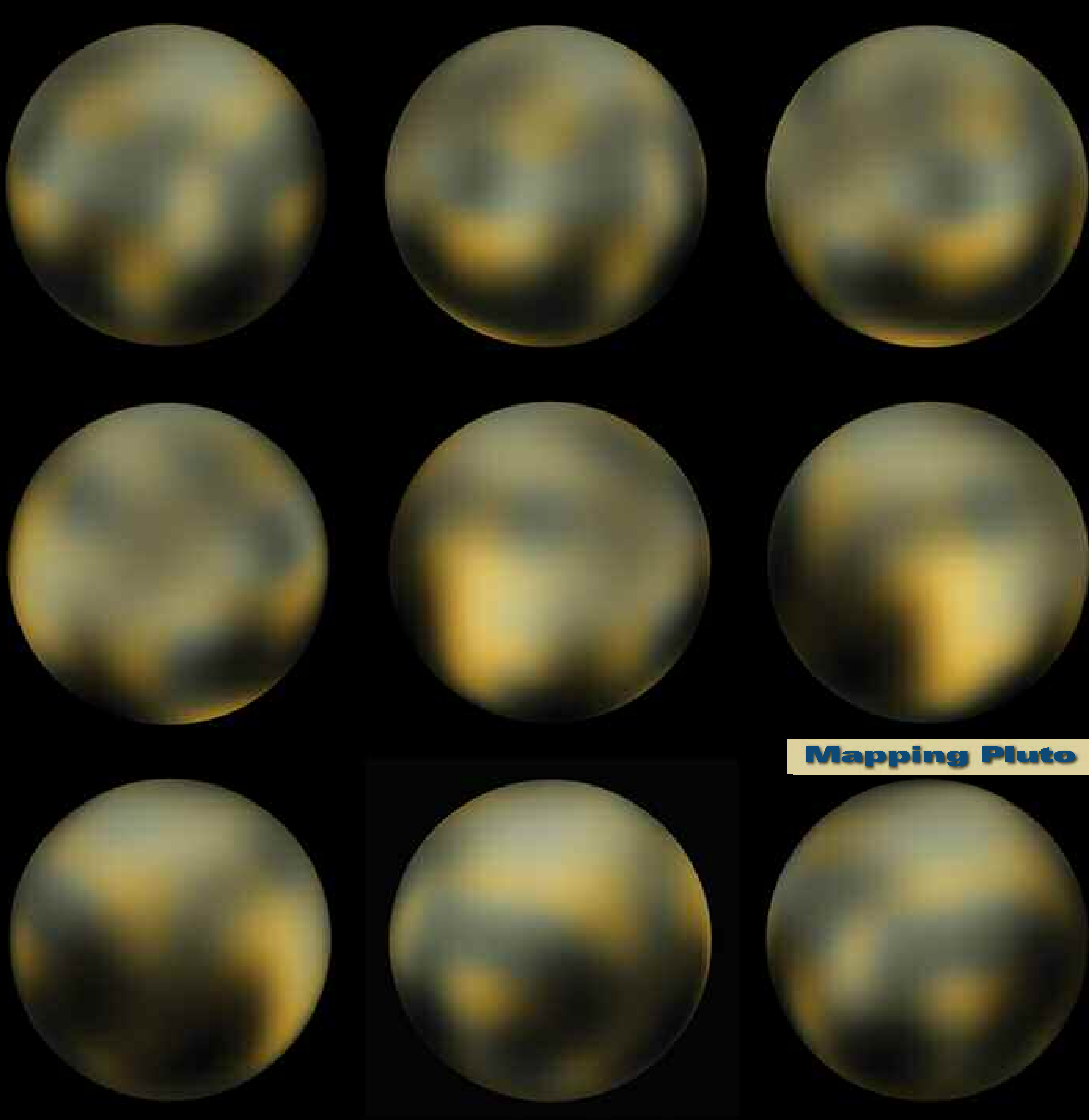
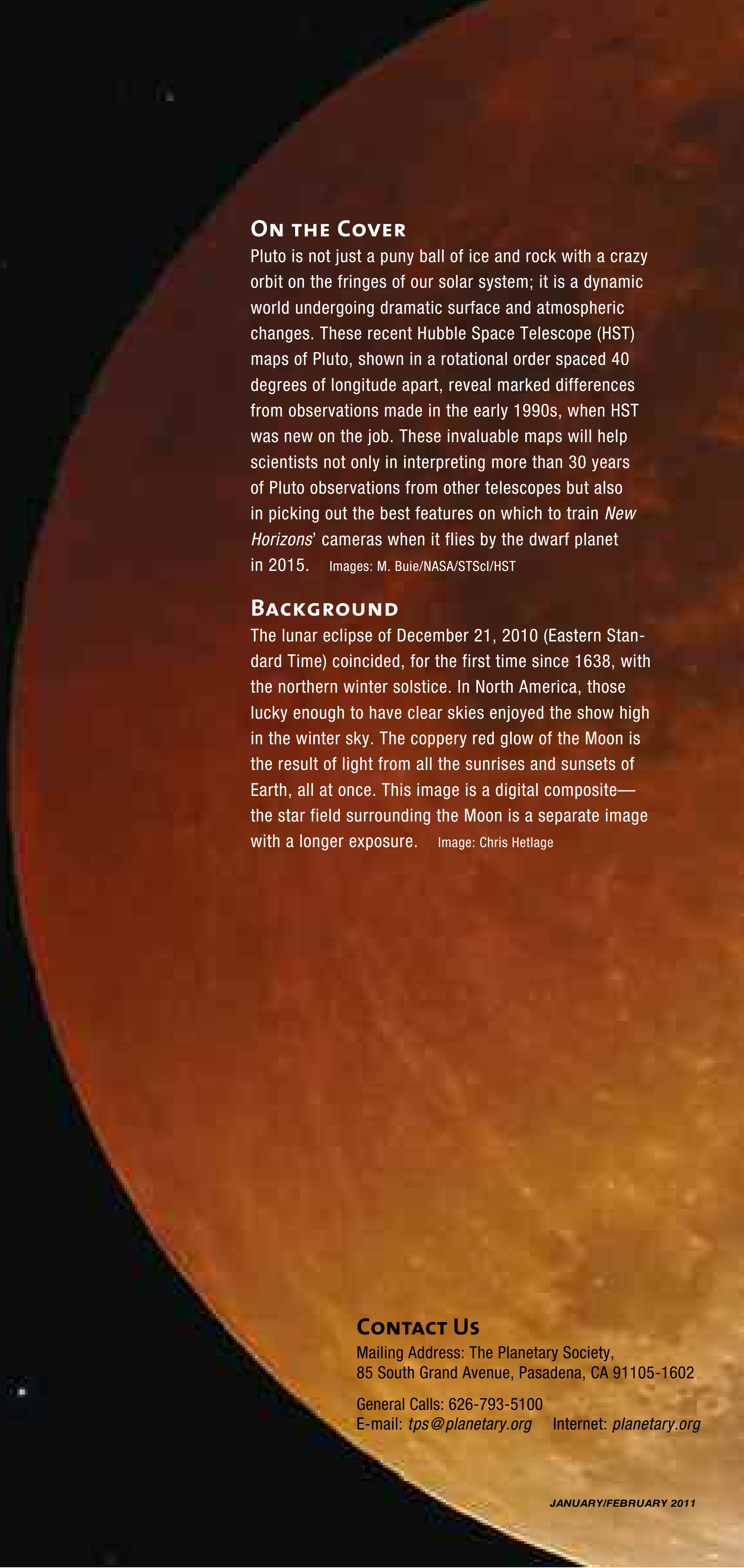
The PLANETARY REPORT

Volume XXXI Number 1 January/February 2011



Mapping Pluto



From The Editor

Carl Sagan, Bruce Murray, and Lou Friedman may have founded the Planetary Society, but it did not spring fullly grown from their heads. They had the help of some extraordinary people who knew how to build "constituency groups," and through their wisdom, this organization was born. Two people in particular shaped what became the prime benefit of membership, *The Planetary Report*: Peter Tagger and Harry Ashmore.

Peter set up the membership side of operations and was the greatest (and most patient) teacher I have ever known. Harry was a Pulitzer Prize–winning journalist and an avuncular guide to non-profit publishing. They helped in many ways, but one contribution was their most lasting: they insisted that we hire Barbara Smith to design *The Planetary Report*.

It's a good thing they insisted. Under Barbara's artistic hand, *The Planetary Report* became one of the most distinctive—and just plain lovely—magazines covering space exploration.

After 30 years of working with our wild bunch, Barbara has decided it's time to tackle new challenges. As this issue goes to press, she is retiring as art director. We are going to miss her immensely. Intelligent, wise-cracking, imaginative, and talented, she has brought passion and flare to what could have been just another membership-benefit magazine.

So, Barbara, I'm going to miss you. Planetary Society members are going to miss your work. We could never have come so far without you. Thank you! (And Peter and Harry, wherever you are, thank you for insisting.)

—Charlene M. Anderson

On the Cover

Pluto is not just a puny ball of ice and rock with a crazy orbit on the fringes of our solar system; it is a dynamic world undergoing dramatic surface and atmospheric changes. These recent Hubble Space Telescope (HST) maps of Pluto, shown in a rotational order spaced 40 degrees of longitude apart, reveal marked differences from observations made in the early 1990s, when HST was new on the job. These invaluable maps will help scientists not only in interpreting more than 30 years of Pluto observations from other telescopes but also in picking out the best features on which to train *New Horizons*' cameras when it flies by the dwarf planet in 2015. Images: M. Buie/NASA/STScI/HST

Background

The lunar eclipse of December 21, 2010 (Eastern Standard Time) coincided, for the first time since 1638, with the northern winter solstice. In North America, those lucky enough to have clear skies enjoyed the show high in the winter sky. The coppery red glow of the Moon is the result of light from all the sunrises and sunsets of Earth, all at once. This image is a digital composite—the star field surrounding the Moon is a separate image with a longer exposure. Image: Chris Hetlage

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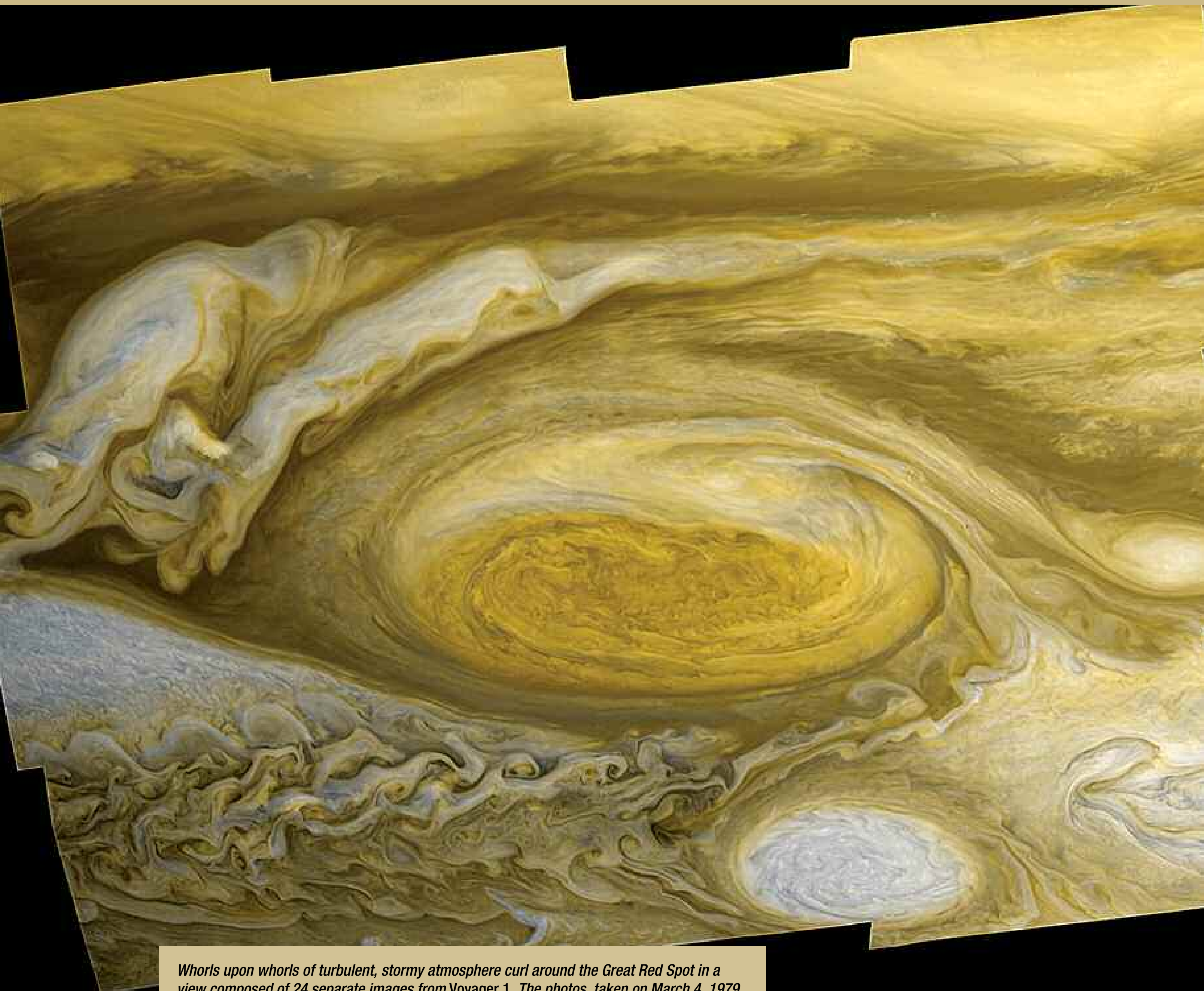
A PUBLICATION OF THE PLANETARY SOCIETY

THE GIANT'S BALEFUL EYE

BY EMILY STEWART LAKDAWALLA



Whorls upon whorls of turbulent, stormy atmosphere curl around the Great Red Spot in a view composed of 24 separate images from Voyager 1. *The photos, taken on March 4, 1979, have been here on Earth for more than 30 years, but computing power in 1979 was insufficient to process the data into such a spectacular, seamless mosaic, and it has never before been published in its entirety.*

This view was composed in 2010 by amateur image processor Björn Jónsson, who said, "This is the highest resolution color mosaic completely covering the Great Red Spot that I have ever seen. I feel like I'm processing stuff from a new planetary encounter when I see this." He has since produced another mosaic, taken four months later by Voyager 2, *showing the Red Spot in even greater detail.*

The Great Red Spot is, of course, still swirling on Jupiter, three decades after the Voyagers *passed by, but the white spot below and to its right is gone, having merged with two others to form Oval BA, also known as "Red Spot Junior."*

Emily Stewart Lakdawalla is science and technology coordinator for the Planetary Society and writes for the Society's blog at *planetary.org/blog*.

EXPLORE MORE

- You can learn more about this image at ***planetary.org/snapshots.***
- A poster print of this image is available at ***cafepress.com/planetaryshop.***
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- Get your daily dose of space news, fascinating pictures, and commentary at the Planetary Society's blog at ***planetary.org/blog.***

Here and Now: Our Unique Perspective

by Bill Nye

This bright thread of light is a long-exposure view of the International Space Station gliding through the twilight above Altadena, California on July 14, 2010. We fellow space explorers are lucky to live in a time when this visitor to our evening skies is a familiar—though always special—sight. Photo: Bill Westphal

Like many animals, I find myself drawn to shiny objects, especially ones that move and fly. Near the end of a recent workday, all of us on the office staff left our desks and stood outside to observe the flight of the International Space Station (ISS). It went right over us. At dusk on a clear evening, it is a very bright thing to see.

The ISS is a human-made assembly. From the ground, with unaided eyes, the details of its construction are not apparent. A few of our fellow citizens are on board, but somehow that wasn't the point of watching it. The point was that it was moving—unfettered by wind, unconcerned with nightfall, and oblivious to us.
As it passed, I realized that our ancestors must have felt much the same way about every object in the night sky, or when observing the Moon, just about any time it was visible. Everything up there is moving. Everything.

I cannot help but reason that some among our ancient ancestors came to accept that it was just possible that the solid-feeling place where they stood might be moving as well. These prescient few realized that our home would be tallied as just another object in some alien world's night sky.

It also seems to me that these thoughtful progenitors must have had the same feeling that I get when I garner my thoughts about our planet's position among the stars. I want to accost strangers, grab them by the lapels, and ask them, "Do you realize what's going on up there and all around us?" Perhaps our ancestors felt the same way—wanting to grab their contemporaries by the bearskin singlet. Do you see how astonishing it all is—how wonderful are the workings of the cosmos? Of course, one must also accept that those enlightened few probably were outcasts. The history of planetary discovery reminds us how long it took for people everywhere to accept our modern understanding of worlds in space.

The astronomers among our ancient ancestors surely saw that everything in the sky moves, and we are fortunate that they painted and carved rocks as records of their observations. In New Mexico's Chaco Canyon National Historic Park, a pictogram of a hand and a crescent Moon appears next to what may be the Crab nebula supernova of 1054. On the floor is a pecked-out spiral, painted with a flaming tail of red. Halley's comet appeared only 12 years after the supernova. Photo: Tyler Nordgren

As frustrating as it may be to reflect on the many centuries that must have passed between one of us realizing that our world must be one of an uncountable multitude, and our scientific proof of it, we can be thankful that we're living now, and part of space exploration now.

This, for me, is the excitement and the deep joy that the Planetary Society brings to people everywhere. If you want to participate in the next discovery, if you want to be part of the next remarkable, clever spacecraft design, then join the Planetary Society.

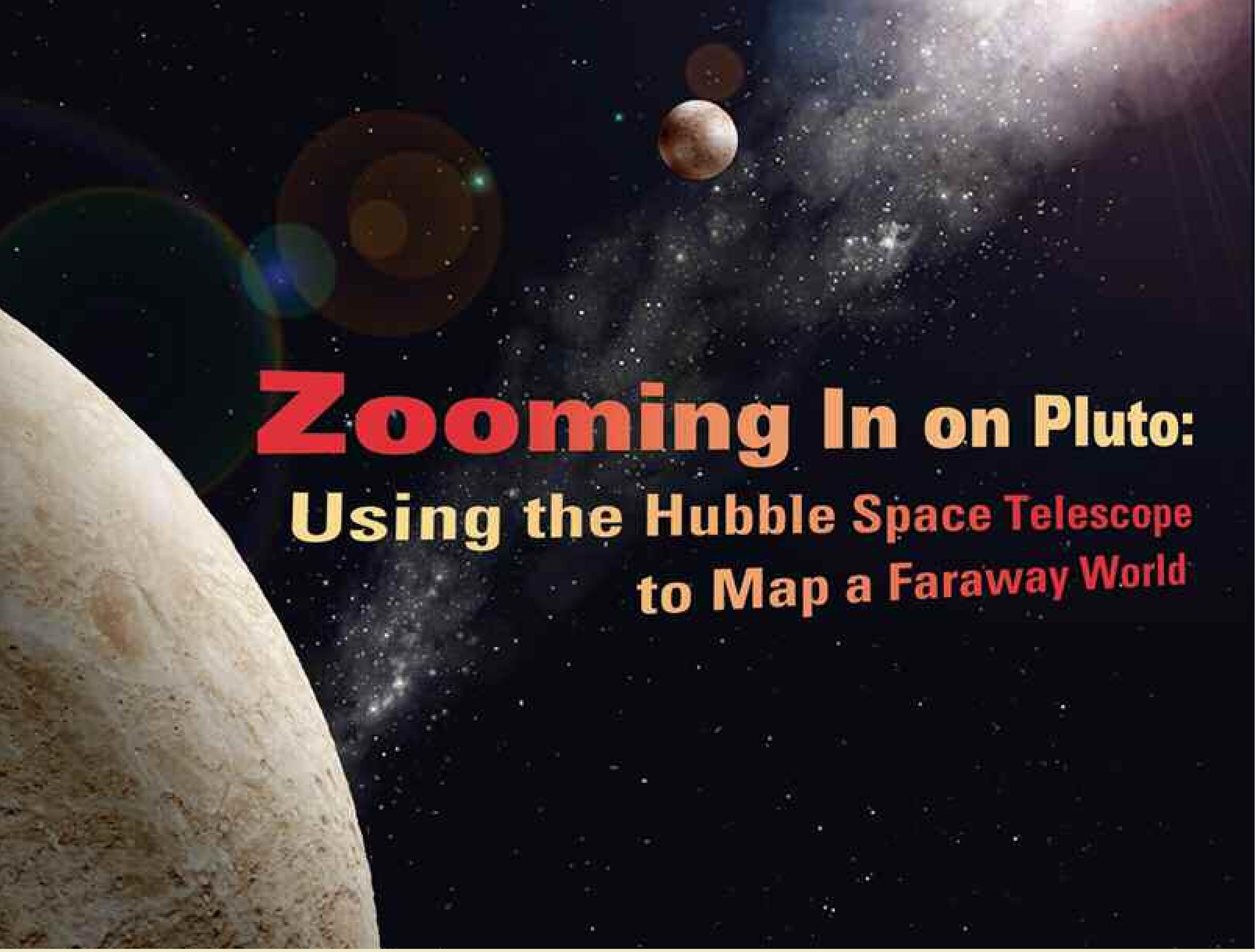
Carl Sagan, one of our founders and one of my college professors, often remarked that when you're in love, you want to tell the world. So it is with us. We at the Planetary Society want everyone in the world to realize how fantastic our time is—this time, now, at the beginning of the 21st century.

The idea that we can understand much of anything at all about our place in space is almost beyond belief. Because the joy of discovery is what makes our species special, we're investigating the possibility of life traveling between planets. It's also why we're building the first solar sail spacecraft maneuverable enough to tack in Earth orbit, yet be driven by the diminutive momentum of sunlight. It's why we search for life elsewhere. It's why we keep as many eyes as possible on objects that might be hurtling toward us, near our Earth. We are working to help humans everywhere better appreciate our place in space.

Let's change the world.

Bill Nye *Bill Nye*

Zooming In on Pluto: Using the Hubble Space Telescope to Map a Faraway World



Often voted people's favorite solar system body (aside from Earth), Pluto is a complicated world with an eccentric orbit, a moon nearly as large as it is, and a new status as a "dwarf planet" rather than a planet. Mapping this remote body has been a long and challenging process. In this artist's view, Pluto (foreground) and its large satellite Charon are visible against the backdrop of the Milky Way.
Illustration: Jay Inge

BY MARC W. BUIE

High above the interference caused by Earth's atmosphere, the Hubble Space Telescope (HST) has been soldiering away since its launch in 1990, undertaking a huge array of diverse scientific investigations. Researchers seek to use it perhaps more than any other astronomical tool ever built.

Any proposal to observe with HST is accompanied by a request for orbits. When researchers ask for time on HST, they ask for the number of orbits it will take to accomplish the planned science. Each orbit lasts roughly 90 minutes; of that time, an observer gets to look at an object for 35–40 minutes.

Over the past 20 years, HST has orbited Earth almost 120,000 times. I have been extremely fortunate to get time on HST to look at Pluto—in fact, I've had a grand total of 83 orbits for my research. I have used these observations to dramatically improve our knowledge of Pluto and its satellite companions. Everything about working with HST is challenging; a proposal typically has a 10 percent chance of success, and the data analysis is always difficult, but the results are well worth the effort.

A Blurry View

My first images of Pluto with HST were taken in 1992, with the original Wide-Field/Planetary Camera (WFPC). Despite the blurring caused by the now widely known error in the telescope optics, these images were still much better than anything we can get from ground-based observatories, even today.

I remember being concerned about how to calibrate these images. In particular, I wanted to know the scale of the images and how well we knew the scale. To do this, I scheduled the observations in pairs so that Pluto would move as far as possible relative to a star during the two observations. I also made sure that both the star and Pluto were still visible on the images. We know the motion of

Pluto very accurately, so the plan was to use this motion to calibrate the scale.

Even though HST is a robotic telescope, it still must be told what to do. I went through a long and tedious chore of mapping out all the times that Pluto would pass near a suitably bright star. I think that was probably the last time I used a compass and protractor in my research. To keep entertained while doing this, I watched the Winter Olympics (my favorite sport is downhill skiing).

These images were a breakthrough and returned the first separate light curves of Pluto and Charon. The light curve of Pluto indicates that some parts of its surface are very dark (low albedo) and other parts are very bright (high albedo). The data proved, for the first time, that Charon has the same rotation rate as Pluto, which is also the same as Charon's orbital period. This was not a surprising result, but it was a welcome confirmation. These data also have given us the best absolute scale of the Pluto/Charon system—a number not likely to be improved in accuracy before the arrival of *New Horizons* at Pluto in 2015.

As happens when any new data are collected, new questions were raised. In this case, we were able to derive a very accurate orbit for Charon, but there was one nagging problem: the major axis of the orbit seemed to be pointing right at Earth. Although this isn't impossible (after all, it has to point somewhere), the alignment seemed very unlikely. Upon further thought, we realized that the bright and dark albedo patches on Pluto's surface could make it appear to shift, with a repeatable pattern as it rotates. This shift would then cause the orbit to be distorted from its true shape.

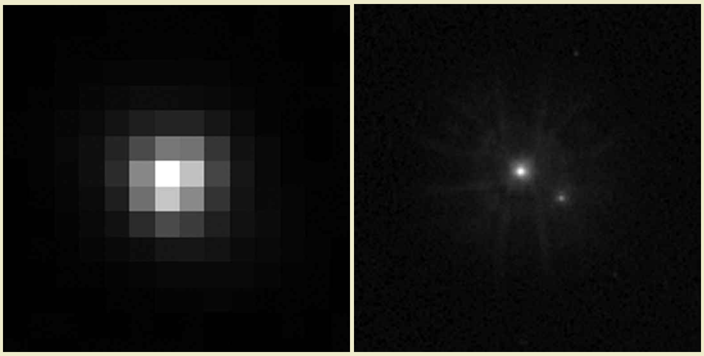
The question in dispute concerns just how noncircular Charon's orbit is. The WFPC data seemed to be telling us that Charon's orbit deviates from a perfect circle by 20 to 40 kilometers (12 to 25 miles) with a 40,000-kilometer (25,000-mile) diameter.

The only way to ensure one has the right answer is to have a good map of the entire surface. The maps available at the time simply were not good enough for making the necessary corrections, and the blurred images from the WFPC were inadequate for making the needed maps.

Alphabet Soup

Warning: this article contains abbreviations!
Keep track of them with the following list:

ACS—Advanced Camera for Surveys
FOC—Faint Object Camera
FOV—Field of view
HRC—High-Resolution Camera
HST—Hubble Space Telescope
WFC—Wide-Field Camera
WFPC—Wide-Field/Planetary Camera



These views of the Pluto/Charon system, taken on June 10 and June 7, 1993, respectively, show the differences between ground-based and early HST imaging. The image at left is from the Lowell Observatory's 1.1-meter Hall telescope. Charon is not visible in this image, which is blurred due to Earth's atmosphere. At right, the finer scale and lack of atmosphere in this view, taken by HST's WFPC, make it easy to see both Pluto and Charon. The faint tendrils around Pluto are caused by the spherical aberration of HST's uncorrected primary mirror. Left image: M. Buie; right image: M. Buie/NASA/STScI/HST

A Different Perspective

For the next chapter of the story, Alan Stern talked me into using the Faint Object Camera (FOC) with its High-Resolution Camera (HRC) mode to look at Pluto in 1994. After the corrective optics were installed, Stern figured we would be able to retrieve a useful, although low-resolution, map of Pluto.

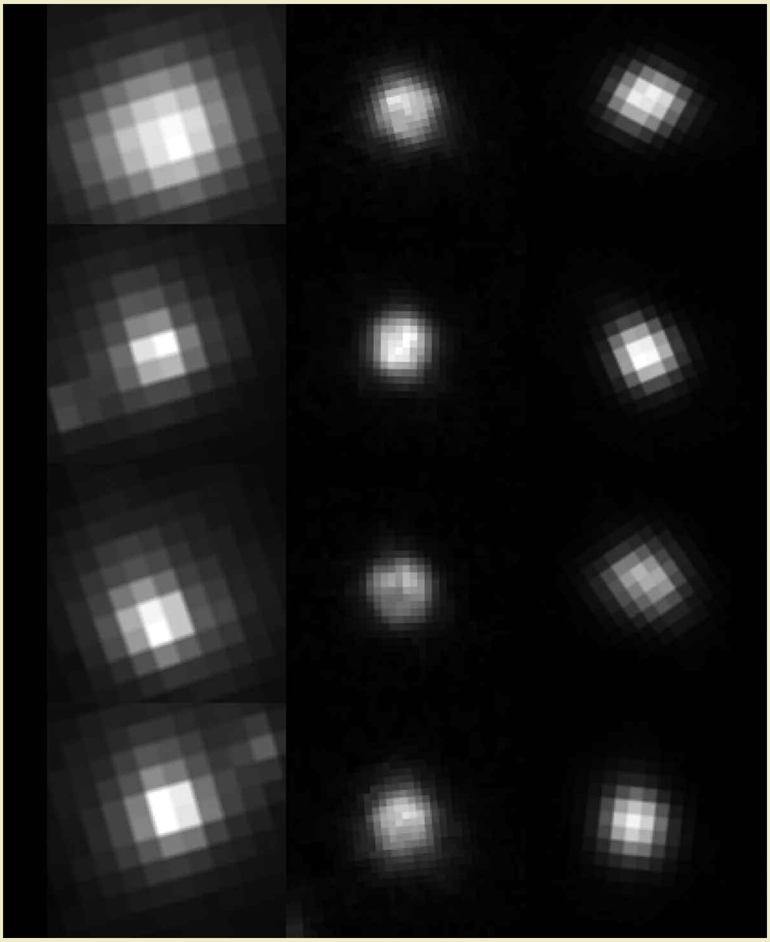
His hunch turned out to be correct, and in 1996, we released our first global image-based maps of Pluto. These maps were based on four orbits of HST, timed so that Pluto would rotate 90 degrees from one view to the next.

I thought that these maps might resolve the problems with the WFPC data, but that didn't happen. The FOC data had two fundamental limitations. First, our image, taken with a 90-degree longitude spacing, provided data that were just too coarse to provide reliable map information everywhere. The second and more serious problem concerns the design of the FOC itself. The "F" in FOC stands for "faint," and the instrument designers really meant it. The camera used to this day remains the instrument with the best spatial resolution of any camera ever used on HST, but because of the design of the detector, it cannot tolerate looking at bright sources. An object must not emit (or reflect) more than one photon per second on each pixel in the image. Looking at anything brighter means looking through the equivalent of welder's goggles. In other words, we had to make Pluto appear to be much fainter than it really is so that we could collect any useful data.

Working around these two problems left us with tantalizing information that confirmed the presence of large areas of light and dark that were suggested by Pluto's light curve, but we still couldn't answer all the other questions we wanted to resolve.

HST Keeps Getting Better

One of the best aspects of working with HST (though it comes at a very high price) is that we have been able to send people up to visit the instrument and swap in new



These direct images of Pluto are products of three separate HST imaging systems and three different years. From left to right, we see pictures from WFPC, FOC/HRC, and ACS/HRC from 1993, 1994, and 2002. From top to bottom, the rows show Pluto at sub-Earth longitudes of 270, 180, 90, and 0 degrees. The variation in the sizes of the detector pixels shows why the best images were taken by the FOC. *Images: M. Buie/NASA/STScI/HST*

instruments to improve and expand this incredible resource. In March 2002, astronauts installed the Advanced Camera for Surveys (ACS), a trio of cameras, including the High-Resolution Camera (HRC), the second-best imaging device ever installed on HST. It could have been the best, at least for my purposes, but for one critical design priority: that of field of view (FOV) over resolution.

When building a camera, one usually starts with the detector, because this item is the most difficult to control. One of the most important aspects of a detector is how many pixels it has. At the time, the best detectors that could be used had a 1024 x 1024 array of pixels (a 1-megapixel camera). Once this item is chosen, the second design choice usually is the angular scale or field of view of the camera. One goal is to maximize the FOV, and the wide-field camera followed that path.

The trade-off for a large FOV is that the pixels are very coarse, meaning that the image is grainier. The WFC takes advantage of the lack of atmospheric distortion but does not use the full spatial resolution possible with HST. As a partial compensation for this choice, the HRC was included in the ACS. That camera has a finer pixel scale and thus a smaller FOV, but it still does not quite use the full resolution of HST, as was possible with the FOC/HRC.

The ACS, however, had one huge advantage over the FOC in that it could look at both bright and faint objects. A single image of Pluto with ACS/HRC records more photons from Pluto than all the previous FOC/HRC data combined.

A major downside to ACS/HRC is that the optical design leads to distortion in the images: the pictures it takes are stretched and skewed. Removing these effects takes a considerable amount of information about the camera as well as intense computer processing of the data.

The Challenge of Mapping Pluto

The goal of using the new ACS camera was simple enough: generate a map of the surface of Pluto. The observations were also designed to refine our knowledge about Pluto's and Charon's light curves, surface properties, and color, and to make detailed positional measurements to permit further refinement of Charon's orbit. These data also turned out to include information about Pluto's newly discovered satellites and led to the determination of their orbits.

The observing plan called for using 12 orbits (also called *visits*) of HST time. These 12 visits were spaced out between June 2002 and June 2003, the largest spread in time allowed for this program. Each visit was targeted at a specific central meridian longitude of Pluto, such that the 12 visits were evenly distributed, thus giving a spacing of 30 degrees between visits.

Pluto rotates once every 6.4 days, and these 12 visits could have been done in a single rotation, but I wanted to get more information than would be possible over such a short time span. There is a small, but perceptible, change in the viewing geometry of Pluto as seen from Earth, however, largely caused by Earth's motion around the Sun. Observing changes in the brightness of an object as the geometry changes can reveal interesting clues about the nature of its surface. In addition, Pluto's seasons are changing quickly right now, with significant changes in geometry in just a year's time. If there are any changes on the surface to be seen, the data would help spot them if they happen on an even faster time scale. We didn't expect particularly rapid changes, but still, I wanted to stretch out the observations as long as possible.

Each visit used an identical observing pattern. The first half of the orbit was devoted to taking images through a blue (435-nanometer) filter, and the second half used a green (555-nanometer) filter. The exposures for Pluto are quite short—12 seconds for blue and 6 seconds for green. Given the amount of time in an orbit, I calculated that I could take 16 exposures in each filter during my brief window of looking at Pluto. You might ask, "Why are so many images necessary?"

Between pictures, HST was commanded to move by a very tiny amount. This technique, known as *dithering,* causes Pluto to fall on the image pixels in a different way for each picture. The use of dithering makes it possible to compensate for the coarse pixels and recover the full resolution of the telescope.

Each image is used to constrain the properties of a Pluto map. The final map is the one that is most closely consistent with all of the 384 images (192 per filter).

A map starts out with a grid of variables that describes the brightness of the surface in that particular location. For each image, this grid is mapped to a spherical surface at a very high resolution. This version ends up looking like an array of farm plots with sharp boundaries.

The next step blurs the map on the surface to remove the boundaries between areas that cannot be seen by HST even if it were nearer Pluto. This smoothed map is then projected onto a sphere representing Pluto at the orientation seen for each image.

Finally, the model image is distorted and blurred to match the effects of the optics in the HST camera. The output product is intended to look exactly like the images of Pluto from HST if the map is correct. My job was to find the map that best matches the data by adjusting all the map variables.

If this sounds like a lot of work, you are right. In reality, almost all these steps take little time and are pretty easy to do with available computers. That last step, involving image distortion, however, takes a lot more time. How much? About 5 seconds on an AMD 2500+ processor—the most cost-effective one I could buy in 2003.

Five seconds may not sound like much, but consider this: each time I test a map, this 5-second calculation is done 192 times (for a single filter). Thus, checking one trial map takes 960 seconds (16 minutes). This still doesn't sound so bad, until you know that it can take as many as 100,000 such calculations to reach the answer.

When I first got the software working, I made a quick estimate of how long it would take to complete all the calculations I wanted to do. The answer was horrifying! It appeared that it would take 80 years or more before I'd have my maps.

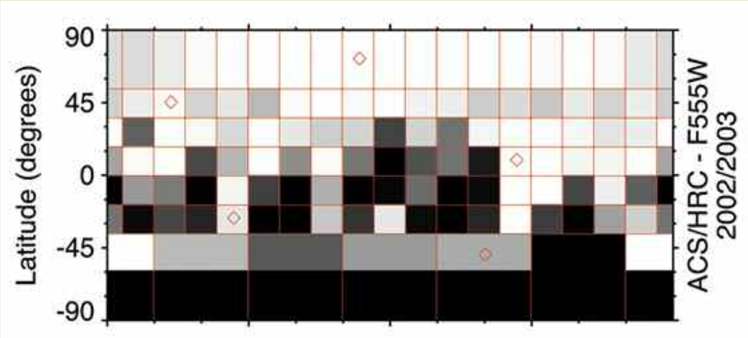
Creative Supercomputing

These days, computers are not getting much faster. The frontier in computational research involves getting a larger number of CPUs working together on a single task. This type of computing, called *parallel processing*, requires breaking up tasks into smaller units that all can run at the same time. In my case, I could, in principle, split my calculation into 192 separate bits, one for each data image.

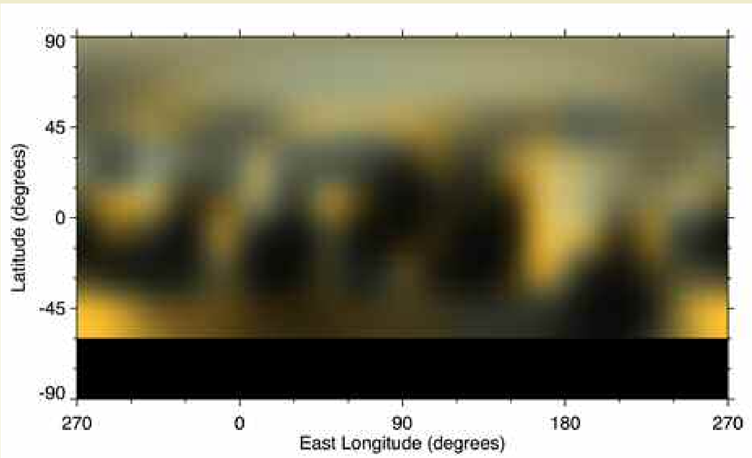
The challenges didn't end with building the computers. It turns out that the software available for managing computer clusters could not handle the type of calculation I needed. Most systems are designed for what I call *open-ended calculations*. A good example of this comes from the film-animation industry. Filmmakers have a description of every single image in the movie and use a computer to do all the calculations needed to make each image. If done right, each image can be computed independently of the others and in any order; the goal is simply to have the images. In this example, you can use a thousand computers at once, and that will speed things up by a factor of a thousand. Your speed-up factor is limited only by how much you want to spend.

My calculations are fundamentally different from this open-ended example. I need something I call *feedback calculations*, in which variables used in a new calculation depend on feedback regarding how well the previously calculated map fit the data. In my case, the most I could possibly speed up the calculation would be a factor of 192, to coincide with how many individual images I need to fit against. I set up a calculation based on a guess of a surface map. From that setup, I then needed to compute the 192 images to be compared with the data. In practice, there is some computational overhead with managing the

On March 7, 2002, astronauts Jim Newman and Mike Massimino installed the new Advanced Camera for Surveys, possibly the most significant scientific upgrade in HST's life. ***Photo: NASA***



The construction of the cylindrical projection map of Pluto's surface began, in part, with this black-and-white grid, which shows the location and brightness of each adjustable element in the map. In the image below, we see the end result of converting these elements to a map at the resolution possible with HST. *Grid and map: M. Buie for* The Astronomical Journal



The grand prize for these years of mapping effort is a set of global views like this and the ones on the cover. These globes show how Pluto's surface features would look to your naked eyes if you were close enough. This view shows Pluto at 330 degrees longitude. *Image: M. Buie/NASA/STScI/HST*

parallel calculations, and I also didn't have enough funding to buy that many ready-made computers. Instead, I bought a lot of parts and put the machines together myself. In the end, I was able to afford to put together 20 computers for a total cost of about $8,000.

Doug Loucks, a talented programmer working with me at the time, helped me to design and build a software system that allowed us to do the parallel processing on this group of computers. In the end, we increased computing speed nearly 20-fold using this method and brought the calculation time down to about four years.

Success!

After four years of grinding away on the problem, the final results are the best maps ever of the surface of Pluto. These new maps confirm the results from the FOC data in 1994 and also reveal that the surface is changing in color (it's getting redder). The mystery of the shape and orientation of Charon's orbit also was laid to rest. The orbit is noncircular by 0.35 percent, or 68.2 kilometers (42 miles), and the orientation of the major axis is not pointed at the Earth.

These maps and images are likely to be the best we will see prior to the arrival of the *New Horizons* spacecraft for its July 2015 encounter with the Pluto system. HST no longer has a camera capable of repeating this experiment, and ground-based optical images are completely beyond our technical abilities. It's exciting to think that we will get a chance to view things up close in the not-too-distant future and see how well I did.

I can only imagine what we'll see when we have vastly superior spatial resolution; we will be able to see how geologic features line up with these strong albedo and color patterns. Will we even see craters, or will everything be completely erased by atmospheric effects? I believe that albedo will be correlated with age, such that the darkest regions will be the oldest and will show cratering, whereas the brightest regions will appear to be very young. Overlain on all this likely will be other strange and wonderful details that will keep planetary geologists busy for decades to come.

Marc W. Buie is a planetary astronomer who has been looking at and thinking about Pluto for the past 30 years. He also studies other objects in the outer solar system and has discovered hundreds of Kuiper belt objects.

Explore MORE

Find out more about Marc and his work at ***www.boulder.swri.edu/~buie/.***

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ROAST AND TOAST

Planetary Society cofounder and former Executive Director

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Celebrate Lou's 30 years as captain of Earth's leading team of citizen space explorers

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All proceeds for the ***Roast and Toast of Louis Friedman*** *will benefit the projects and programs of the Planetary Society. The amount of the Roast and Toast that is tax deductible is $150 per ticket.*

Please Roast and Toast Lou! *Use 150 words or less.* _________Yes, you may publish my tribute to Lou.

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Names of my guest(s) ____

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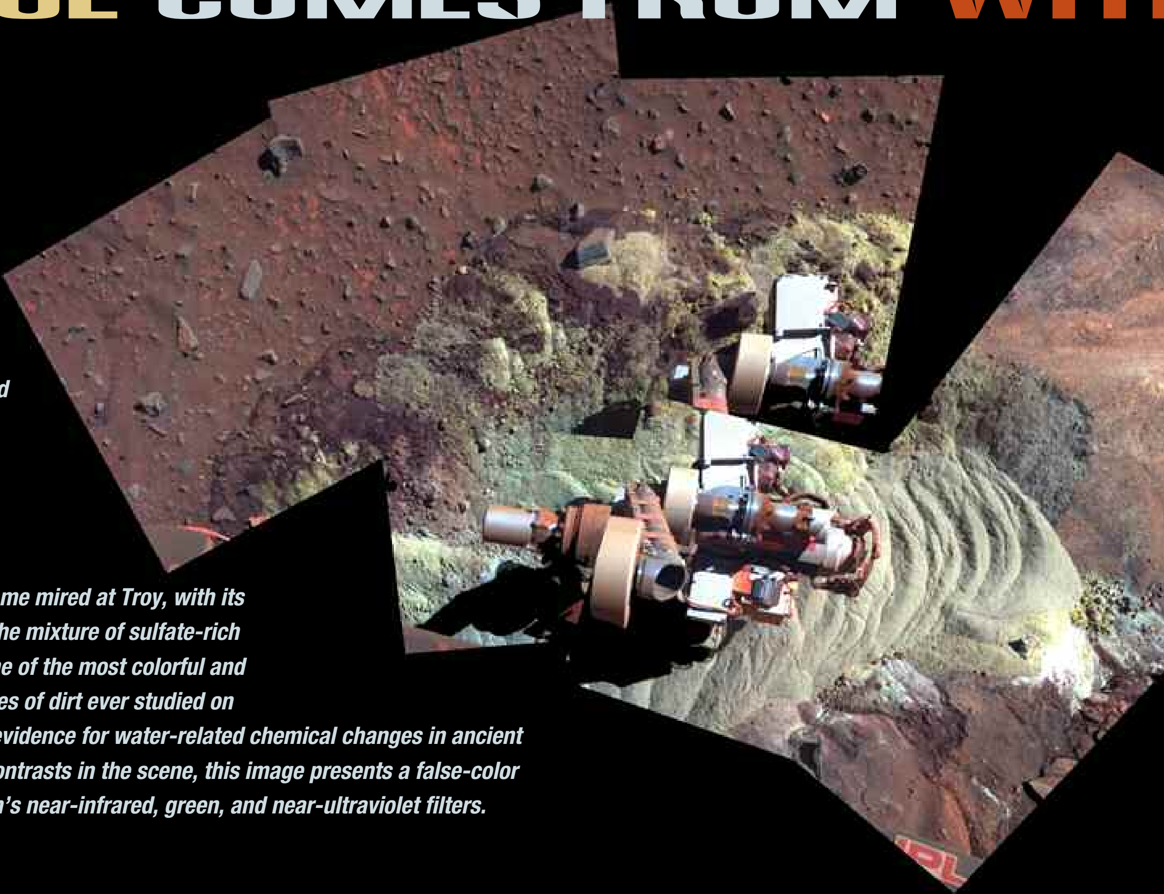
Questions? Call Andrea Carroll at (626) 793-5100, extension 214, or e-mail her at *andrea.carroll@planetary.org.*

CHANGE COMES FROM WIT

BY JIM BELL



This Pancam mosaic was acquired by the Mars Exploration Rover Spirit *on sol 2163 (February 2, 2010) of its mission. The image shows a soil patch called Troy in front of the rover, along with part of* Spirit*'s robotic arm.* Spirit *became mired at Troy, with its wheels digging and churning up the mixture of sulfate-rich soils and basaltic sand. Troy is one of the most colorful and chemically interesting little patches of dirt ever studied on Mars, and it provides significant evidence for water-related chemical changes in ancient Martian soils. To enhance color contrasts in the scene, this image presents a false-color mosaic RGB composite of Pancam's near-infrared, green, and near-ultraviolet filters.*
Image: NASA/JPL/Cornell

As I reflect back on the first year of the second decade of the 21st century, it's clear that 2010 saw dramatic changes for the United States, NASA, the Planetary Society, and even me.

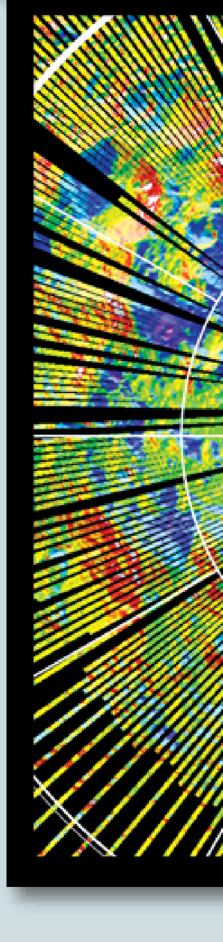
The United States and the world slipped deeper into their worst economic funk in 80 years, seeing losses of jobs, homes, and dreams. These losses brought calls for change; the U.S. government responded with short-term bailouts and stimulus programs rather than long-term solutions. The U.S. government, and the world as a whole, largely set aside bigger issues such as energy policy and the climate—and space exploration.

NASA went through (and is still going through) convulsive changes, with a new policy for human space exploration announced in February, with revisions to it in April, and the agency still looking for traction in its plans to change the nature of human access to space. Decisions being made and plans being drawn up right now will change the way an entire generation thinks about people going into space, much as the conception and eventual implementation of the space shuttle did in the 1970s and 1980s. I'm glad that the Planetary Society is playing such an active role in the dialogue.

The Planetary Society is going through major changes of its own. The worldwide economic downturn has profoundly affected people's ability to join, and to donate to, causes like ours—making us that much more thankful for the passion and commitment of new and renewing Members and donors who have pledged support during this difficult time.

We turned 30—middle aged!—and saw one of our founders and mentors change his life dramatically by stepping down as executive director. Fortunately, he did not step away. Lou Friedman will continue to be our *LightSail* program manager, one of our most important advisers, and one of our biggest champions. He handed over the reins to Bill Nye, the (Planetary) Science Guy, in September. Our new executive director is rising to the challenge of this major change in his life, starting new initiatives and projects, reaching out to our friends at NASA and other space agencies, and embracing his own mantra, "Let's Change the World!"

Then there's me. I'm also going through a major change in my life and career, leaving Cornell University after spending 15 years in the Astronomy Department of our late cofounder, Carl



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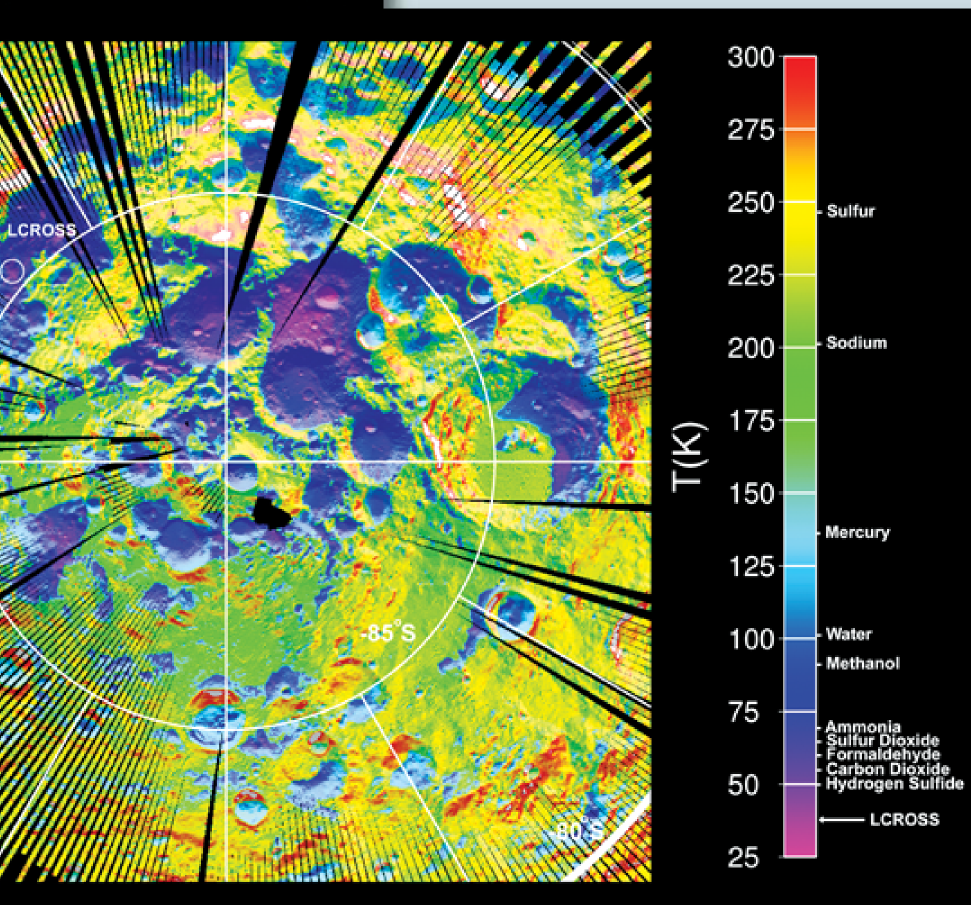
Sagan, in Ithaca. I've been offered a great opportunity to work in and help build the new School of Earth and Space Exploration (SESE) at Arizona State University in Tempe. The dynamic and growing group there already includes many colleagues who have played major roles in NASA's robotic space exploration of Mars, the Moon, Europa, and even Earth. SESE is being built from the ground up as a cross-disciplinary environment, mixing astronomers, geologists, climatologists, planetary scientists, engineers, and—of course—students into a collaborative environment of teaching, research, instrument/spacecraft design, and mission operations.

I'm excited about the new opportunities, but my family and I are a little daunted about the prospects of both southwestern desert and city living. I've spent most of my life growing up or working in small towns in the green (or white) northeast. Friends and colleagues who have lived in the Southwest tell us we'll love it. "It's just like Mars!" they say, "except the food is better."

My career change, the Society's leadership changes, and even NASA's attempts to change the very way we get people into space exhibit a common theme. The choices made are not imposed by random external forces; they are carefully considered attempts made individually, as a board, or as a society to try to manage a basic truth that Isaac Asimov discovered about our universe: the only constant is change.

This reminds me of a Zen Buddhist monk who walks up to a hot dog vendor and says, "Make me One with Everything." The vendor smirks and gives him his dog. The monk gives the vendor a $10 bill and waits. Nothing happens. "Where's my change?" he asks. The vendor replies (wait for it . . .), "Change comes from within."

Jim Bell is president of the Planetary Society's Board of Directors and lead scientist for the Spirit *and* Opportunity *rovers' Pancam cameras. He recently gave up a position as a professor in the Department of Astronomy at Cornell University; as of January, he is a professor in the School of Earth and Space Exploration at Arizona State University.*



Some of the coldest temperatures ever measured in the solar system occur right in our own backyard, as shown by this temperature map of the south pole of the Moon from the Diniver thermal instrument on the* Lunar Reconnaissance Orbiter *spacecraft. Temperatures in some permanently shadowed lunar polar craters reach about 30 degrees above absolute zero. The exciting thing about such low temperatures is that even extremely volatile ices—such as ices of methane, ammonia, methanol, CO_2, and sulfur dioxide, which may have come from outer solar system comets or asteroids or perhaps even from the volcanic outgassing of the early Moon itself—could be stable there. How has the inventory of life-giving organic materials and water changed over the history of the Earth-Moon system? The record of changes may be sitting at the poles of our nearest celestial neighbor. *Image: UCLA/NASA-JPL/GSFC*

See also Emily Lakdawalla's blog on this topic at http://planetary.org/blog/article/00002728/.

World **Watch**

by Louis D. Friedman

Planetary exploration is now truly a global enterprise. As the new year begins, I thought we should take a quick trip around the world.

United States—NASA has proclaimed the two-year period from mid-2010 to mid-2012 as the "Year of the Solar System," and indeed it is exciting to realize how much will be happening. The recent *Deep Impact* spacecraft fly-through of comet Hartley 2 was extraordinarily successful. We are looking forward this year to the arrival of *Dawn* at the asteroid Vesta (the second largest asteroid in the solar system) in midsummer, along with the launch of *Mars Science Laboratory* in November. Other notable events in 2011 will be the *Stardust* encounter with comet Tempel 1 (on Valentine's Day, February 14), *MESSENGER* going into orbit around Mercury in March, and the launches of *Juno* to Jupiter in August and *GRAIL* to the Moon in September.

Politically, space science and planetary exploration have received excellent support in Congress and from the Obama administration. Nevertheless, budget pressures are increasing—especially with the increased attention on budget cuts that is expected when the new Congress takes office this month. The increased cost of the James Webb Space Telescope, whose launch has now slipped to 2015, is of principal concern in the space science budget. We also will be watching the proposed funding for a new start on the Europa orbiter and for Mars missions in 2016 and 2018. Both the Europa and Mars missions are being planned cooperatively with the European Space Agency (ESA), and both represent large new ventures in solar system exploration.

Europe—With its *Mars Express* and *Venus Express* successes mostly behind it, ESA is looking forward to new milestones in the next decade. The *Rosetta* spacecraft returned outstanding results from its mid-2010 close flyby of asteroid Lutetia. The spacecraft continues on its nearly 10-year journey to rendezvous with comet 67P/Churyumov-Gerasimenko in 2014.

Coming up, ESA plans to launch *BepiColombo* to Mercury in 2013, a Mars orbiter with a technology test lander in 2016, the *ExoMars* rover in 2018, and a Ganymede orbiter in 2020. *BepiColombo* is a collaborative project with the Japanese space agency, and the other three missions are collaborative projects with NASA.

Japan—The past year was notable for space exploration in Japan. The *Hayabusa* mission brought back tiny samples from the asteroid Itokawa in a brilliantly conducted mission. The *Akatsuki* Venus orbiter successfully launched but unfortunately did not achieve Venus orbit. Piggybacking along the *Akatsuki* launch was *IKAROS*, the first solar sail to fly successfully.

Looking forward, Japan is developing a magnetosphere observing orbiter for the *BepiColombo* mission. The Japanese space agency is also developing a follow-on to its very successful lunar orbiter mission (*SELENE*), to test landing and surface exploration technologies on the Moon. *SELENE-2* is planned for the middle of this decade.

Russia—Russia has not conducted a planetary mission since *Phobos* in 1988–1989. The last attempt was the failed launch of *Mars-96*. Russia will attempt to come back as a major player with the *Phobos Sample Return* mission scheduled for launch in 2011. This mission is extraordinarily large and ambitious, and, with even partial success, it will mark a Russian return to the solar system. *Phobos Sample Return* will carry our LIFE module—the first experiment from Earth to purposefully send life into the solar system. Another space science mission to watch is the long-awaited Radio Astronomy satellite, scheduled to be launched this coming spring.

The Space Research Institute in Moscow has described plans for a lunar lander program with two missions: one lander for a Russian mission, perhaps in 2012, and the other for an Indian mission in 2013. The space agency is also studying landers for Venus later this decade and for Europa in the following decade, perhaps cooperatively with NASA and ESA.

India—The Indian Space Research Organization concluded a very successful *Chandrayaan-1* lunar orbiter mission last year and made some extraordinary discoveries about water embedded in the lunar surface. A second lunar mission, *Chandrayaan-2*, is being planned in cooperation with Russia. *Chandrayaan-2* will include a small rover; if all works as planned, India will be the second nation to place a rover on the Moon. Press reports indicate that India is considering a Mars mission in 2016 or 2018.

China—*Yinghuo-1*, China's Mars orbiter, will be launched as a piggyback on the Russian *Phobos Sample Return* mission later this year. China is also conducting its second lunar orbiter mission with *Chang'E-2* and has announced that development is under way for a lunar lander and rover. With China and India both pressing ahead on lunar surface exploration, and Russia now potentially returning to the Moon, we might anticipate another automated lunar sample return mission before the 50th anniversary of the Soviet Union's *Luna* sample return, conducted in 1972.

Many locations—A number of private companies are competing for the Google Lunar X-Prize with the objective of placing a lander on the Moon and moving 500 meters on the Moon's surface by 2013. (The Planetary Society is part of one of these efforts, *Moon Express*.) Recently, NASA agreed to purchase scientific data from successful missions and provided seed money for several companies, following a competition to evaluate their capabilities.

Washington, D.C.—The future of U.S. human space exploration is still being debated in Washington. In the first week of February, the Obama administration will present the proposed budget for fiscal year 2012 and beyond. Look for updates at *planetary.org*.

Louis D. Friedman is cofounder and board member of the Planetary Society.

LightSail **UPDATE**

Testing, Learning, and Waiting

by Louis D. Friedman

Development of our *LightSail-1* spacecraft is proceeding well. The spacecraft has passed several key tests, including subjecting the engineering models to vibration, shock, and thermal-vacuum tests.

The vibration and thermal-vacuum tests of the *LightSail-1* engineering model were conducted at California Polytechnic University (Cal Poly) in November by the Stellar Exploration team of Chris Biddy, Alex Diaz, and Justin Jang. The vibration test proved to be valuable in verifying structural integrity and provided assurance that the harness-routing scheme was correct.

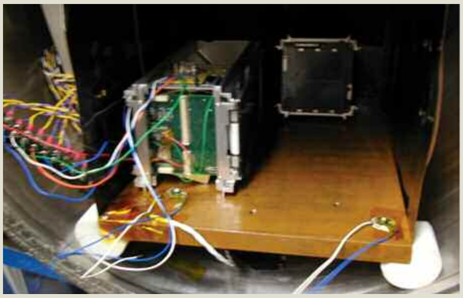
LightSail-1 is a very tightly integrated spacecraft with absolutely no spare volume. During assembly of the vibration test model, the builders found that the cameras interfered with the bottom corner of the deployer bottom plate, but by less than 0.5 millimeter. We can correct this problem by shifting the bolt pattern.

The thermal-vacuum test verified the deployment of the solar panel (see third image at right) in extreme space environment conditions. The temperature was –42 degrees Celsius (–44 degrees Fahrenheit), and the vacuum was 6.66 millipascals (approx. 7×10^{-8} atmospheric pressure). The first attempt at testing revealed some problems with the burn wire assembly that holds the cover in place before deployment (the burn wire was installed under too high tension and broke off prematurely). We corrected these problems by carefully measuring and adjusting the tension on the burn wire, and the second test (conducted a few days later) deployed correctly and verified the design.

Our schedule, however, has slipped, mostly due to delivery delays of the new TRAC booms. The boom design is good, but manufacturing problems with the metal have now caused more than six weeks of delay, which will affect our assembly and testing of the sail module and sail deployment.

We hoped for a test of the booms (of the identical design) on the NASA *Nanosail-D* spacecraft, which was launched on November 19, 2010 as a piggyback satellite on the new *Fast, Affordable, Science and Technology Satellite* (*FASTSAT*). The launch and delivery of *FASTSAT* and the other cubesats were successful, but it appears that the deployment of the Nanosail cubesat was not successful. No data were ever received.

Here our* LightSail-1 *engineering model is in its test POD and mounted to the shake table at Cal Poly.



We wired up test sections of* LightSail-1 *and loaded them into the thermal-vacuum chamber to test solar panel and antenna deployments.

This photo shows the deployed solar panel and antenna after the thermal-vacuum test.
Photos: Louis D. Friedman

Nanosail-D was very similar to our own *LightSail-1*, although our craft is about twice the size and has a payload that includes attitude determination and control, accelerometers, solar cell arrays to recharge the batteries, onboard cameras, and a telemetry system. Another difference is that *Nanosail-D* was designed to be sent to a lower orbit, where atmospheric drag dominates the solar pressure force.

It was NASA's *Nanosail-D* that inspired the Planetary Society to consider the nanosat design for *LightSail-1*. Nanosail opened the way for a class of advanced spacecraft that someday may take us to the stars.

Keep checking *planetary.org/programs/projects/solar_sailing/updates.html* for updates about *Nanosail-D* and about *LightSail-1*.

Explore MORE

Keep up with our *LightSail* program at ***planetary.org/programs/projects/solar_sailing/.***

Louis D. Friedman is a cofounder and board member of the Planetary Society. He is program director for the LightSail *program.*

Questions and Answers

Do radio telescopes send signals, or is their only function to receive signals? If any telescopes send signals, what are the signals?
—Robert Hale
Baltimore, Maryland

Radio astronomy is completely passive, which is to say that its instruments only receive cosmic signals. This is largely because of the impracticality of bouncing radio waves off distant objects such as galactic nebulae or galaxies (not to mention the delay time in waiting for any bounced signal to return to Earth). Consequently, almost no radio telescopes have transmitting capability. Indeed, powerful transmitters would pose a threat to the highly sensitive amplifiers near the focus of a radio telescope. Their emissions would completely swamp, and possibly destroy, the delicate electronics within.

The closely related discipline known as radar astronomy, however, does use transmitters. Radar astronomers study targets within the solar system, such as asteroids. They can make surprisingly detailed maps of these objects by illuminating them with a high-powered signal and analyzing the return radio echo. Before we could send orbiters to our planetary neighbors, scientists used radar to map the surface of Venus, whose torrid landscape is hidden under a thick atmosphere that blocks the view for optical telescopes.

The most powerful radar telescope is the 1,000-foot antenna at Arecibo, Puerto Rico, which has a one-million-watt transmitter. Arecibo's antenna is also used for radio astronomy and SETI, so this one instrument has both extensive receiving and transmitting capabilities.
—SETH SHOSTAK,
SETI Institute

In the Factinos section of your July/August 2010 issue, you reported that, until recently, scientists believed that the trace amounts of carbon on the Moon's surface came from the solar wind. I was under the impression that the solar wind consisted of electrons and protons, and not heavy molecules such as carbon. How did carbon find its way into the solar wind?
—Dennis Middlebrooks
Brooklyn, New York

The solar wind is composed predominantly of electrons and protons, but it also contains heavier elements. Although the total influx of carbon on the Moon's surface is small, that surface has been directly exposed to solar wind for billions of years and has, therefore, accumulated measurable amounts of carbon.
—MARC FRIES,
Planetary Science Institute

On page 11 of the November/December 2010 issue of* The Planetary Report *there is a* MESSENGER *photo of Earth and the Moon as seen from orbit around Mercury. To my eye, the Earth image appears to have a small flat edge on the left side. Examination with a magnifying glass confirms this observation. Even if the appearance of an Earth phase were possible, the edge of Earth would appear curved, rather than flat, and the Moon would have a flat edge, which it does not. How is this possible?
—Richard Hartung
Bellingham, Washington

You have a good eye: the left side of Earth does indeed appear flattened with respect to the rest of the planet. Although Earth has very little variation in phase when viewed from Mercury's orbit, we are indeed looking at a gibbous Earth in this image. This alone probably would not be enough to make Earth look as flattened along one side as it appears, but the shape is exacerbated by the way we take images with *MESSENGER*'s camera.

We take the images by exposing light onto a CCD detector. Each pixel in the detector registers the amount of light that falls on it, then converts it to a signal that is represented as an image. Because the pixels are square, a curved surface will be represented by a jagged edge, and some pixels will appear brighter than they are because part of the planet falls only partially onto them. (Imagine making a planet disc out of Legos and you will get the idea.) If we then incorporate the fact that Earth is not at full phase, we are now looking at a sphere with one flattened edge, and the flattened part (the terminator) is lined up closely with the grid of the pixels in our image. Therefore, light from the flatter portions falls more squarely into some pixels than does light from curved surfaces, which is more spread out among adjacent pixels.

This effect is heightened by the fact that in order to view Earth and the Moon in the same image, we have to overexpose one or underexpose the other, because Earth is brighter than the Moon. If we had exposed Earth correctly, the Moon would be very hard to see. Instead, we overexposed Earth, so that the Moon would be clearly visible. Because Earth is overexposed, light is scattered more than it should be into adjacent pixels, creating an enhanced gradation of light away from the curved part of the disk and also resulting in a more distinct boundary along the slightly flattened terminator, where the light is falling more fully into each pixel and scattering less.

You are also correct in pointing out that if Earth is not at full phase, then the Moon should not be either. The explanation for this is that the Moon is not overexposed, so its light falls mainly in pixels that it covers. Also, its size compared with Earth in this image is more of a point source of light, so it really does look small and round.

—LOUISE M. PROCKTER,
Applied Physics Laboratory

Factinos

We now have evidence of an extrasolar planet from a galaxy other than our own. Scientists discovered the Jupiter-like planet illustrated here with the European Southern Observatory's 2.2-meter telescope in La Silla, Chile. "This discovery is very exciting," says Rainer Klement of the Max-Planck-Institut für Astronomie, who was responsible for the selection of the target stars for this study. "For the first time, astronomers have detected a planetary system in a stellar stream of extragalactic origin. Because of the great distances involved, there are no confirmed detections of planets in other galaxies. But this cosmic merger has brought an extragalactic planet within our reach."
Illustration: ESO/L. Calçada

A team of European scientists has detected an exoplanet orbiting a star that entered the Milky Way from another galaxy. The Jupiter-like planet is particularly unusual because it is orbiting a star nearing the end of its life and could be about to be engulfed by it, giving tantalizing clues about the fate of our own planetary system in the distant future.

Scientists have detected nearly 500 planets orbiting stars in our cosmic neighborhood, but until now, none outside the Milky Way has been confirmed. The parent star is part of the so-called Helmi stream—a group of stars that originally belonged to a dwarf galaxy that was devoured by the Milky Way between six and nine billion years ago.

The star, known as HIP 13044, lies about 2,000 light-years from Earth in the southern constellation of Fornax. The researchers detected the planet, called HIP 13044-b, by looking for the tiny, telltale wobbles of the star caused by the gravitational tug of an orbiting companion. The team made its discovery using the 2.2-meter MPG/ESO telescope at ESO's La Silla Observatory in Chile.

HIP 13044-b is also one of the few exoplanets known to have survived the period when its host star expanded massively after exhausting the hydrogen fuel supply in its core—the red giant phase of stellar evolution.

—from the European Southern Observatory

Astronomers have discovered that a huge, searing-hot planet orbiting another star is loaded with an unusual amount of carbon. The planet, a gas giant named WASP-12b, is the first carbon-rich world ever observed. The team made the discovery using the Spitzer Space Telescope, along with previously published ground-based observations.

"This planet reveals the astounding diversity of worlds out there," said Nikku Madhusudhan of the Massachusetts Institute of Technology and lead author of a report in the December 9, 2010 issue of *Nature*. "Carbon-rich planets would be exotic in every way—formation, interiors, and atmospheres."

Carbon is a common component of planetary systems and a key ingredient of life on Earth. Our Sun has a carbon-to-oxygen ratio of about one to two, meaning it has about half as much carbon as oxygen. None of the planets in our solar system is known to have more carbon than oxygen, or a ratio of one or greater. (This ratio is unknown, however, for Jupiter, Saturn, Uranus, and Neptune.)

WASP-12b is the first planet ever to have its carbon-to-oxygen ratio measured at greater than one (the actual ratio is most likely between one and two). This means the planet has excess carbon, some of which is in the form of atmospheric methane.

"When the relative amount of carbon gets that high, it's as though you flip a switch, and everything changes," said Marc Kuchner, a Goddard Space Flight Center astronomer who helped develop the theory of carbon-rich rocky planets, but who is not associated with the study. "If something like this had happened on Earth, your expensive engagement ring would be made of glass, which would be rare, and the mountains would all be made of diamonds."

—from NASA/JPL-Caltech

We Make It **HAPPEN!**

Fun with Microrovers

Small in size, but not in capabilities, microrovers may one day play a larger role in exploring other worlds. The Planetary Society, in partnership with Cornell University and with partial funding from NASA and from you, our Members, has been investigating the future role of microrovers in solar system exploration.

For our study, we defined microrovers as rovers with a mass of roughly 10 kilograms (22 pounds) or less. This class of rover has been studied very little with respect to planetary exploration and essentially not at all regarding how they might be used with future astronauts exploring the Moon, Mars, or asteroids.

We took leadership in the current study as a way of addressing this lack of research. We began by asking some top-level questions, addressing what rovers can do, how they might help humans, and what key design components should be included. We worked with scientists, engineers, astronauts, and students to find answers to these questions.

Microrovers are intriguing because of their low cost, mass, and volume. Combine those characteristics with the many uses we have defined, and you have a powerful little package, or set of packages.

Microrover Catalog

When we looked into conducting this study, we found that although microrovers had been used for many purposes, both military and commercial, and mostly on Earth, there was no easy way to see what had been done before. To avoid duplicating past research, we compiled

Left: Although smaller than the test "cliffbot" seen in this image, microrovers would be designed to assist humans exploring other worlds. These robotic aides might venture into areas that could be dangerous for astronauts or do reconnaissance to identify rocks, craters, or other features that could be interesting for humans to investigate.

This photo was taken at the 2006 Arctic Mars Analogue Svalbard Expedition, during which humans in test space suits practiced interacting with robotic coworkers—an interaction we hope one day will play out on the Moon and Mars. *Photo: Courtesy Jake Maule*

When is a rover considered **micro*****? Although there is no precise definition for the size of a microrover, for the purpose of our study the Planetary Society defined microrovers as those with a mass of approximately 1 to 12 kilograms (2 to 26 pounds). To put it another way, they range in size from*** **MUSES-CN** ***(foreground) to*** **Sojourner*****, which traveled to Mars in 1997 with*** **Mars Pathfinder.** *Photo: NASA/JPL*

a catalog of what had been done before, for both Earth and space applications.

Obviously, some aspects of Earth microrovers, such as thermal control, are not highly relevant for space applications, but other aspects, such as locomotion, can be. Thanks to our team, and particularly college intern Forest Purnell, we not only gathered the information but also have made it available to the public, at *planetary.org/microrovers*. That Web page contains information on more than 100 Earth and planetary rovers. Our catalog includes rovers in our microrover mass range as well as others weighing up to 100 kilograms (220 pounds).

Microrover Uses

One of our major tasks was to investigate whether, and how, microrovers could be useful to human space explorers. We collected ideas and opinions from a number of experts with complementary backgrounds. We also solicited input from you, our Members, and then held a virtual workshop.

Our results were presented and published at the 2010 International Astronautical Congress. The following are some of the most promising microrover applications for increasing efficiency, return, safety, and public interest on future missions.

Increasing Astronaut Efficiency and Extending Human Senses

Reconnaissance: Whether teleoperated from Earth or by astronauts in orbit or on the surface, or used with some autonomy, one or more microrovers could be used to scout possible traverses for astronauts or larger rovers, thus maximizing science return and increasing efficiency. Deployment of multiple microrovers could enable exploration of a variety of possible traverses. Several microrovers could quickly explore a far larger area than could one large rover.

Science: Microrovers would be able to do a wide range of science, depending on payload instruments. Instruments could range from imaging to contact science. The science could be used independently of human exploration for greater area sampling, or used with human exploration as a means of determining traverses—finding the most scientifically interesting locations to which to send astronauts.

Extended "high-risk" exploration: Because of their

EXPLORE **MORE**

Check out our Microver Catalog at **_planetary.org/microrovers,_** and learn more about the project at **_planetary.org/programs/projects/microrovers/._**

comparatively low cost, mass, and volume, microrovers could be deployed robotically or by astronauts into areas too dangerous for astronauts or even larger rovers. For example, they could be deployed down steep slopes or into lava tubes. They could be tethered for retrieval. Low-cost microrovers could be useful in reducing the monetary risk of explorations that promise potentially high science value but that also involve high probabilities of losing equipment.

Materials delivery/transport (supply and logistics): Although the task perhaps is not standard, microrovers could be used to transport samples or supplies. For example, if an astronaut performing extravehicular activity (EVA) encountered an unanticipated need for a tool or equipment, a microrover could be dispatched from the habitat to take it to the astronaut.

INCREASING ASTRONAUT SAFETY

Decreasing or improving EVA: Human EVA is one of the most dangerous parts of space missions. Microrovers' abilities to assist human explorers with the basic tasks described here will enable astronauts to minimize EVA activity and/or focus EVAs on activities that best utilize human capabilities. In particular, on distant bodies such as asteroids or Mars, where teleoperation (joysticking) is not practical from Earth, astronauts could teleoperate microrovers from a habitat or even from orbit, thus adding exploration time to the limited EVA time.

Facilities inspection: Microrovers would be able to go around and under landing modules and other spacecraft and facilities, enabling remote inspection of their condition and identification of any issues affecting them.

Communications network: Communication on bodies such as the Moon requires line of sight. The later *Apollo* missions used the lunar rover as a communication relay back to the lunar module and even used one EVA suit as a relay for the other.

Microrovers could be deployed at or near high points surrounding a landing site or outpost and serve as communication relays between astronauts and their module/base when the astronauts explore out of direct line of sight, doing "over the next hill" work. Again, taking advantage of their small size and low cost, explorers could deploy multiple microrovers to provide redundancy in the communications links.

Increasing Public Excitement and Student and Public Involvement

Engaging the public: Microrovers at a landing site will make the site more "fun" and more real for the public. Because microrovers are analogous to (really capable) radio-controlled cars, they will be engaging to the public. Microrovers also will enable imaging of other rovers, landing modules, and astronauts from a variety of perspectives not otherwise possible, adding to interest in and recording of missions.

Engaging students: A standardized microrover, analogous to a standardized cubesat, will enable a variety of types of payloads and would be well suited to projects or payloads directed by universities and students, as well as payloads proposed by professionals. Microrovers will be of a scale that is accessible for universities, in addition to aerospace companies and governments. Students and the public also could be engaged in teleoperating the microrovers in some cases—for example, through competitions and training.

The Big Picture

Microrovers for use with and by astronauts could help enable safer, more efficient, and more publicly engaging human exploration of the Moon, Mars, or asteroids—and they're really fun!

Please check out the extended information about rovers and about the members of our rather large team on our website. This work was supported by an agreement with Cornell University; the Center for Radiophysics and Space Research, under Prime Agreement NNX10AC20A from NASA; and Members of the Planetary Society.

Thank you!

Bruce Betts is director of projects for the Planetary Society.

What's UP?

In the Sky—February and March

Jupiter is the brightest starlike object in the evening sky, getting lower in the west over the coming weeks. It appears near the crescent Moon on February 6 and March 6. Mercury is low in the west in the early evening in March and very close to Jupiter in the sky on March 15. Venus dominates the predawn eastern sky, with dimmer Saturn high above it. Look for the Moon near Saturn on February 21 and near Venus on February 28.

Random Space Fact

The total surface area of the Moon (about 38 million square kilometers or 15 million square miles) is equal to 7.4 percent of the surface area of Earth and would fit completely within the continent of Asia (about 44 million square kilometers or 17 million square miles).

Trivia Contest

Our July/August contest winner from Apopka, Florida wishes to remain anonymous. Congratulations!

The Question was: At what three locations have space shuttles landed after flying in space?

The Answer is: Kennedy Space Center, Florida; Edwards Air Force Base, California; and White Sands, New Mexico (where only STS-3 landed).

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

What are the only two vehicles to have performed fully autonomous re-entry and runway landings from Earth orbit?

E-mail your answer to *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 April 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 guests, listen to Planetary Radio at *planetary.org/radio.*

Society News

Ringing in the New

Happy New Year! Thanks to you—Planetary Society Members and donors, volunteers and partners—we are off to a terrific start.

We are delighted to welcome new and renewing New Millennium Committee and Discovery Team Members, and also those Planetary Society Legacy Members who have named us in their estate plans. Thank you, too, to the many thousands of other renewing Members. You are part of the excitement of exploring—and shaping—our place in space.

With you, and with a generous grant of $25,000 from the M. R. & Evelyn Hudson Foundation, we are embarking on a strategic plan for the Society. We'll capitalize on our 30-year history of inspiring and involving the public internationally in space science and exploration, through projects, education, and advocacy. And we'll grow and expand our reach as we shape the future of exploration with you and with ever more people around the world.

Stay tuned for exciting projects and for more ways for you to be involved.

From all of us at the Planetary Society, thank you! We are thrilled to have you on board.
—Andrea Carroll,
Director of Development

Planetary Radio—Giving You the Universe

Give us 30 minutes . . . we'll give you the universe.

Thanks to your donations and to a grant of $5,000 from the Kenneth T. and Eileen L. Norris Foundation, Planetary Radio does just that.

The Society's weekly radio show will quench your thirst for knowledge about our solar system and beyond.

Our cast is stellar: host Mat Kaplan, Executive Director Bill Nye, Planetary Society blogger Emily Lakdawalla, and Project Director Bruce Betts.

We've gone to the Red Planet with science fiction great Ray Bradbury and with Mars expert Chris McKay, and on a flyby of a comet with Deep Impact scientist Jessica Sunshine; *Apollo 11* moonwalker Buzz Aldrin has joined us on air, as has science journalist Andrew Chaikin; shuttle astronaut Tom Jones revealed the secret "smell of space"; and we talked rockets with SpaceX structural engineer Jeff Richichi.

So, when you get a chance, tune in (if you don't already) to Planetary Radio—online at *planetary.org/radio*, via podcast, or to more than 125 stations and XM Radio—for an entertaining and incisive half-hour journey through our planetary neighborhood.

If you like what you hear, please consider supporting Planetary Radio with your gift. You can donate online at *planetary.org/radio* or call or mail us your donation. Feel free to e-mail *andrea.carroll@planetary.org* or call me at (626) 793-5100, extension 214. Thank you, and happy listening.
—AC

A Remembrance

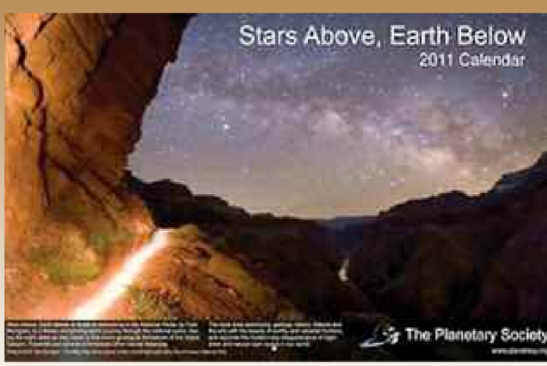
The Planetary Society has lost a very dear friend and tireless volunteer. Anna May Tomaszewski was the volunteer coordinator at the Planetary Society headquarters in Pasadena, California. Her passing leaves us with a loss, but those who knew her benefited greatly from her friendship.

Anna May was full of energy and enthusiasm, leading the Pasadena volunteer group and assisting the staff with whatever needed to be done. Whether it was stuffing envelopes or helping to organize a major event like Planetfest, her level of involvement and devotion was always the same: "Engage, Warp Speed!" A person of integrity, warmth, and kindness, Anna May will be missed by all of us whose lives she touched.
—Tom Kemp, Global Volunteer Coordinator, and Mary Brown, Telescope Group Coordinator

New at the Planetary Society Store! *www.cafepress.com/planetaryshop*

***Stars Above, Earth Below* Large Calendar**

Stars Above, Earth Below, by Tyler Nordgren, is a literary and photographic journey through the night skies of America's national parks.



Planetary Park Posters and T-Shirts

U.N. Department of the Exterior Planetary Park posters in the style of the iconic 1930s WPA posters for America's National Parks, by astronomer and artist Tyler Nordgren.

Find these items and more at *www.cafepress.com/planetaryshop*

Members' Dialogue

Revisit Our Goals

In your September/October issue, Robert J. Douglas voiced his views on the Planetary Society under "Stay Focused." I, too, have been a member of the Society for nearly 30 years. I found Mr. Douglas's response appropriate and very timely.

Most of the members have remained loyal to the Society come rain or shine, however, we seem not to be satisfied with the way the executives have made certain decisions supporting the current administration's attitude toward NASA. The Planetary Society is not a political organization, but a public scientific gathering of space enthusiasts and explorers who have supported it for many years.

Carl Sagan managed to communicate and to educate laypeople and our youth in ways that other scientists haven't been able to do so far. His *Cosmos* series is still a masterwork. His books are still informative and inspiring. This excitement is gone from the Society. The management has become timid and content with the status quo.

I am sure there are other members, like Mr. Douglas and myself, who are not happy with our current situation. Perhaps we need to revisit our goals and objectives and the path we have devised to achieve these goals by utilizing current management. We need to get back to our original focus on space pioneering and exploration.

Instead of boasting about and appreciating the new office, we would like to read about space and innovative ideas from the Society's leadership. Contentment with what we have will gradually wither away what is remaining of the Society we once knew.
—AL ZANGANEH,
Carlsbad, California

We Can All Explore Mars

Exploring can be as simple as walking in the forest, but some exploration is complex and expensive; money and human resources must be pooled to achieve any meaningful results. The Planetary Society allows us to take steps toward the exploration of other worlds. In "Looking Aft, Looking Forward" (November/December 2010), Bill Nye described a lot of the progress we have made in reaching out into the solar system.

As individuals, we can now explore Mars as part of NASA's HiWish Program (*uahirise.org/hiwish*), which allows regular folks to use the powerful High Resolution Imaging Science Experiment (HiRISE) on *Mars Reconnaissance Orbiter* (*MRO*). After the program was announced about a year ago, I submitted some suggestions. When some of my suggestions were imaged, I was overjoyed to see places that no one had seen before. The first Wednesday of each month, when new pictures are released, is a major highlight of my life. The pictures are a size that we can wrap our heads around—if you were on the planet, you could almost walk across the width of a picture in a few hours, or a day.

If you like to discover what Mars is really like, register for the HiWish program. A good way to begin is to look at a Context Camera (CTX) image (*global-data.mars.asu.edu/bin/ctx.pl*) to find interesting locations. The CTX images, also produced by *MRO*, are large in area while still showing a lot of detail. So far, about 50 percent of the planet has been covered by CTX.

The more sets of eyes we have looking at these images, the more discoveries will be made. It would be good if other members of the Planetary Society could share the images they receive. I put mine on my Facebook page for everyone to see.
—JIM SECOSKY,
Lakewood, Colorado

From *planetary.org*

We received this member's comment in response to our LightSail *video update, "Construction Begins!"*

Thanks a lot for your e-mail and the attached movie. You are doing historic work.

When I joined the Planetary Society, I expected just this, that my money (from my space dream), even if small in amount, would be converted into reality. Congratulations, and please go on so.
—GIOVANNI VULPETTI,
Rome, Italy

We Stand Corrected

In "Your Place in Space" (September/October 2010), Bill Nye stated that *IKAROS* uses "light-emitting diode displays" to steer the solar sail. Actually, the *IKAROS* team is using LCD (liquid crystal display) panels to implement their directional control.

Thanks for all you do!
—RON DAVISON,
Broadalbin, New York

Per Seth Shostak's SETI response in your September/October 2010 Q&A: FM station W1XOJ did not begin broadcasting until May 1939. It received its permit in 1937. Two months later, W2XMN, with a tower in Alpine, New Jersey, a short distance from my home, also started broadcasting.
—DONALD BEATTIE,
St. Johns, Florida

Please send your letters to
Members' Dialogue
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The surface of the comet in David A. Hardy's *Comet Probe* (2004) looks bright only because of light reflected from the Sun (which is eclipsed by the spacecraft in this view). In the foreground, boulders perch on the pinnacles of ice they have shielded from solar heat. The comet bears a striking resemblance to Hartley 2, which was visited in November 2010 by NASA's *Deep Impact* spacecraft. The mission (recently renamed *EPOXI*) has returned images of Hartley 2 showing spectacular jets of carbon dioxide gas and rocky particles bursting forth from specific features on that comet's surface.

David A. Hardy has been a space, science, and science fiction artist for more than 50 years. He has illustrated and produced covers for books by Patrick Moore, Arthur C. Clarke, and Carl Sagan, among other authors. *Comet Probe* appeared in *Futures: 50 Years in Space* (2004), which Hardy illustrated and coauthored with Patrick Moore.