type of single-celled organism called *archaeons*—lives in extremely salty environments. If ancient Mars had water on its surface at some point in the past, it was in all likelihood very briny. Any life that existed there probably would have lived in those salty seas. It’s important to learn if such a salt-loving organism can survive a long journey through space.



**FIRE EATER** *Pyrococcus furiosus* was discovered in 1986 in volcanically heated ocean sediments off the coast of Italy, and it thrives in temperatures between 70 and more than 100 degrees Celsius (158 and 212 degrees Fahrenheit). But interplanetary space isn’t hot; nor is the surface of Mars or Phobos. So why send a heat-seeking extremophile on the journey? There is always the small risk that somewhere in processing the payload, some mistake would cause it to overheat. If we found that only *Pyrococcus furiosus* survived the trip, this would indicate that overheating rather than conditions in space caused the loss of the other organisms.

our LIFE tubes returned from space, the Nanoracks team and their colleagues removed the tiny tubes from the tiny wells and shipped the tubes back to where most of them originated: our partner, ATCC in Virginia, the leading repository for microorganisms in the United States.

We shipped two sets of unopened tubes back to our partners in Europe: *Bacillus subtilis* MWO1 went to Petra Rettberg, Marko Wassman, and colleagues with DLR, the German space agency; the ever-popular tardigrades, or water bears, went to Ingemar Jönsson at Kristianstad University in Sweden for analysis. The other organisms—a radiation-resistant bacteria species, *Deinococcus radiodurans*; a heat-resistant an-

aerobic archaea species, *Pyrococcus furiosus*; and a salt-loving archaea species, *Haloarcula marismortui*—are undergoing the first steps in the process of analysis at ATCC.

At ATCC, the freeze-dried samples were placed into “broths”—environments specific to each organism (for example, *Pyrococcus furiosus* got a sulfur-rich liquid at nearly the temperature of boiling water). Over time, each organism will be “grown out” in this way, facilitating more analyses in the coming weeks and months.

Shortly after opening the tubes, we took some of each sample, mixed it with liquid, and put it through a machine I like to call the “Machine of the Living Dead” because it counts living and dead cells. Our first look at

the results showed there were many survivors of all three species. Of course, the work has only just begun; more detailed analyses are in process on both sides of the Atlantic. We’ll continue to update you on the results as we receive them in *The Planetary Report* and on the Web at [planetary.org/life](http://planetary.org/life).

Shuttle LIFE was a great success! It gave us an opportunity for a “dress rehearsal” for Phobos LIFE. We had the chance to run through and refine operational procedures that we’ll use when our Phobos LIFE capsule returns. Shuttle LIFE also provided real science, allowing us to learn more about the reaction of organisms to spaceflight and providing points of comparison for the deep-space, long-term Phobos LIFE. 🍀

**BELOW** From left, Amy Smith, ATCC; Bruce Betts; and Tim Lilburn, ATCC, pose with the sealed tubes destined for flight on Endeavour.



**ABOVE** Astronauts Greg Chamitoff (left) and Mark Kelly in the mid-deck of Endeavour during the STS-134 mission. The Shuttle LIFE experiment is in the oblong experiment block floating in the middle of the picture.

Thanks! Planetary Society Members made the Shuttle LIFE project possible with their generous donations.



*Imagining the interior of a Martian lava tube, Michael Carroll recalls the long history of explorers on Earth who ventured into the unknown underground. They used caves as sacred spaces and made images to understand mysteries of the cosmos. Their cave paintings represent a high point in the history of human imagination. Earthly explorers could carry this ancient art form into the future on Mars.*



**JACQUES BLAMONT** is professor emeritus at the University of Paris. He was instrumental in creating the French space agency CNES, and in 1972 he became chief scientist and adviser to the Director General of CNES. Blamont is a member of the Society's Advisory Council.

# Planetary Cave Dwelling

## A Strategy for Exploration

by Jacques Blamont

**MISSIONS TO MARS WITH** humans aboard will face several challenging requirements for sheltering their crews. First is the radiation in the natural environment, a combination of galactic cosmic rays, solar particle events, and secondary radiation from the interaction of both of these with atmosphere and soil. Radiation would rise to peak levels during large solar eruptions, which occur one to three times per 11-year solar cycle. Based on data from NASA's Mars Radiation Environment Experiment (MARIE), the total radiation dose equivalent during a 540-day mission would be 14,795 millisieverts, or mSv. (The sievert is the international unit measuring the biological effects of an absorbed dose of radiation.) The allowable dose is between 1 and 4 mSv per year.

Using caves as habitats provides an intriguing possibility: the total dose equivalent for the same mission in a cave habitat would be 0.212 mSv. Caves two or three meters below the surface can provide effective shielding, although a more conservative five-meter depth would give greater assurance of protection. To date, no other cost-

efficient shielding system has been engineered for Mars missions—although it has been suggested that astronauts' waste, rich in hydrocarbons, could be wrapped around crew quarters during flights to Mars. This makeshift approach could not provide a long-term solution for a large Mars station with extensive laboratories and industrial developments. Gone are the days of *Gemini 7*, a mission astronaut Jim Lowell said was "like spending two weeks in a latrine."

Caves also protect against temperature extremes at the Martian surface and make it easier to manage air filtration. *Apollo* missions showed that lunar dust is a health risk, triggering inflammatory lesions in lungs. Martian dust is even riskier because of oxidants. In caves, keeping dust out is simply a problem that good engineering at the entrances could solve. Shielded from dust storms, structures and equipment would require less maintenance.

Other advantages of caves include protection against meteoric impacts, additional living space for privacy and community life,

and support of the COSPAR Planetary Protection Policy. A sealed habitat enclosed within a cave would facilitate containment of human-associated contaminants.



On the downside, the viability of microbes in caves and the presence of remains of extinct life-forms are possibilities to be studied carefully by precursor missions. Survival of living organisms in Martian caves could be interesting ... or deadly.

### CAVES NEAR VOLCANOES

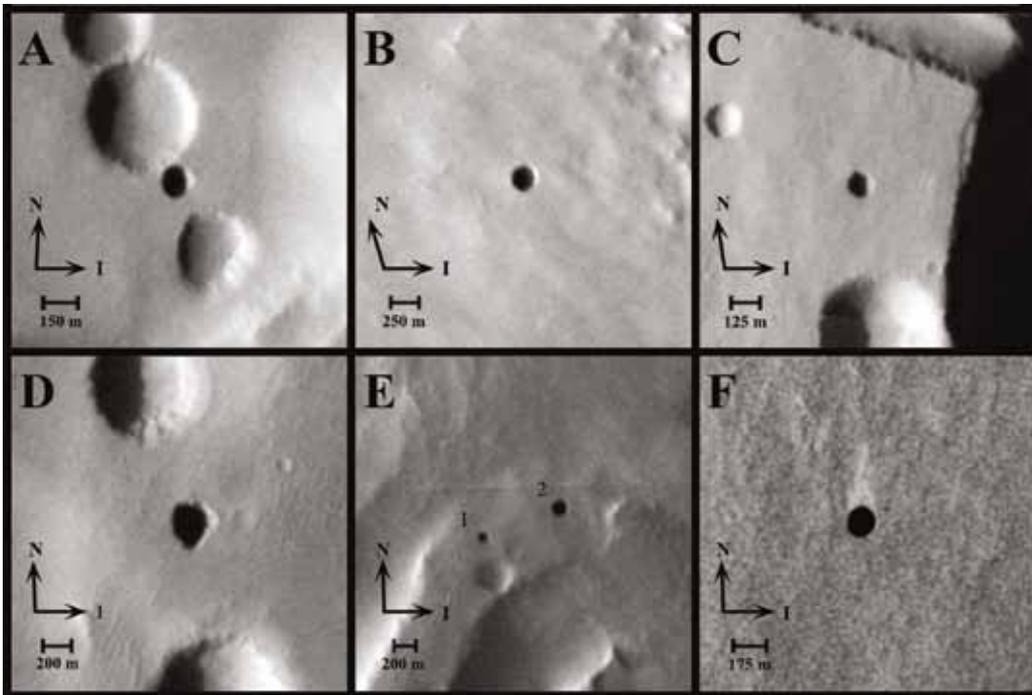
Mars has a ready supply of potentially habitable caves in the form of lava tubes. A lava tube results from a low-viscosity (fast-running)

**ABOVE** Sunlight falls across the exterior of this lava cave on South Korea's Jeju Island. By studying analog lava tube sites on Earth and the Moon, researchers will be better able to evaluate risks from increased human activity within them. One such study of a site in South Korea found the caves able to withstand a normal amount of such activities.

stream of lava cooling and solidifying on the outside while continuing to flow on the inside. When the last of the lava runs out, an emp-

Earth and the Moon. A study of a site in South Korea, for example, seeking to evaluate risks from increased human activity, found the

may be skylights already have been identified on Mars. In 2007, Glen Cushing of the U.S. Geological Survey and colleagues compared images from the HiRISE camera aboard *Mars Reconnaissance Orbiter* with images from the THEMIS thermal mapper aboard *Mars Odyssey* and reported seven possible lava tubes on the slopes of Arsia Mons. The craters range in diameter from 100 to 225 meters. Another hole was found in 2010 on Pavonis Mons. On Earth's Moon, the Japanese *SELENE* imager discovered holes indicating the presence of underground lava tubes.



**ABOVE** These THEMIS images reveal seven dark spots on Arsia Mons (two in image E) that could be skylights, opening into lava tubes beneath the surface. The arrows point in the direction of Mars' north pole as well as toward solar illumination (I).

ty cylinder remains, with smooth surfaces on the floor, walls, and ceiling. On Earth, such tubes frequently have a diameter of around 15 meters. They seem to be bigger on Mars.

Underground lava tubes become accessible when a section of the roof collapses, creating a pit, or skylight, and exposing two cave openings. After a skylight opens, other parts of the lava tube can remain geologically stable, surviving intact for millions of years. Guidelines for selecting stable and otherwise suitable caves will have to be developed, drawing on research of analog sites on

observed structures were able to withstand "normal engineering loads."

One limitation of lava tubes is their obligatory presence in volcanic terrains. The best sites for a Mars base will be at the lowest possible altitude and highest possible latitude, with the hope of finding subterranean ice. Syrtis Mons, Nili Fossae, and Mawrth Vallis are regions that could contain lava tubes and offer scientific interest. Many lava tubes also will be found in the lava beds around Alba Patera and in volcanic regions apart from the Tharsis shield, such as Elysium.

Several pit craters that

**HOME SWEET HOLE  
IN THE GROUND**

On approach to an underground Mars base, as envisioned, the skylight is the first feature visible. Next, the station's solar photovoltaic array comes into view, and the landing area, surrounded by buildings for maintenance and other work but not for residence. Also visible are antennas and vehicles, including a transport system to the floor of the skylight. If the lava tube is deep, it might require an elevator for vertical descent. If the skylight offers a slope, as seen at lava tube sites on Earth, crew members could travel by cable car to the station entrance below.

At the skylight floor, a pressurized passageway connects

Images: NASA/JPL-Caltech/USGS

two caves. The cave on one side is for housing, privacy, and societal functions. The cave opposite is devoted to life-support systems and the industrial activity of the station, including a nuclear-powered generator for electricity, facilities for *in situ* production of chemicals, recycling systems, maintenance shops, storage rooms, and so forth.

Design studies for space colonies suggest that the minimum area for privacy and community life could not be less than 50 square meters per person, with another 20 square meters per person required for agriculture and food processing. The gardening and animal-breeding facilities are situated on the living quarters side of the base. The presence of living beings other than people is crucial for the psychic equilibrium of crew members. The agricultural section looks like a garden in an open space, perhaps with pseudo-landscapes of Earth projected as holograms—a cheerful world where the real and the virtual are indistinguishable.

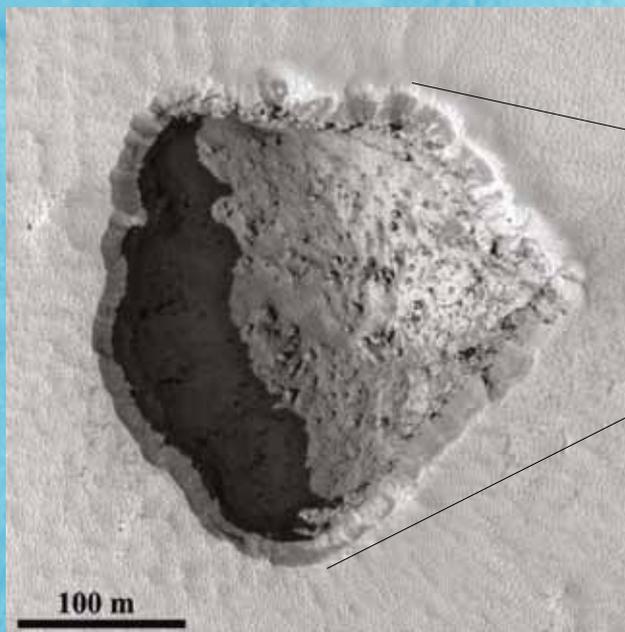
Food requirements for a six-person crew amount to 6.8 kilograms (15 pounds) per day, with a total of nearly 4,000 kilograms (more than 8,000 pounds) for an 18-month stay. According to one estimate, a greenhouse of 40 square meters under artificial light could grow 25

## FINDING A SAFE PLACE TO BUILD A BASE

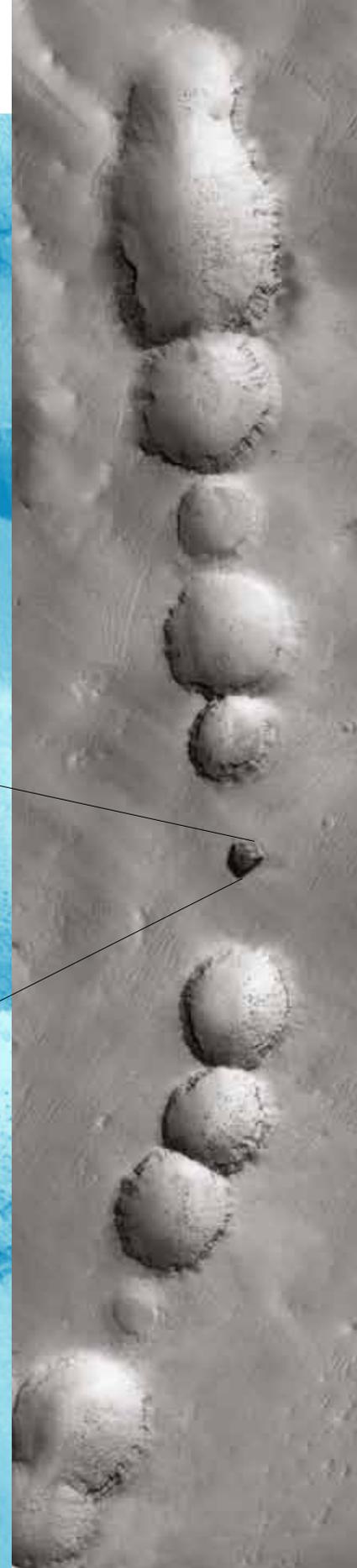
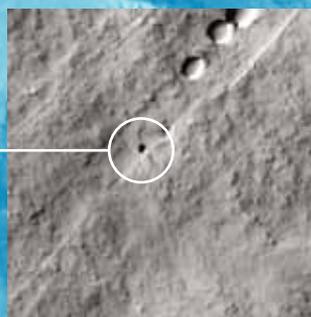
The quickest way to find a lava tube is to look near a volcano. A lava tube usually is indicated by evidence of “cave-ins,” represented by a line of indentations in the planet’s surface. Most cave-ins are partial, leaving the tube inside intact, but a full cave-in—a darker spot in the chain—might be an ideal entrance to the subterranean caves.

**RIGHT** *The small pit crater in the middle of this chain of collapsed pits on Arsia Mons is the probable skylight labeled “D” in the picture on page 12. Mars Global Surveyor captured this image in March 2006.*

**BELOW** *A close-up Mars Odyssey image of the putative skylight, which scientists have nicknamed Annie, shows windblown sediment accumulated on one side, creating a relatively low-gradient slope to possible cave entrances.*

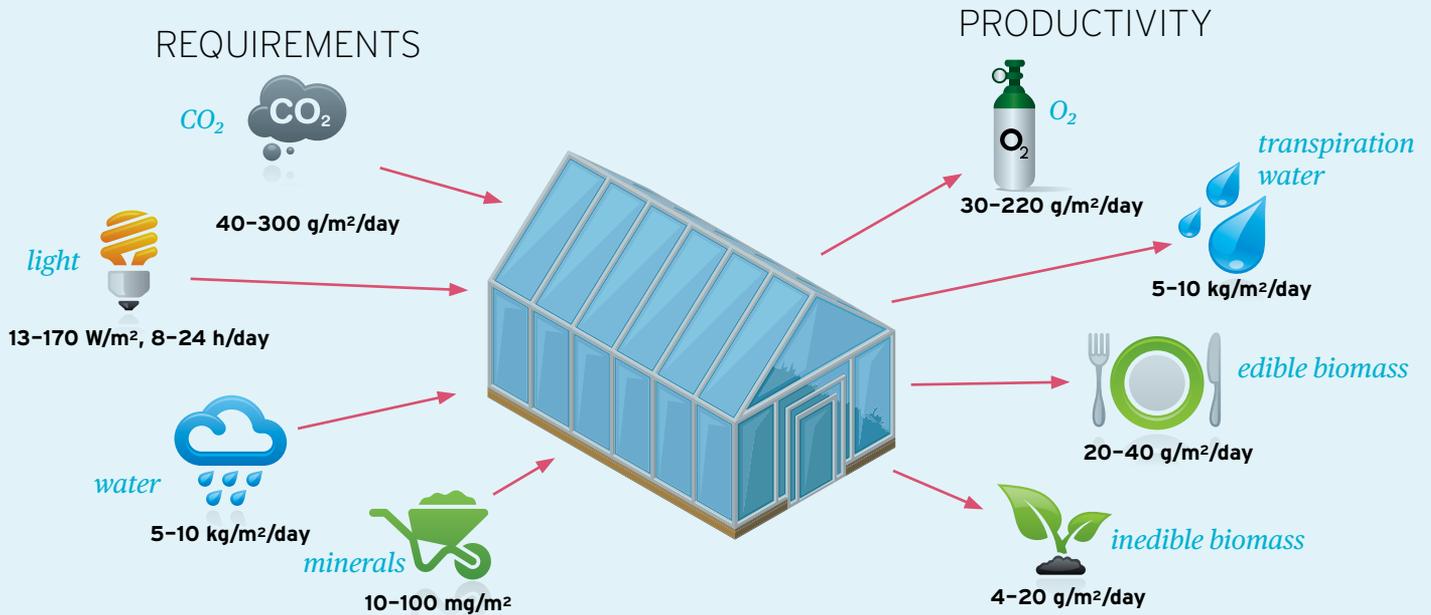


**RIGHT** *Students working with scientists in NASA’s Mars Student Imaging Program found a sizable opening, 190 by 160 meters, in the slope of Pavonis Mons. Seventh graders from Evergreen Middle School (Cottonwood, California) made the discovery in June 2010.*



## REQUIREMENTS AND PRODUCTIVITY OF HIGHER PLANTS

(1,000 m<sup>2</sup> greenhouse in an underground Mars base)



**ABOVE** Long-term residents of Mars will need to closely monitor what goes in and what goes out of a greenhouse. Advanced life-support systems designed to grow food and regenerate water and air while helping the recovery of the waste are strong candidates for a long-term human mission to Mars.

percent of the food for the six-person crew. By extrapolation, about 200 square meters could grow 100 percent of the crew's requirement. A project called ACCESS Mars, at the International Space University summer program in 2009, calculated requirements and production for a greenhouse of 1,000 square meters—not inconceivable in Martian lava tubes.

Plants are able to grow in a surprising variety of conditions—in sand, vermiculite, and styrofoams, and even with their roots exposed—as long as they have support and nutrients. In addition to plants, the agricultural area has high-yield fish ponds and facilities for breeding animals such as rabbits. It is likely that insects will be accepted as food within the next few decades, and they should be welcome on Mars for this purpose: the Martian farm will concentrate on breeding

nutritious maggots, crispy grasshoppers, or fat cockchafer larvae, all of which grow quickly at minimal expense of energy and with small surface requirements.

The large open space between the two caves could shelter the inflatable rovers needed for long-range exploration and sample harvesting.

### IN THE OTHER CAVE

The second cave contains the machines and facilities to support the station's infrastructure and industrial operations. On entering, a visitor would notice construction techniques developed for bases on the Moon. The walls might be stuccoed with a mixture of local regolith or dust with additives from Earth. A possibility preferred to that is inflatable structures, essentially tents inside the caves, which are easy to deploy and might be tubes 10 or 20 meters long

in the early phases, leading eventually to tubes hundreds of meters wide and made of a membrane-like fabric. A third possibility, less appealing, is metallic structures assembled on site.

At the far end of the second cave is a nuclear reactor, the station's principal source of energy. Estimates of power needs range from 30 kilowatts for a small habitat studied by the European Space Agency to 160 kilowatts in NASA's first Mars Reference Design Mission. Doubling the 160 kilowatts to achieve ample reserve capacity, the reactor could resemble the SP-100, with a mass of 14 tons. The station would draw on solar power from photovoltaic arrays above ground as a complementary energy source.

Life support—beginning with the generation of oxygen and removal of carbon dioxide—will use techniques

proven on the Moon. Water will be recycled, but the station will require additional supplies, which might be available by dehumidification of cave air or from cave ice. Management of wastes will be the same as for other missions. Residues will be sterilized, packaged, and stored. Decomposable products, including feces and urine, will be pyrolyzed to recover water.

Industrial operations will be an essential part of any long-term settlement on Mars. Exploration will lead to discoveries that will point to products that can be manufactured from Martian materials or processed on Mars for use on Earth. Thus, the second cave will have equipment for manipulation of dust, minerals, molecules, and living organisms. Genetic engineering of viruses, bacteria, and fungi could become a specialty of laboratories on Mars—for example, if a bioengineering project is considered too dangerous for Earth because of possible escapes by uncontrollable species. Pursuing research of this kind in advanced containment facilities might be the most serious and compelling justification for human missions to Mars. Eventually, development of new genomes could expand to mass production of modified or new organisms for utilization on Earth.

Although particular appli-

cations are unforeseeable, it is likely that industry will be the driver for a human presence on Mars.

#### A UNIFIED STRATEGY

Human missions to Mars are not feasible without some sort of apprenticeship. Bases in Martian caves will require preliminary testing of equipment and methods in lunar caves. How might this sequence of events come about?

From a strategic perspective, cave dwelling on the Moon and then Mars offers a unifying concept for exploration of the solar system. It is a way to organize international efforts in a coherent, phased plan. The International Lunar Exploration Working Group, a liaison for space agencies with Moon missions, has proposed coordinating separate programs in a so-called Robotic Village, which could be a first step toward an International Lunar Base. This base, with human occupants, might be deployed in a lunar lava tube. A habitat successfully established in a lunar lava tube would encourage development of the International Lunar Base, which might be in place by the year 2030 or shortly thereafter, very possibly under the leadership of Chinese engineers.

In addition to being the logical testing ground for missions to Mars, the International Lunar Base will be

the political *sine qua non* for human flights beyond the Moon. New agreements will be needed to integrate emerging space powers, such as China and India, into the Mars mission team. The team might take shape as an ad hoc space agency, following the successful example of international science co-



operation groups such as CERN and ITER.

The power and prestige of science will be important to any eventual Mars mission, capturing worldwide attention and support. If humans reach Mars, it will happen for two reasons. First will be the general public's admiration for scientific exploration. Second will be an economic motive, which, as noted earlier, may be a need to conduct genetic engineering research in a remote place. Without these two motivations, there will be no human presence on Mars. 🌱

**ABOVE** A greenhouse as large as 1,000 square meters might be feasible inside a Martian lava tube. Although artificial growth lights are one possibility, this future concept shows an inflatable "light pipe" made of highly reflective Mylar attached to an opening in the cave's ceiling, exposing the trees, plants, and vegetables to natural sunlight.



**JAMES D. BURKE** is technical editor of *The Planetary Report*.  
**ANDREA CARROLL** is development director for the Planetary Society.

# A Symphony of Voices in Vienna

## The 2011 General Assembly of the European Geosciences Union



### EXTREME PRECISION AND PATIENCE NEEDED

The detection principles of *FINDS*, *Kepler*, and *COROT* are simple, but making them work in practice is almost impossible. *FINDS* measures the tiny toward-and-away movements of a star as unseen planets tug on it. *COROT* and *Kepler* measure the minuscule drop in brightness of a star-planet system as a planet transits in front of and behind a star. The first technique is spectrometry; the second is photometry. Once detected by one technique, a planet can be confirmed and, in some cases, examined by the other.

Download our poster and learn more about the Society's *FINDS* Exo-Earths project at [PLANETARY.ORG/FINDS](http://PLANETARY.ORG/FINDS)

Find more exoplanet abstracts and poster presentations from the EGU General Assembly at [HTTP://BIT.LY/TPS0558](http://BIT.LY/TPS0558)

Visit the EGU website at [WWW.EGU.EU](http://WWW.EGU.EU) to follow its blog and view other exciting presentations (select "General Assembly 2011" from the drop-down list)

**IMAGINE THIS: 10,725** Scientists and space enthusiasts (more than 3,000 of them students) from 96 countries, giving 4,333 lectures and 8,439 poster presentations and joining in innumerable informal discussions during five days in April at the Austria Centre, Vienna. It would be easy to imagine a cacophonous occasion.

Instead, it was the 2011 General Assembly of the European Geosciences Union (EGU), an annual gathering devoted to Earth, planetary, and space sciences. The event hummed with excitement and optimism, and we were there to add our voices.

Our mission: to showcase your vital role—as Planetary Society Members—in the hunt for Earth-like worlds. “Exoplanet Activity of the Planetary Society,” our poster presentation, led with a bold statement: “We—Earth’s people—are on the threshold of finding answers to questions about life in the cosmos.”

These answers could change the course of civilization. It’s your kind of challenge—a Planetary Society endeavor. Indeed, Society Members are already planet-hunters, building public

support for exoplanet research and discovery as well as providing seed funding for the *FINDS* Exo-Earths project and, now, for its follow-on, the *FINDS* Exo-Earths 2 system (see the March/April 2011 issue of *The Planetary Report*).

*FINDS* uses ultra-precise spectrometry to detect unseen planets (see box). ESA’s *COROT* and NASA’s *Kepler* note the tiny drop in light as a planet passes in front of and behind its star. Both techniques are bedeviled by a multitude of error sources; yet, with extreme care and devotion, planet-hunters have now found almost 2,000 candidate worlds.

NASA scientist Daniel Winterhalter and Russian Federation scientist Yuri Barkin loaded the exoplanet track of the EGU conference with presentations. *Kepler* mission Principal Investigator William Borucki shared recent mission results. Other presenters suggested (if there is enough funding) how much more there is in store for us, from ground- and space-based spectroscopy of extrasolar planets, to innovative methods for observing exoplanet debris disks that are signposts of planetary formation, to un-

derstanding the planets’ atmospheric compositions.

Dr. Borucki stopped by our poster and told stories from the early days of exoplanet research, days when he and individual planet-hunters struggled to fund the most basic exoplanet research and hardware. Governmental, academic, and private support was nearly nonexistent. In general, the public did not yet know (or yet care) about hunting for these possible Earth-like worlds.

Today, though there still is not enough funding to go around, your impact on the field is visible. You, as Planetary Society Members, help create the broad public interest, understanding, and support that leads to government and private investment. You also provide seed funding that can lead to larger grants from other sources.

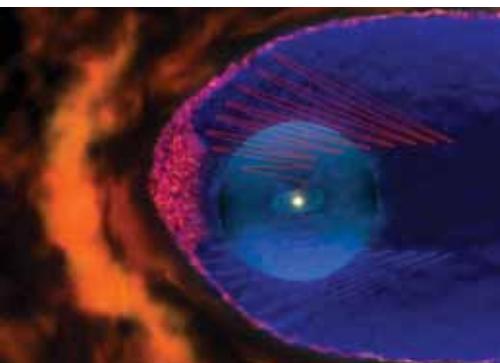
One thing is clear: opportunities exist for more innovative Planetary Society initiatives in the field of exoplanet research and discovery. Together, we will bring these questions about exoplanets—and, in due time, their answers, if answers there may be—into the consciousness of the people of Earth. 🐾

*Thanks!* Planetary Society Members made the *FINDS* Exo-Earths project possible with their generous donations.

## A Bubbly Edge

**THE EDGE OF OUR SOLAR SYSTEM MAY NOT** be smooth but, instead, filled with a turbulent sea of magnetic bubbles. Scientists using a new computer model to analyze *Voyager* data discovered that the Sun's distant magnetic field is made up of bubbles approximately 160 million kilometers (100 million miles) wide. The bubbles are created when the magnetic field lines (streams of charged particles emanating from our star) reorganize. The new model suggests that the field lines are broken up into self-contained structures disconnected from the solar magnetic field.

The *Voyager* spacecraft, more than 14 billion kilometers (9 billion miles) away from Earth, are traveling in a boundary region where the solar wind and magnetic field interact with, and are affected by, material expelled from other stars in our corner of the galaxy.



"The Sun's magnetic field extends all the way to the edge of the solar system," said astronomer Merav Opher of Boston University. "Because the Sun spins, its magnetic field becomes twisted and wrinkled, a bit like a ballerina's skirt. Far, far away from the Sun, where the *Voyagers* are, the folds of the skirt bunch up."

Understanding the structure of the Sun's magnetic field will allow scientists to explain how galactic cosmic rays enter our solar system and help define how our star interacts with the rest of the galaxy. More at

[HTTP://1.U.S.A.GOV/TPS0551](http://1.usa.gov/TPS0551).

—from NASA



## Breaking News

**ASTRONOMERS FROM THE EUROPEAN** Southern Observatory have photographed a spiral galaxy that could be a twin of our own Milky Way. The beautiful spiral, named NGC 6744, lies about 30 million light-years away in the southern constellation of Pavo (the Peacock). This galaxy so closely resembles our own that it could be a picture postcard photographed by an extragalactic friend.

One significant difference between NGC 6744 and the Milky Way is in the two galaxies' sizes. Whereas our galaxy is roughly 100,000 light-years across, our "twin," pictured above, extends to almost twice that diameter. The red spots glowing from NGC 6744's spiral arms are regions where new stars are being born.

—from the European Southern Observatory

**DAWN IS RAPIDLY CLOSING IN ON ITS** July 16 encounter with asteroid Vesta. The view at right is a still from a 20-frame animation made of images taken on June 1, 2011 from a distance of 483,000 kilometers (300,000 miles). The 20 images loop five times to show a period spanning 30 minutes. During that time, Vesta rotates about 30 degrees. These pictures are being used by mission navigators to fine-tune *Dawn*'s trajectory as it homes in on its target.

Vesta is 530 kilometers (330 miles) in diameter and is the second most massive object in the asteroid belt. To watch the video, go to [HTTP://1.U.S.A.GOV/TPS0552](http://1.usa.gov/TPS0552).

—from NASA/JPL

**ABOVE** This picture of the nearby spiral galaxy NGC 6744 was imaged by the Wide Field Imager on the MPG/ESO 2.2-meter telescope at the European Southern Observatory's La Silla Observatory in Chile.

**LEFT** New data from *Voyager* add a magnetic "froth" to the outer solar system (in pink).

**BELOW** Surface details begin to resolve as NASA's *Dawn* spacecraft closes in on the giant asteroid Vesta. This is a single frame from an animation obtained on June 1, 2011 from a distance of about 483,000 kilometers (300,000 miles).





**CHARLENE M. ANDERSON**  
is associate director of the  
*Planetary Society.*

# Time for a Course Correction

**You can make the difference.**

**DO YOU WANT TO WATCH ROBOTIC SURROGATES** explore worlds never seen by human eyes? Do you want to know if other life-forms share the universe with us? Do you want to see human explorers walk on other worlds? If so, we've got a problem: we can't get there from here.

Space exploration—of both the human and robotic varieties—is in serious trouble, and without concerted efforts and strong leadership to establish clear, realistic, and affordable goals, space exploration will become a thing of the past.

Yes, money is scarce, but the problems facing space exploration are only partly due to limited resources. The larger, more fundamental, issue is a lack of leadership in developing a coherent strategy and then setting priorities to maximize scientific and technological achievement with the resources available.

Left to its own devices, the political establishment will use the prerogatives of power to serve its own political interests, without regard for the larger goals of exploration in the national—and international—interest. This has been demonstrated all too clearly in recent years. But it does not have to be so.

You can make the difference.

The Planetary Society provides both the ways and the means for you to maximize your power to influence politicians and direct their focus on space exploration. By acting in concert with your fellow Members, you have shaped and will continue to shape space policy, as you proved when *New Horizons* launched to Pluto and when drastic cuts to NASA's science budget were rolled back.

It's time for Planetary Society Members to take up the fight again. Right now, the U.S. space program and others around the world are being dragged down by shortsighted politicians who can't grasp that this exhilarating endeavor requires them to think beyond parochial interests and the next re-election campaign.

Vision, commitment, and endurance are absolute

requirements. Governments often lack them. They are what you and other Planetary Society Members must provide. We must get organized, focus our collective energy, and make our voices heard.

Here are four issues concerning the U.S. space program on which the Planetary Society is focusing this year.

## **SET A GOAL FOR HUMAN SPACE EXPLORATION**

Only if we know where we are going in space do we have a chance of getting anywhere. Space exploration is too big, too ambitious, and too demanding an endeavor to succeed without realistic goals, proper funding, and a sound technical plan. Right now, the space program is lacking those requirements. Human space programs are drifting like a boat at sea without a rudder. The politicians in Washington, D.C. have failed to agree on specific destinations. They've cut NASA funding while mandating an unaffordable and backward-looking rocket design. This Space Launch System, designed by a congressional committee, threatens to suck money from critical long-term investments in science and technology.

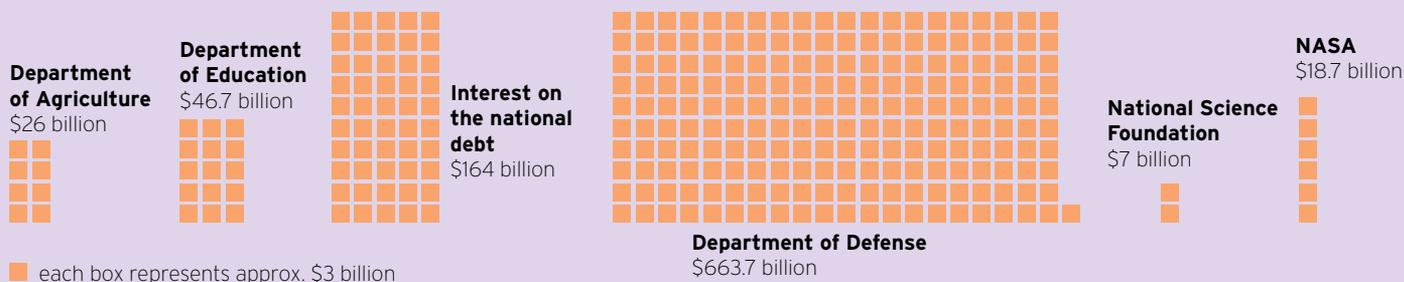
To get out of Earth orbit and onto other worlds, we need both the U.S. president and Congress to focus their deliberations on reaching agreement on achievable goals and backing up the goals with the funding necessary to achieve them. We need to build strong partnerships among spacefaring nations. The political leadership in Washington must give NASA latitude, both to craft the best space exploration plan possible within the constraints of available resources and to make decisions based on sound engineering and technical merit.

## **DON'T ABANDON FLAGSHIP MISSIONS**

Within the current NASA plan, there will not be enough money to fly flagship missions, such as Mars Sample Return or a Europa orbiter. It is unconscionable that we might not again see any space mission

*By acting in concert with your fellow Members, you have shaped and will continue to shape space policy.*

## HOW MUCH FOR THAT SPACECRAFT IN THE WINDOW? Comparing costs in the 2010 U.S. budget



as spectacular as *Voyager* on its grand tour, *Galileo* going to the Jupiter system, or *Cassini*, still exploring the realm of Saturn. Under the projected budgets for the next few years, planetary exploration will consist solely of small- to medium-sized missions. Although such missions make valuable scientific contributions and form the foundation of a healthy research program, the candidate flagship missions to Mars and the Jovian system promise truly awesome discoveries that will inspire the public, fundamentally alter our understanding of our solar neighborhood, and potentially discover life on another world.

Flagship missions are extraordinary, and they make extraordinary demands on the governments that fund them and the people and institutions that run them. Their size and technical demands may require partnerships among international space agencies. But we can't shrink our ideas of what is possible in space simply because those ideas are demanding. Where there is no vision, people get disinterested—and lose passion for space exploration.

### KEEP OUR EYES ON PLANET EARTH

Even while the changing climate threatens lives and livelihoods on Earth, the U.S. Congress is cutting the science and observations that can help us understand the changes, determine how to mitigate the effects, and preserve the people, places, and ecosystems under threat. Global coverage of Earth's environment can be obtained only from space, but the necessary satellites are being canceled or postponed. If current budget cuts are allowed to stand, the task of understanding and dealing with the changing climate will become much more difficult and uncertain.

NASA, NOAA (the National Oceanic and Atmospheric Administration) and the USGS (United States Geological Survey) fly Earth-observing satellites so that scientists and policymakers have the data they need to craft wise policies and fulfill their responsibilities to the public. Many of these satellites are nearing

the ends of their design lifetimes and may soon fail. If they are not replaced, humanity will slowly start losing its vision of the most important planet, Earth.

Our planet's changing environment will affect every person on Earth, so nations and their space agencies share the responsibility of monitoring this change from orbiting platforms. We in the Planetary Society must advocate for international cooperation in this critical endeavor.

### SUPPORT COMMERCIAL SPACEFLIGHT

Getting to space usually is the most forbiddingly expensive part of space exploration. The nascent commercial spaceflight industry holds the potential to make transportation to orbit more affordable—and space exploration more attainable. But this promise is endangered by entrenched interests seeking to maintain the status quo and keep contracts flowing to the biggest, already established aerospace contractors. The U.S. Congress must overcome its resistance to change and stop inhibiting technological evolution and improvement.

Old technologies are still capable of placing people and their machines in orbit, but it will take breakthroughs to make space exploration more affordable. NASA and other space agencies should have their technology development budgets boosted. Investment in commercial spaceflight should be encouraged.

### WHAT CAN YOU DO?

Support your Planetary Society. Respond to our calls to action. Join your voice with those of your fellow Members as we fight to get politicians to support space exploration. If we don't act now, damage will be done. We may lose the grand missions of discovery that we had hoped to see and that we hoped would inspire our children to achievements even greater than those of their parents and grandparents. It's up to us to put space exploration back on course to the best possible future for this planet among other worlds. 🌍

*Join your voice with those of your fellow Members as we fight to get politicians to support space exploration.*

# Annual Report to Our Members

*Dear Planetary Society  
Members, Donors, and Friends,*

## **IT'S AN EXCITING TIME AT THE PLANETARY SOCIETY!**

Together, we're entering our 31st year, and the last one has been as remarkable as any. It has been a year of significant changes, but we remain committed to developing innovative projects and effective political advocacy, and sharing the adventure and inspiration of space exploration with the world.

## **BIG CHANGES**

In 2010, we moved the Society headquarters from a beautiful old house to a lovely building that was once part of a luxury hotel. In the move, we went through three decades of history, keeping the very best memories intact. The last of the three founders, Lou Friedman, stepped aside as executive director, and Bill Nye (the Science Guy®) took over the helm of our wonderful planetary ship.

Bill wants everyone on Earth to know and appreciate what he calls "our place in space." I couldn't be more pleased. Bill had Carl Sagan as a professor and joined the Society back in 1980. Bill embraced Carl's message, continually advocating for people everywhere to have a planetary view. Bill has made Carl's view his own.

As we move through fiscal year 2011 (October 1 through September 30), we find the Society in a good cash position. We have the money from the sale of the old house, and our membership provides strong support. But, as we look toward the future, we need to make changes now to ensure a strong and effective organization 10, 20, and 30 years in the future. We need to recruit new and younger supporters or the Planetary Society will shrink to what I consider an unacceptably small number of members.

This is where Bill comes in. I am confident that he will grow our organization. In this issue, you'll find our new kids' section. You, our Members, have urged us to focus more on science education and engaging young people, and now we have a science educator on board who can make this happen.

## **A CONTINUED DEDICATION TO OUR MISSION**

Our projects continue to be innovative and outstanding. At last, we will fly our Phobos LIFE (Living Interplanetary Flight Experiment) on the *Phobos Sample Return* mission, set to launch at the end of 2011. With LIFE, we're sending microbes and tardigrade "water bears" on a three-year round trip to Phobos, a moon of Mars, to test if an organism can survive a trip from one planet to another. As a precursor to that mission, we arranged to have our tiny passengers on board *Endeavour*, on the second-to-last shuttle flight (more on page 8). Thanks to your support, our test organisms are now undergoing analyses.

As I write, our *LightSail-1* solar sail spacecraft is nearly complete. Soon, we'll have two exquisitely built, very small cubesat spacecraft ready to fly at the first opportunity. We need to launch *LightSail-1* to an altitude of about 840 kilometers (520 miles). Up there, we escape Earth's atmosphere, and we can do some sailing with the pressure of photons. People everywhere will be able to see the shiny sail as it passes overhead. *LightSail-1* is a testament to what we can do together as the Planetary Society. You should be very proud.

And there's more: along with our excellent projects involving near-Earth objects, microrovers, and extrasolar planets, we've kept our eye on the politics and policy of space. We have stayed connected with lawmakers and policymakers. As we have for 30 years, we will continue to represent your views in the space agencies of the United States, Europe, Russia, India, China, and Japan.

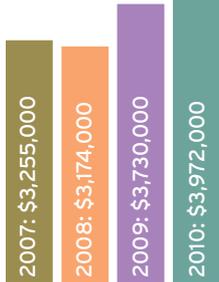
## **DOING MORE WITH LESS**

My intense optimism about the future is tempered by the reality of a very difficult economic environment. We're not alone. Countless nonprofits have had to cut back severely or close their doors. Thanks to you, our organization is in a good position. Nevertheless, after careful deliberation and analysis, we have decided to reduce the number of issues of *The Planetary Report* that we produce, print, and mail, from six each year to four.

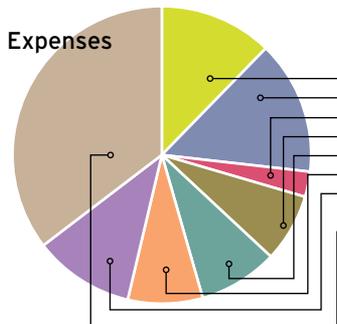
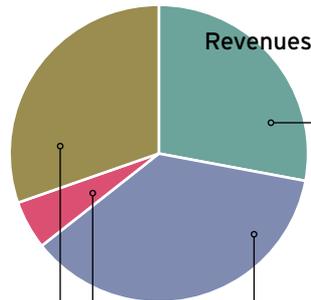
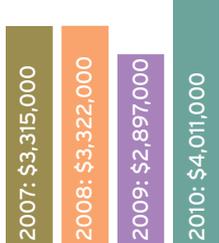
In the meantime, we are ramping up our efforts

**YEAR-TO-YEAR:**

**Revenues**



**Expenses**



# Balance Sheet

For the fiscal years ended September 30, 2007, 2008, 2009, and 2010 in thousands of dollars

Total All Funds:	FY2010	FY2009	FY2008	FY2007
<b>Assets</b>				
<b>Current Assets</b>				
Cash and Cash Equivalents and Investments	2,984	2,636	1,316	1,612
Membership Dues and Misc. Receivables	32	41	29	32
Inventories	0	28	39	42
Prepaid Expenses	51	64	39	37
<b>Total Current Assets</b>	<b>3,067</b>	<b>2,769</b>	<b>1,423</b>	<b>1,723</b>
<b>Land, Building, and Equipment</b>	<b>61</b>	<b>583</b>	<b>618</b>	<b>617</b>
<b>Total Assets</b>	<b>3,128</b>	<b>3,352</b>	<b>2,041</b>	<b>2,340</b>
<b>Liabilities</b>				
Accounts Payable and Accrued Expenses	232	141	154	286
Deferred Dues and Grant Revenue*	1,330	1,606	1,115	1,134
<b>Total Liabilities</b>	<b>1,562</b>	<b>1,747</b>	<b>1,269</b>	<b>1,420</b>
<b>Net Assets (Deficits)</b>				
Unrestricted	876	226	192	389
Temporarily Restricted	688	1,377	578	529
Permanently Restricted	2	2	2	2
<b>Total Net Assets</b>	<b>1,566</b>	<b>1,605</b>	<b>772</b>	<b>920</b>
<b>Total Liabilities and Net Assets (Fund Balances)</b>				
	<b>3,128</b>	<b>3,352</b>	<b>2,041</b>	<b>2,340</b>

	FY2010	FY2009	FY2008	FY2007
<b>Revenues</b>				
Membership Dues	1,110	1,101	1,207	1,212
Donations/Grants	1,446	2,208	1,613	1,835
Bequests	210	277	170	3
Other**	1,206	144	184	205
<b>Total</b>	<b>3,972</b>	<b>3,730</b>	<b>3,174</b>	<b>3,255</b>
<b>Expenses</b>				
Member Development and Fundraising	492	488	400	534
Publications: Print & Web	583	621	552	467
Education & Information	110	81	184	228
Programs***	298	172	353	364
Member Services	345	371	426	345
Administration	325	318	304	305
Projects	438	616	921	805
Special Solar Sail Expenses	1,420	230	182	267
<b>Total</b>	<b>4,011</b>	<b>2,897</b>	<b>3,322</b>	<b>3,315</b>

\* Income received but not yet recognized  
 \*\* Admissions, events, interest, net sales, royalties, gain on sale of property, etc.  
 \*\*\* Events, lectures, tours, and expeditions

on our website, radio show, and social media. Follow us on Facebook and Twitter, keep up-to-date with our award-winning blog at [planetary.org/blog](http://planetary.org/blog), and listen to our fun and informative podcast at [planetary.org/radio](http://planetary.org/radio). Our information and insights into space policy will be available more quickly than ever through these electronic media. This transition will both reduce our costs and keep you better informed than ever.

**HONORING OUR VISIONARY LEADER**

Finally, a few words about Lou Friedman. He guided the Planetary Society so very well for so many years. I especially want to thank him for his decades of service and his passion for our organization. In April of this year, we threw Lou a big party to celebrate him and his leadership. There, we presented him with a

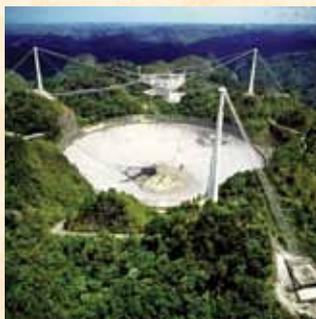
plaque representing the inner planets—Mercury, Venus, Earth, and Mars—held in place with gold-filled wire orbits. The background is a star-field calculated for his day of retirement. Mars is represented by a piece of that planet, a Martian meteorite. The plaque features an inscription: “To Louis Friedman for 30 years of bringing worlds to Earth.”

Now, I’d like to thank you as well. Your steadfast support has kept our unique and remarkable Society thriving. It is a legacy we can all be proud of, and I am confident that, thanks to you, the best is yet to come.

Dan Geraci

Dan Geraci  
 Chairman of the Board

We roasted &



## Explorers Wanted! Travel with the Planetary Society

The Planetary Society is calling explorers to travel with us to remote, beautiful, and even alien regions on planet Earth to witness some of our world's most breathtaking wonders. Escorted by knowledgeable guides and speakers, the tours we offer through Betchart Expeditions span the globe.

Coming up, we invite you to join us on an amazing adventure to the Caribbean, starting January 26, 2012. Our trip combines two tremendous opportunities—a chance to see the world's largest radio telescope near San Juan, Puerto Rico and an opportunity to explore the Lesser Antilles, a ring of volcanic islands that circles the eastern Caribbean.

We'll travel on board the 227-foot, five-masted *Royal Clipper*—one of the world's largest sailing yachts. Our own Bill Nye will join the group at the famous Arecibo Radio Telescope, where scientists search for extraterrestrial signals and conduct fascinating deep-sky research on topics ranging from quasars and pulsars to the origins of the universe starting at the moment of the Big Bang.

Join us for ARECIBO & the Lesser Antilles, January 26–February 4, 2012, or join us on one of these other great adventures!

For more information or to sign up for any of these trips, visit [betchartexpeditions.com](http://betchartexpeditions.com) or contact:

Betchart Expeditions  
17050 Montebello Road  
Cupertino, CA 95014-5435  
Tel.: (800) 252-4910 or (408) 252-4910  
Fax: (408) 252-1444  
E-mail: [info@betchartexpeditions.com](mailto:info@betchartexpeditions.com)

**HOW DO YOU PROPERLY CELEBRATE THE** man who helped create the Planetary Society and ran the organization for its first 30 years?

On April 30, 2011, the Planetary Society roasted and toasted **LOU FRIEDMAN**—our cofounder and retiring executive director—at a lovely and fun party at the remarkable Cicada Restaurant in downtown Los Angeles. Hosted by gala cochairs, myself and Board Member Neil deGrasse Tyson, the fete was both a successful fundraiser for our organization and a heartfelt tribute to Lou's 30 years at the helm.

We met up with old colleagues and made new friends. The Not Ready for Planetary Players (the staff) presented a comedy sketch that featured Advisory Board Member Robert Picardo of *Star Trek Voyager* fame playing Lou himself. Robert also sang some Planetary Society songs along with chanteuse and longtime Member and friend of Lou, Angela Brown.

Several wonderful roasts were presented by Lou's old cronies, including John Casani, Jim Burke, Michael Shermer, John Garvey, Tom Thornbury, Slava Linkin, Mike Brown (a video roast), and Dave Doody, as well as Board Members Jim Bell, Joe Ryan, John Logsdon, and, of course, Neil. There were plenty of laughs—really. And there were some wonderful, warm tributes. It was a delightful evening.

I'd like to again thank our sponsors, Joseph and Kathy Ryan, Toshiba America, Bamag Industries, NASA's Jet Propulsion Laboratory, Stellar Exploration, and Underwriters Laboratories, Inc., as well as the many Members and friends who represent 30 years of the Planetary Society and our myriad projects.

Thank you, too, to all who sent in your roasts and toasts for Lou. He's going to enjoy reading them over the weeks to come.

We had an outstanding time celebrating our first 30 years, and we're excited indeed about the next 30 and what's to come. 🐉

— Bill Nye

Royal Clipper photo: Monique Allard-Jobé, Arecibo; Arecibo: NAIC Arecibo Observatory, a facility of the NSF; Roast photos by Planetary Society staff.



**ARECIBO &  
the Lesser Antilles**  
January 26–February 4, 2012

**Treasures of TURKEY, including  
the Draconid Meteor Shower**  
October 3–14, 2011

**MAYA WORLD & the Great  
Dinosaur Extinction**  
November 10–18, 2011

**ANTARCTICA!**  
December 30, 2011–  
January 11, 2012

**ALASKA's Aurora Borealis**  
March 15–21, 2012

**The GRAND CANYON and the  
2010 Annular Solar Eclipse**  
May 14–21, 2012

**SIBERIA & LAKE BAIKAL  
for the Transit of Venus**  
June 1–12, 2012

**Discover HAWAII  
and the Transit of Venus**  
June 4–12, 2012

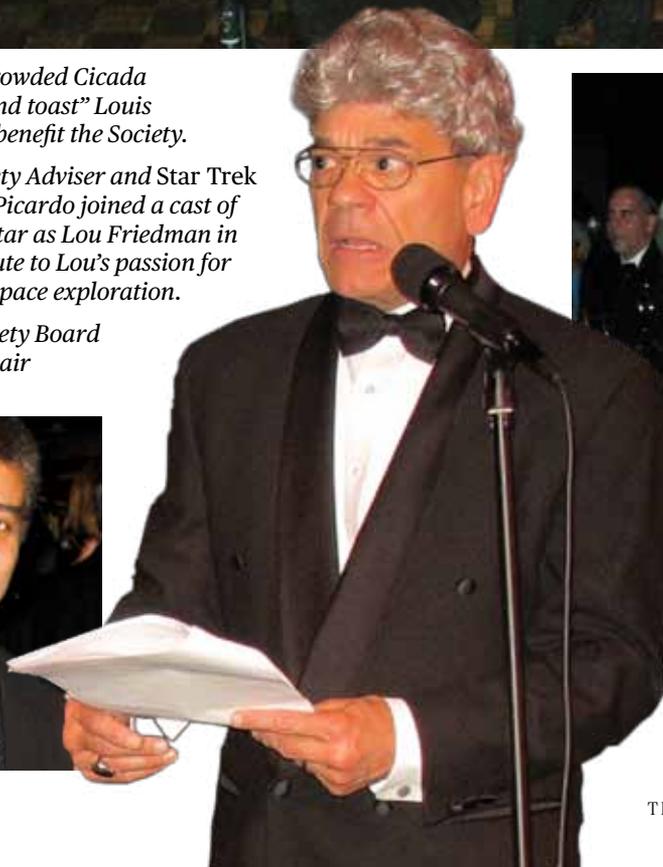
*we toasted...*



**ABOVE** Well-wishers crowded Cicada Restaurant to “roast and toast” Louis Friedman at a gala to benefit the Society.

**RIGHT** Planetary Society Adviser and Star Trek Voyager actor Robert Picardo joined a cast of Planetary Citizens to star as Lou Friedman in a sketch that paid tribute to Lou’s passion for baseball and creative space exploration.

**BELOW** Planetary Society Board Member and gala cochair Neil deGrasse Tyson.



**ABOVE** Lou (center), his wife Connie Friedman (left), and Dave Doody (JPL engineer and Planet Trek project manager) enjoy a “roast” from Planetary Society President Jim Bell.



THE PLANETARY SOCIETY  
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PASADENA CA 91105-1602 USA



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Image: Max Corneau

## M51A/B INTERACTING GALAXIES

Planetary Society Member and amateur astronomer Max Corneau took this elapsed-time image using equipment at the Tzec Maun Observatory in Mayhill, New Mexico, where he is the NASA JPL Solar System Ambassador Team Leader. He used an Astrophysics AP206 refractor on a Paramount ME mount with an SBIG ST11000 camera to capture the image (2 hours and 35 minutes total time).

Want to share your space image? Send us an e-mail with a jpeg (less than 5 MB) attachment of your image to [planetaryreport@planetary.org](mailto:planetaryreport@planetary.org). Please use the subject line "MySky" and include a short caption (such as where you took the image and, if appropriate, with what equipment) and credit line for the image. Please include just one MySky image per submission. Also be sure to include your name, contact information, and membership number (it's on your membership card and on the mailing label of your magazine). We'd also love to receive a picture of you and to learn more about what is most important to you about being a Planetary Society Member. Questions? E-mail [andrea.carroll@planetary.org](mailto:andrea.carroll@planetary.org) or call (626) 793-5100, extension 214.

## A NEW MEMBERS-ONLY BENEFIT

Your space image here? In *The Planetary Report*? Or on the Planetary Society website? That's what many Members (including you, perhaps) have been asking.

With our redesigned magazine comes an answer: yes! We've added a new Members-only benefit, **MySky**.

We're looking for images you've taken of your sky—whether those images are of galaxies captured through a telescope or perhaps pictures of an incredible night sky, an eclipse, a star party, or a rocket launch.

We can't guarantee that we'll publish every image—there just isn't enough space—but we will look at each and every one and will showcase as many as possible on our website at [mysky.planetary.org](http://mysky.planetary.org) or in *The Planetary Report*.

We look forward to seeing your Sky!

—Andrea Carroll,  
Director of Development