The PLANETARY REPORT

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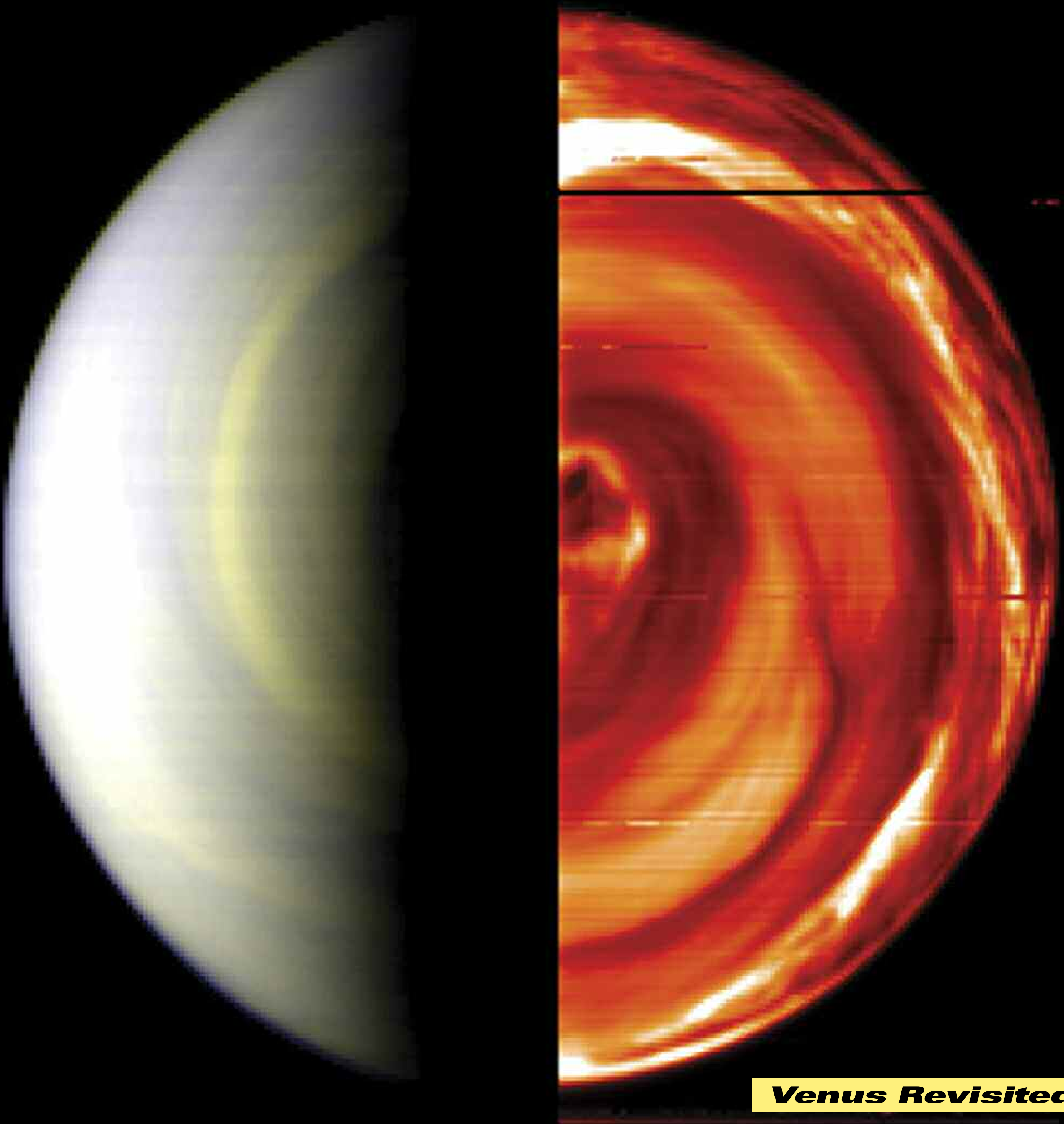

Venus Revisited

A PUBLICATION OF THE PLANETARY SOCIETY

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From The Editor

"To boldly go where we have gone before." We've been hearing that a lot lately, as The Planetary Society and its members contemplate the proposals for NASA's science program over the next few years.

On the surface, it might look like planetary science is sitting pretty, with *Voyager 1* at the boundary of our solar system, *Messenger* on its way to Mercury, and a fleet of spacecraft exploring the worlds between. In this issue of *The Planetary Report*, you'll read of missions at Mars and Venus, a conference on astrobiology, and the opening of a new Planetary Society telescope to search for evidence of alien life. Shouldn't we be content with that?

Yes, today, things are great. It's the future we're fighting for.

The American space program is standing at a crossroads. One road follows the Vision for Space Exploration and would take us on to Mars and continue the exploration of other worlds. The other road continues in circles, not only keeping humans bound in Earth orbit, but even scaling back robotic ventures to other worlds.

Europe is already at Mars and the Moon. Japan, India, and China are making plans for the Moon. All are waiting to see which road America chooses to take.

We know which one we'd take: the one that goes where no one has gone before.
—Charlene M. Anderson

On the Cover:

This view of Venus, the first released by the Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) on the European Space Agency's *Venus Express*, reveals swirling patterns in the upper levels of the planet's thick atmosphere. The left side of this south polar view shows all that is visible to our Earthly eyes in reflected sunlight. The right side is an infrared view of thermal energy emitted by Venus' overheated atmosphere. For more information on these images, go to *http://planetary.org/news/2006/0414_First_Venus_Express_VIRTIS_Images_Peel.html*

Image: ESA/INAF-IASF, Rome, Italy, and Observatoire de Paris, France

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Members' Dialogue

Stay on Course

I've just finished reading the letters under "Society Priorities" in Members' Dialogue from March/April 2006. I have to agree with Louis Friedman on the Europa/Enceladus issue. We can't just throw away all those years of work on the Europa mission. It would be like leaving an important book we're reading on a certain subject unfinished because there's a new exciting book on another subject. There'd be much unlearned.

William Laub's position on change with new information is not wrong, but if we change directions too often, we'll never get to our destination.

I'm very glad to see that The Planetary Society's position is not to leave important space exploration work and projects unfinished.

—PABLO CAFISO,
Dundas, Ontario, Canada

Meters and Miles

It is perhaps too much for me to travel to a meeting of The Planetary Society, but were I to do so, I would make a motion that [after a metric measurement] *The Planetary Report* no longer add in parentheses the equivalent imperial value. It is not necessary, and I am sure a large majority of members will agree.

Further, I believe that an important goal of The Planetary Society is to inform and educate. Continuing this journalistic style promotes the use of a measurement system which most hope will be abandoned someday soon. Please do not forget that the continued common use of two measurement systems directly led to the destruction of a Mars-bound spacecraft.

I suggest that if you must add something to help readers understand the measurement, relate it to something physical.

—PHILLIP WOELLHOF,
Ridgefield, Connecticut

At one time, we tried using only metrics in the magazine. We soon heard from members who preferred imperial units and wanted us to go back to the old style. It doesn't take much space to give the conversion, so we don't lose space for more content. To make sure that everyone is able to appreciate sizes and distances, we went back to giving the measurement both ways. —Editor

This poem, inspired by the Mars Exploration Rover Spirit*, was sent to us by Stuart Atkinson of the Eddington Astronomical Society.*

The Spirit of Exploration

I am tired. *So* tired.
Scratching, biting dried-blood dust
Coats and smothers me,
Eating at me, *into* me,
Planting itches I can never scratch.

I am lame. Where once
I used to dash across this ruddy, rocky land
I can now only crawl; limping like a dusty crone
From weathered stone to weathered stone.

Once I scaled a mountain:
High above this boulder-cluttered land stood I,
A martian Queen, triumphant!
But now the hills laugh cruelly
As I drag my useless wheel.
Exhausted.

Half a thousand frozen sols
Ago I knew no fear!
Laughing, I scorned the shrunken Sun,
Mocking its meagre, half-hearted heat;
Now I long for its waning warmth.
As dervish dust devils dance giddily past,
Mocking *me*, scorning my crawling quest
For that same Sun's precious touch
My blood is ice, I feel it crack
As I haul myself onwards . . . onwards . . .

But if I die here, They will find me
One day, after travelling from the Evening Star.
Warm arms will surround me, wrap around me,
Lift me out of my rusted, dusty grave
And brush me clean once more.

One day I'll stand behind walls of glass,
Warm again, clean again;
Honoured and worshiped by wide-eyed martian Children
not yet born on the day I died.
Their Columbus.

—STUART ATKINSON,
Kendal, England

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by Bruce Betts

The Planetary Society Optical SETI Telescope

On April 11, 2006, a new era dawned in the search for extraterrestrial intelligence (SETI) with the dedication and beginning of operations of The Planetary Society Optical SETI Telescope in Harvard, Massachusetts. It is the first dedicated optical SETI telescope in the world. The telescope was constructed by Paul Horowitz and his group at Harvard University using funding from Planetary Society members.

An unassuming structure, looking something like a small storage building, sits in a clearing at the Oak Ridge site of the Harvard College observatory. The building's only unusual features are a small weather station and a mysterious rod on top and, more unusual, a strange-looking set of metal beams on one end of the building. It looks like the builders ran out of money and didn't cover the second half of the building structure. On a pleasant spring day in April 2006, 75 people gathered at this site. With a remote computer command, the unusual began, and the roof of the building began to slide off onto the mystery beams, revealing cutting-edge technology—the great new hope in the search for extraterrestrial intelligence.

Radio Versus Optical

Much has changed in our world since 1959, including in the field of optics. That's when Giuseppe Cocconni and Philip Morrison first suggested SETI be carried out at radio wavelengths, particularly at the 21-centimeter emission line of hydrogen. At the time, there were no operational lasers. Only 2 years later, R. N. Schwartz and Charles Townes suggested that perhaps SETI should also be carried out at optical wavelengths. (Townes won a Nobel Prize in 1964 for co-inventing the laser.) The technology was still in its infancy, however, and it was hard to imagine where it would develop. Thus, SETI began at radio wavelengths and continued that way for 40 years.

In that time, lasers have become much more powerful, and they continue to improve rapidly. Optical light communication began to replace other forms of communication in our world, primarily through fiber optics, and the SETI community began to look again at optical SETI.

How plausible is it that an alien civilization could use optical wavelengths to communicate across the galaxy? Well, for reference, using 2006 Earth technology, one could construct a device that is capable of outshining our Sun by a factor of more than 10,000 for a brief instant, or a set of repeatable instants. Pretty amazing—and eye-opening, so to speak. And that is just using 2006 Earth technology in a field that is rapidly growing and developing. If alien civilizations are communicating, they are likely more advanced than ours and easily could be outshining their parent stars by factors of 100,000 or more.

Advantages of Optical Communication

So, communicating across the galaxy with lasers is plausible, but would ET want to use optical laser pulses? Radio certainly has its advantages, particularly its ability to penetrate through intervening clouds or other material in the interstellar medium. But optical communication has some distinct advantages as well for galactic communication, many of which are the same reasons that on Earth we now use light for communication more and more and why NASA is developing the techniques necessary for optical communication with deep space spacecraft. Optical provides the following advantages over radio:

- Higher frequencies mean optical signals can carry far more information, the same reason we are using fiber optics and pursuing optical spacecraft communication.
- Optical signals can form a more tightly focused beam, enabling better targeting.
- Dispersion, which broadens radio wavelengths, is negligible at optical wavelengths.
- Radio transmitters have reached a stable maturity, whereas lasers continue to develop rapidly.
- Radio observations are plagued by interference by radio, television, cell phones, and other sources.

But if ET sends a laser pulse into the galactic forest and no one is there to see it, does it really . . . well, you get the idea. ET could have been pulsing our planet constantly for aeons and we wouldn't have known, until recently.

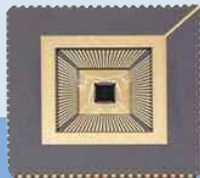
A Brief History of Optical SETI

In the late 1990s, The Planetary Society began funding groups at both Harvard University and the University of

Is this just an unassuming, unfinished storage shed?

With the roof rolled back into observing position, the humble shed is transformed into a state-of-the-art optical SETI observatory.

These are the eight boards that hold the 32 custom-designed PulseNet chips. These chips allow the telescope system to process the same amount of data as that in all of the world's books in print—every second!



A close-up of one of the custom-designed PulseNet chips. Each chip contains more than 250,000 transistors.

The telescope with an open frame (in operation, the sides will be covered and the top cover, shown here, will be removed). Note the 1.8-meter primary mirror at lower left as well as the back of the 0.9-meter secondary mirror at upper right.

Background: On the roof is a weather-monitoring system to aid in remotely checking weather at the observatory and to keep accurate time using a GPS antenna. Photo: Paul Horowitz

We are looking down into the telescope. The large mirror is the 72-inch primary mirror. It reflects light to the 36-inch secondary mirror, which we see the back of here (it's the circular object at left). Light is then reflected to the detectors, which, along with the electronics, are in the cubelike structure at right, next to graduate students Andrew Howard (left) and Curtis Mead. Photo: Paul Horowitz

The ribbon-cutting ceremony at the dedication of the telescope on April 11, 2006. Left to right: project leader Paul Horowitz, Horowitz's wife Vida Kazemi, Planetary Society Executive Director Louis Friedman, and Charles Alcock, director of the Harvard-Smithsonian Center for Astrophysics. All photos by Bruce Betts unless otherwise noted.

California at Berkeley to do targeted optical SETI research. They would either target a select number of stars and then observe them or piggyback on other observations already being carried out. They were looking for sudden rapid spikes in the light coming from a star system. To match typical pulse times and to reduce the

What's **Up?**

In the Sky—June and July

In the first 2 weeks of June, Mercury is visible low in the west just after sunset. Orangish Mars and pale-yellow Saturn are a little higher in the west in the early evening and very close together at this time. Bright Jupiter is in the east after sunset. In the pre-dawn sky, Venus is the very bright starlike object in the east and Jupiter is in the west.

Random Space Fact

Billions of neutrinos—most from the Sun—are passing through your body every second, but they pass through things so easily, on average you will absorb only one or two of these particles in a lifetime.

Trivia Contest

Our January/February contest winner is Maurice Benzaken of Oakland Park, Florida. Congratulations!

The Question was: What spacecraft left Earth with the highest speed?

The Answer: When *New Horizons* launched in January 2006, it became the fastest spacecraft ever to leave Earth.

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

What is the longest channel on Venus?

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

Submissions must be received by August 1, 2006. 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.*

effects of the parent star, they tried to measure pulses that were only a billionth of a second long.

The problem with targeted approaches is that we can sample only a limited number of stars. Searchers have to make a guess as to where to look or take their chances with piggyback observations. They have also assumed that communication would come from a star system. What we'd really like to do is survey the entire sky. Then, no assumptions need to be made about where a signal may come from, and, at least spatially, nothing is overlooked.

The challenge of all-sky optical SETI is considerable. In fact, various astronomers told Paul Horowitz that it was impossible. Part of Horowitz's inspiration was to prove them wrong. The big challenge is that the sky is a vast place to cover, and we need to collect samples at billionths of a second (a nanosecond). This means we need a really fast and capable customized system of electronics. As we'll see, Horowitz and his students created a cutting-edge, custom-designed system of electronics to process unbelievable quantities of data. This is perhaps not too surprising when you realize that Horowitz coauthored *the* standard college-level electronics book. (I can hear all the physics and electrical engineering majors out there saying, "Oh, *that* Horowitz!") With support from The Planetary Society, Horowitz and his team set out to do "the impossible."

Covering the Sky

In order to cover the entire sky, the telescope will look at one elevation (altitude, in telescope terms) each night. For a night, the telescope remains fixed, pointing at a particular angle. Meanwhile, you and I and the telescope rotate under the stars, thanks to Earth's rotation. As Earth rotates, it sweeps the telescope's field of view across the sky. In this way, a stripe of the sky is covered. The next night, the altitude is changed, and a new stripe is covered. Each clear night, one can cover about one third of the sky in any given stripe. (Half the "sky" is on the other side of Earth, and one can't observe too close to daylight; thus, the other one sixth of the sky is lost.) As Earth orbits the Sun, new pieces of sky are visible at night, and one can reobserve each altitude and fill in the other parts of the stripe. The search can cover the entire sky in about 200 nights, and we predict it will take 1 to 2 years to get those 200 clear nights.

At any one moment, the camera images a 1.6 by 0.2-degree rectangle of the sky with a pair of 512-pixel nanosecond-speed photodetectors. It has a minimum viewing time of about 1 minute per target—that is how long the system has to detect a signal from any given point in the sky, at least the first time through on the survey. One minute may not seem very long, but remember that the system is taking data every nanosecond, so each minute gathers a lot of data for every point in the sky. The system does rely on ET to be putting out a signal at least once every minute, or it requires getting lucky, but that is the trade-off for covering the entire sky.

The Observatory and Telescope

Part of the brilliance of this search strategy is that the telescope's mechanical systems can be simplified. The telescope needs to move in only one axis: altitude. That also means a dome isn't necessary—a clear opening up and down in one direction in the sky is sufficient. This simplification created significant cost savings in the construction of the new optical SETI observatory compared with a normal observatory. This is why the observatory could be a "regular" building, with a unique sliding roof.

The telescope is also atypical. The builders were able to use an easier-to-construct boxlike structure, giving the frame a square cross section—unusual looking, but just as effective for this purpose as a traditional-looking telescope.

The Optics

The telescope has a 72-inch primary mirror, eclipsing its 61-inch neighbor 100 yards away and earning the title of the biggest primary mirror in the eastern United States. Unusual for a telescope, the 72-inch mirror is spherical rather than parabolic, because spherical mirrors are easier and cheaper to produce. One of the advantages of a dedicated optical SETI telescope is that one can "simplify" in various areas compared with a typical astronomical observatory. The optics, too, can be simplified because we don't need to produce the highest-resolution images possible. Fundamentally, we are counting photons. We need to know where those photons came from, but we don't need to produce pretty pictures or know where they came from to an arc second resolution. For these reasons, Horowitz says the telescope is more properly called a *light bucket*—but The Planetary Society Optical SETI Light Bucket just didn't have a very nice ring to it.

The Camera and Electronics

One important thing in science—as with much of life—is knowing where you can and where you can't simplify without harming the result. Where this system can't skimp is the camera and the electronics. This telescope needs to be able to image an area of the sky every nanosecond. To do so, it utilizes a pair of 512-pixel photodetectors (each pair observes the same location in order to get rid of spurious results that may occur in just one detector). The system has to use photomultiplier tubes, an older technology, rather than charge-coupled devices (CCDs) because CCDs just can't begin to count photons at nanosecond intervals—they are a million times too slow.

The signals are then fed into 32 identical processors. Horowitz's graduate student Andrew Howard designed these amazing chips specifically for this task. Each contains more than 250,000 transistors. Together, these processors process 3.5 terabits (3.5 trillion bits) of data *per second*! That is the equivalent of the information in all the books in print . . . every second.

The processors highlight and keep track of any possible event—a large increase in photons occurring in at least one of the detectors. For precise and accurate timing, the system uses the Global Positioning System (the extra mast near the weather station on the building).

Remote Control

In the modern era, I believe no piece of electronics is truly complete without a remote control. The telescope and even its building are no exception. The entire system can be operated remotely over the Internet, whether the operator is in Cambridge, Massachusetts (as Horowitz's group is likely to be) or in Madagascar (less likely to find them there). Information about the observatory comes from the weather station mentioned earlier, a suite of webcams, a number of status sensors on the electronics (such as for temperature and humidity), and the control systems that open the roof, move the telescope, and handle all the other operations. After the system is thoroughly checked out, it will move to fully automated control, and humans won't need to intervene. The system will decide when to observe and then do it. It will then pass all the possible ET events on to the humans. Ah, a remote control that knows what you want without your having to touch it!

I invite you to come to The Planetary Society website, *planetary.org,* and follow project links to Optical SETI to learn more about The Planetary Society's Optical SETI Telescope and see real-time information about the telescope—where it is pointing, whether the roof is open, the stars it will observe that night, and how much of the sky has been covered.

The Future

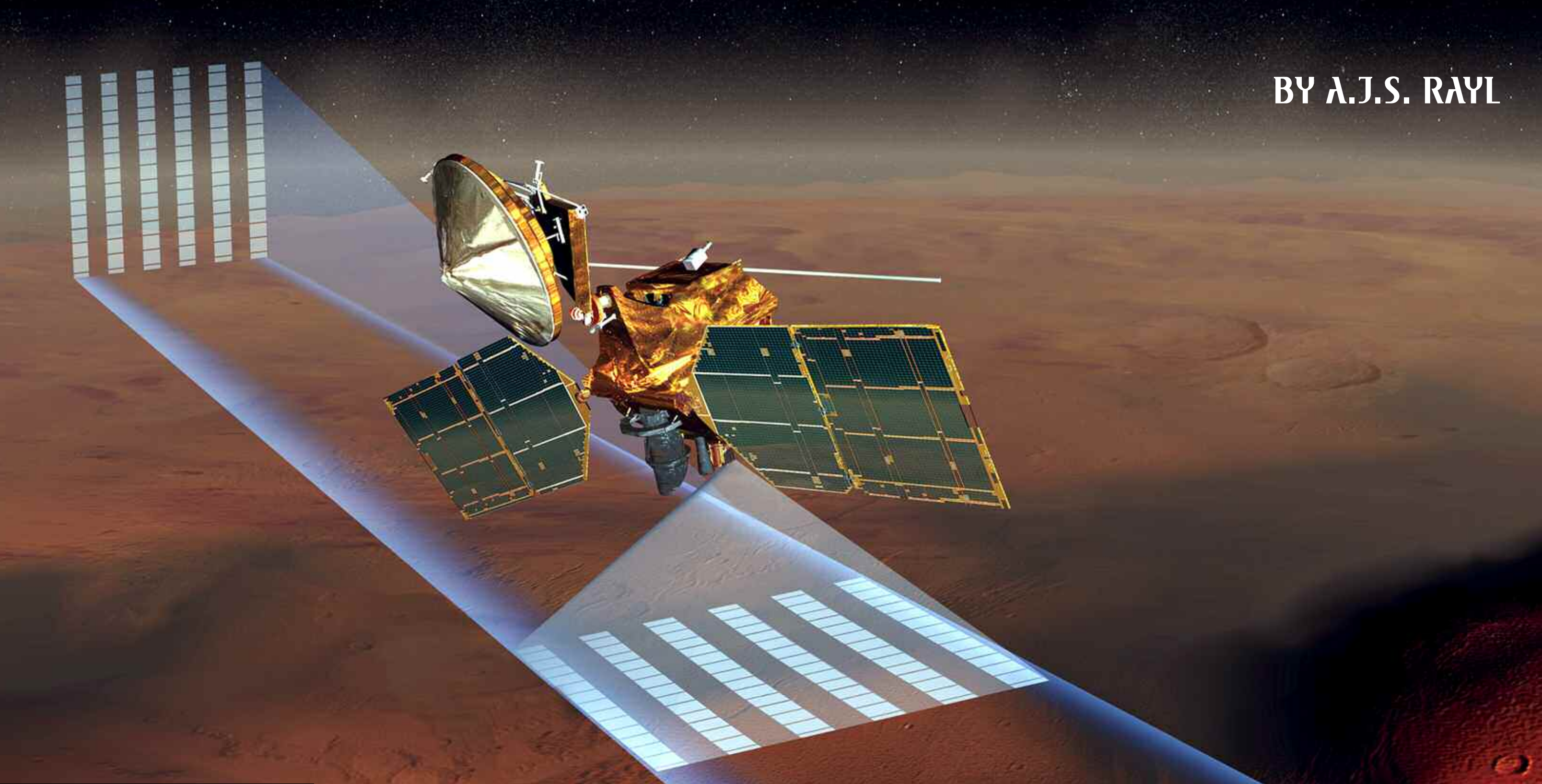
The first steps are to work all the kinks out of the system, fully understand its data, and move to fully automatic control over the next few weeks to months. Assuming that goes swimmingly, and ET isn't discovered immediately, where do we go from here? The answer probably is a second identical observatory a few miles away. With the current setup, every trigger—that is, every time you get a spike in the signal that might indicate ET—needs to be thoroughly checked out, then reobserved to make sure it was not due to a cosmic ray exciting the electronics or some other non-ET source.

With targeted SETI, Horowitz's group collaborated with Princeton University and did some simultaneous observations of the same objects. Requiring that both observatories see a signal at the same time creates much more confidence that with even one observation, you may be seeing ET. It will greatly speed the weeding out of all the false events.

For now, we are ecstatic that the great effort to produce The Planetary Society Optical SETI Telescope is complete and that the new search has begun. The opening of this telescope represents one of those rare moments in a field of scientific endeavor when a great leap forward is enabled. We also keep our eyes looking to the future, when we may find the answer to the question: "Are we alone?"

Bruce Betts is director of projects at The Planetary Society.

The Third Time's a Charm: The Saga



By A.J.S. Rayl

Mars Reconnaissance Orbiter (*MRO*) arrived at the Red Planet on March 10, 2006 with the most technologically advanced payload ever flown to another planet. Beginning in November 2006, the spacecraft's six science instruments will study the planet from the atmosphere to below the surface for 2 Earth years (1 Martian year). One of the instruments—the Mars Climate Sounder (MCS), essentially a Martian weather satellite—actually made the journey to Mars twice before. Because the spacecraft on those missions didn't make it, this mission actually marks the instrument's debut.

This story chronicles the trials, tribulations, and resurrections of the little Martian weather satellite through the memories of Daniel J. McCleese, the atmospheric physicist who, through the last three decades, steadfastly promoted getting it to Mars. Of course, McCleese, who also happens to be the Mars chief scientist at the Jet Propulsion Laboratory (JPL), didn't do it alone. An international team of scientists has contributed to the effort over the years. Some members, including McCleese's deputy principal investigator, Tim Schofield, hail from the United Kingdom, and others are from Russia and the United States. Like the director of a movie, however, McCleese held the vision of the project, and he has worked a lifetime to give it life.

The third time's the charm, as the saying goes, and destiny is presenting a different outcome this time around.

An Emerging Planetary Scientist

The story begins in the late 1960s, when America was going to the Moon. In sunny Southern California, 16-year-old Daniel J. McCleese, then a junior at Chula Vista High School, was into Mars. When it came time to consider projects for the Greater San Diego Science and Engineering Fair, he teamed with schoolmate Michael Hulfactor to create the Mars Environmental Simulator System (MESS). Basically, the MESS was Mars in a box. "We put together a system that simulated all of the environmental conditions of Mars in that box — lighting, temperature, and pressure," recalls McCleese. The duo collaborated for 2 years, and in their senior year, 1967, the MESS won several engineering and science awards.

As life went on, McCleese was accepted at Antioch College. A work-study program dropped him at JPL during those undergraduate years. At JPL, he discovered an interest in atmospheric physics that led him to Oxford University in England for his doctorate. "I wanted to both build hardware to investigate things I was interested in and analyze the data, and do the interpretations of the data for better understanding," he explains.

During the mid-1970s and the buildup to the twin

OF THE MARS CLIMATE SOUNDER

From its perch on Mars Reconnaissance Orbiter*, the Mars Climate Sounder (MCS) will scan the surface and edge of Mars' atmosphere almost continuously. Over the course of 1 Martian year, MCS will build up a four-dimensional view of the temperature, pressure, and composition of the bottom 80 kilometers (50 miles) of Mars' atmosphere.* Illustration: NASA/JPL

Viking landers, McCleese was in England, busy working on his doctorate and focused on Earth; he completely missed the Mars mania taking place at home. Once his doctorate was in hand and he returned home to take a job at JPL, Mars piqued his interest again, but his timing couldn't have been worse. It was the late 1970s, post-*Viking* and a time—as hard as it is to believe now—when NASA had absolutely no interest in exploring the Red Planet.

"As I began to get more and more interested in Mars, I ran into a very, very strong push-back from NASA, along the lines of 'We've gone to Mars with *Viking*. It is a dead planet, no longer very interesting to NASA, and we are headed for the outer planets,'" he remembers. This was the time of the soon-to-be legendary *Voyager* mission, when *Galileo* was gaining steam. "NASA wanted to talk about *Cassini* and Saturn as a new mission and not Mars."

Going for the Dream

By 1980, McCleese decided to go for his personal "red ring" (let the others have brass) despite the odds against him. "I tried very hard to get NASA interested in returning for specific narrow investigations that were opened by *Viking* and not settled," he says. "One of those was the role of water in today's climate, and how that might teach us about water in the past climate of Mars. I wanted to understand the hydrological cycle on Mars."

At JPL, McCleese had been lucky enough to work with Barney Farmer, who had an instrument on the *Viking* orbiter that mapped water in the atmosphere for the first time. "I wanted to try to understand how that water in the atmosphere was exchanging with the surface," McCleese says. In effect, the Pressure Modulator Infrared Radiometer (PMIRR) was born. A nine-channel limb- and nadir-scanning atmospheric sounder, the PMIRR would vertically profile atmospheric temperature, dust, water vapor, and condensate clouds and would quantify surface radiative balance. "I had an instrument idea, but I had no mission," McCleese recalls. As he talked up his idea, he encountered a group of graduate students and scientists at the University of Colorado who had begun to think about very, very tiny missions on the premise that they ought to be able to build and fly planetary spacecraft.

Mars Observer and PMIRR

In 1982, McCleese joined forces with Charlie Barth of the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado, and they began promoting something they called the Mars Water mission. To their good luck and good fortune, NASA started calling for ideas for new missions. "The only ideas the agency expected they would get that would really catch fire were for the outer planets, but we pushed very hard and got some traction for a small mission to Mars to follow up on the water story," McCleese recounts. By 1984, he had approval to submit a proposal.

Meanwhile, several Mars geologists got wind of the project and gave it a nod as a great idea, but they declared that it had to have geology involved to really capture some of the most interesting things about Mars. "Before too long, the Mars Water mission had turned into a very sophisticated, but still modest-sized, mission investigating the geology, atmosphere, and interior of Mars." The mission was soon blessed with funding and christened *Mars Observer*.

Although the mission had grown in scope, the budget did not grow in kind. Projected costs and lists of "musts" were all scrutinized and often eliminated. The predominant attitude was that "it must be cheap, done by industry, and must be able to roll off an assembly line like an Earth communications satellite," explains McCleese. NASA made it clear that the mission was going to be very highly constrained. "In fact, in the original description of the mission, there was to be no camera because it was thought that cameras make missions expensive. It was a little wacky."

McCleese couldn't complain—he finally had an instrument and a mission, and now he had to put together a team. He brought Tim Schofield, with whom he worked at Oxford, over from England as his deputy principal investigator. David Paige, now of UCLA, had just graduated from Caltech and became a postdoc on the team. The team was coming together, and the mission was moving along.

Then, in January 1986, the space shuttle *Challenger* exploded. "It meant that we no longer had a clear path to launch this thing," says McCleese. "In the beginning, we were going to be on a shuttle launch, but *Mars Observer* was one of the very first science missions pulled out of the sequence of flights that the shuttle had laid out in front of it." As a result of the *Challenger* loss, *Mars Observer* lost 2 years and the costs went through the roof. "At launch we were around $700 million, having originally been capped around $250 million."

One thing that happened as the team got closer and

As 16-year-old high school students, Dan McCleese and his friend Michael Hulfactor built the Mars Environmental Simulator System (MESS) and entered this "Mars in a box" experiment in the 1967 San Diego Science Fair. *Photo: courtesy of M. Hulfactor*

closer to launch is that people began to realize how exciting Mars is. Moreover, adds McCleese, "the community of Mars scientists who had been working on *Viking* data realized that this payload would really produce new and completely different data from *Viking* datasets."

The mission finally launched on September 25, 1992 from Cape Canaveral. *Mars Observer* suffered early on from "teething problems," as McCleese puts it, with the propulsion system. "There was a decision to pressurize part of the propulsion system in order to deal with a leak that was perceived. Then, 3 days before we arrived at the planet, when the spacecraft was fully pressurized and the propulsion system was prepared for Mars orbit insertion, it is believed—although we never heard from it after it turned away from Earth pointing and communication—it blew up."

"We picked ourselves up, but slowly, from that disaster," remembers McCleese. The planetary program had almost always built two spacecraft for redundancy, but to cut costs, that wasn't done for *Mars Observer*. "None of us really believed we would have another chance."

Mars Climate Orbiter and PMIRR2

In April 1992, Daniel Goldin assumed the position of NASA administrator. He promptly initiated a new exploration strategy that called for faster, better, cheaper spacecraft. "He was very interested in finding a demonstration for this strategy, and JPL suggested the Mars program," recalls McCleese. "We would get more missions, and the missions would be more focused on science. The launch rate would be high enough to sustain the community that was beginning to atrophy. It was all looking good. The concept appealed to Goldin partly because we were in a position of spreading the risk over multiple missions. The idea he latched onto is that we would split *Mars Observer* into three separate missions, and each of the missions would be smaller and better in every way."

Of course, NASA would decide which of the science instruments would go on which mission, and it certainly did not guarantee that everybody would get a second ride to the planet. In 1993, the agency began a competition, and suddenly everyone who had started with *Mars Observer* and had become friends was now competing with former teammates. "It was a very harrowing part of the process," remembers McCleese. "We had to fight it out."

Five instruments were chosen to go on the first mission, which eventually was dubbed *Mars Global Surveyor* (*MGS*), including Mike Malin's Mars Orbiter Camera, Phil Christensen's Thermal Emission Spectrometer, and Mario Acuna's magnetometer. McCleese and the PMIRR did not make the cut. McCleese was not happy about it, but he stayed in the game anyway and went on to compete with the remaining prime instrument, William Boynton's Gamma Ray Spectrometer, for a guaranteed berth on the second of the three missions resurrected from the ashes of *Mars Observer*.

"In the second competition, one of the things I tried to do was show that if they flew the PMIRR on that next mission, then we would bring along with us the first element of the Mars Together Program," McCleese says. (Mars Together, an international space exploration program, is an example of the effort to share costs and research efforts among nations.) As it turned out, he did land that berth on the second mission, subsequently named the *Mars Climate Orbiter* (*MCO*). "It was obviously focused on what I wanted to do, which I was very pleased about," he says. Boynton and the Gamma Ray Spectrometer, by default, flew on the last of the three missions, what became *Mars Odyssey*.

Once *MGS* arrived safely at Mars in 1997, it served as Goldin's demonstration that faster, better, cheaper worked. "All of the instruments had to be rebuilt, but that was okay, because it was still a relatively cheap mission since there was a lot of hardware left over from *Mars Observer*," explains McCleese. The extremely successful *MGS* mission, which is still in orbit around Mars, "opened our eyes to a new world," McCleese says.

Back on Earth, McCleese and colleagues got started on the *Mars Climate Orbiter* mission. "We decided to build an identical copy of the instrument we lost on *Mars Observer*. As part of Mars Together, we brought a dozen scientists from Russia into the project, and a team led by Vasily Moroz [IKI/Russia] built hardware

These test images, the first returned by the Mars Climate Sounder, were taken of Mars' north polar region on March 24, 2006. The visible and near-infrared view at left shows sunlight reflected off the planet's dayside. At center is a thermal infrared (12-micron) measurement of the temperature of the surface or of atmospheric dust. At right, a longer (15-micron) thermal wavelength shows carbon dioxide in the atmosphere. For more information, go to http://photojournal.jpl.nasa.gov/catalog/PIA08030. *Image: NASA/JPL*

for the second PMIRR instrument according to the blueprints."

Along with the *MCO* came a new lander mission that David Paige, from the original PMIRR group, proposed as a means of studying the terrain in Mars' south polar regions. "We launched about three months apart," recalls McCleese. "We went first. We had a very short development phase. We had a very lean team. The navigation guy had not done a mission before. With the faster, better, cheaper mode, everything we did was done at a minimum—minimum cost and minimum time. The people who were working at Lockheed Martin who built that spacecraft and we here at JPL did not communicate well, and we plowed into the planet—this was the famous metric versus English units error. Three months later we lost Paige's *Polar Lander*."

A pall fell over JPL, and the joke around NASA still echoes through the halls of the agency's centers: faster, better, cheaper—pick two. "We were now a team that was the bad luck team," sighs McCleese. "We as a team had lost our instrument again." They weren't shunned, but they had suffered the worst agony of defeat—twice. Life, as it turned out, helped McCleese keep it all in perspective.

Embracing the Fight

With the birth of each Martian weather satellite in McCleese's career came the birth of a child in his personal life, and when things didn't go well at the office, he and his wife, Judy, turned the negative energy into positive energy toward family. "During the development of the second instrument, my son was diagnosed with a serious disease, and so I turned my sense of loss and frustration with the PMIRR toward the question of how to help get my son well," he explains. "It was during this period that things began to turn around for him. He's doing well now and has earned a degree in physics from Occidental College. In turning our energies to try and make something happen to him, I was able to put the loss of the second orbiter in a context of what is really important in life. I have also been lucky enough to be surrounded by people who understood that failure was part of exploration and life, I suppose."

Seeing the fight and determination in his son made McCleese realize that the apple hadn't fallen too far from the tree. "I have to admit that I was as determined to fly again after the second loss as I was with the first," he says. Besides, he and his deputy principal investigator, Schofield, had already agreed to give it another go. "We wouldn't re-fly PMIRR again. Its size and complexity made that a non-starter. We would never get it built again, and the technology was so old that we couldn't build it. So Tim set about redesigning the instrument into a smaller, more elegant package we called the Mars Climate Sounder (MCS)."

The reason McCleese and Schofield couldn't give up is because the weather on Mars is what is "alive" and what makes the planet so alien. "Mars is a dynamic planet today. Most of the features we see on the surface have been the way they are for a very long while," McCleese begins. "But the climate—the weather—continues to change. When we think about how our atmosphere on Earth behaves, perhaps the most alien aspect of Mars is the dust in the atmosphere. Martian dust actually drives the way the atmosphere behaves—its circulation, dynamical changes, the way it behaves seasonally. Dust is actually raised by high winds at the surface of Mars, and while most often small storms develop and die away, there are times, particularly during a southern spring, when dust storms can evolve and become global, covering the entire planet and reducing the sunlight that falls onto the surface of Mars by as much as 80 percent."

When human crews travel to Mars, knowing which way the wind blows, as well as when, where, and how big those swirling dust storms are going to be, could mean the difference between life and death. "When humans land on the surface of Mars, which I think will eventually happen, they will care about the characteristics of the Martian weather, the dust and intense cold on the surface, and will really care if the weather's going to go south on them when they're out trudging around in their suits or running machinery," McCleese says. "There are things in the Martian atmosphere that can get you."

Human beings have intensely observed the dust storms on Mars since telescopic observation began on Earth. During the last decade, however, Mars missions

At home in the lab, Dan McCleese watches as MCS team members prepare the instrument for its flight to Mars.
Photo: NASA/JPL

have been collecting a record of dust, says McCleese. "What's interesting with the *MGS* thermal emission spectrometer data is that over three Mars years [six Earth years] Mars has behaved very differently year to year, so differently in fact that the atmosphere and the way it behaves from the surface all the way up to high altitudes is quite different. We wonder if what we're observing is a natural variability of the atmosphere of Mars or if we are seeing the process of further climate change, and we designed the Mars Climate Sounder to focus on this question in our effort to observe and better understand that climate and weather on Mars."

Mars Reconnaissance Orbiter and the MCS

Chance, as the old adage goes, favors the prepared mind, and it wasn't long before chance presented itself again. When NASA issued its next request for new mission proposals, McCleese and Schofield responded. This competition was between an orbiter and, as it turned out, the Mars Exploration Rover (MER) mission. McCleese, as JPL's chief scientist of the Mars Program, sat on the committee to make that decision. He voted for MER, with *Mars Reconnaissance Orbiter* to follow.

Now, at long last, McCleese's ship has arrived. Shortly after *MRO* successfully went into orbit around Mars and before it began a series of aerobraking maneuvers to reduce its orbit to a much closer altitude to the planet for science observations, the MCS was turned on. It checked out with flying colors.

The mission objective of the MCS is to profile the atmosphere of Mars by detecting and measuring vertical variation in temperature, dust, and water vapor concentration in the Martian atmosphere with high resolution and full global coverage over at least one full seasonal cycle, or 2 Earth years. The data will be analyzed using computer models of the Martian climate, developed in collaboration between Oxford University and Laboratoire de Meteorologie Dynamique (LMD) in Paris. Using methods similar to those used in monitoring meteorology on Earth, scientists will feed actual MCS data into the models to produce diagnostics and even estimates of future conditions on Mars. What will emerge is a much more detailed picture of the weather systems on Mars, especially the characteristics of the dust storms, all of which will be critical information for future missions.

"MCS observes the atmosphere to better understand dust but also to characterize the weather and climate on Mars," says McCleese. "It does so by observing the edge, or as we call it, the limb, of the atmosphere. You can think of these observations like weather balloons on Earth rising through the atmosphere and collecting information about temperature in water clouds as they rise. But we do the same thing from about one thousand kilometers distance and never touch the atmosphere. The instrument also scans down to the surface to make observations, and in so doing, over a period of one Mars year, in following the 'follow the water' theme, we will characterize some of the aspects of Mars that now cause water to be transported around the planet. We're trying to look at this water to extrapolate back in time to see how water might have formed and moved on Mars many, many years ago and at the same time contribute a beginning to the process of developing enough understanding of the Martian weather system to be able to predict it."

Much time has passed since McCleese put the final touches on his science fair MESS, and it's been nearly 20 years since he conceived of trying to put a weather satellite at Mars. His children are grown. Team members have come and gone. Happily, Conway B. Leovy, who gained renown for his work on the atmospheric studies from *Viking*, will be leaving retirement to rejoin the MCS team. Some, however, have passed on. IKI's Moroz died between the second and third instrument development efforts, and a young JPL investigator, Bob Haskins, who had been instrumental in data analysis preparation, is also gone.

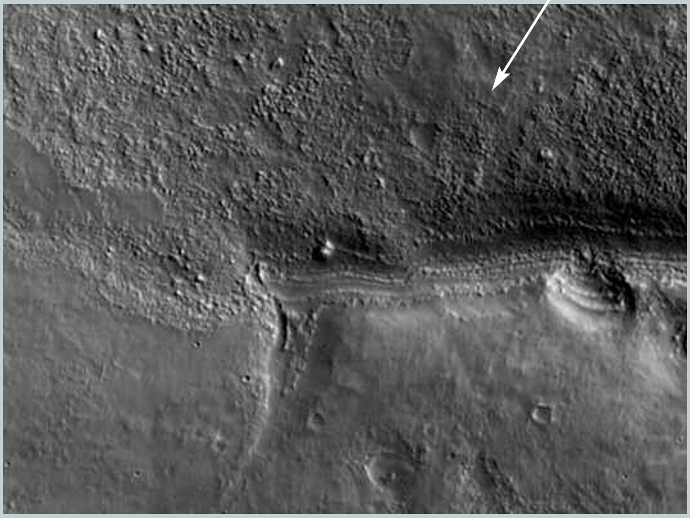
Getting anything to Mars is like taking a shot in the dark and hitting the bull's-eye, but through it all, McCleese's determination has not wavered. Those who might ask why probably could never understand what motivates explorers. "The feeling about the exploration objective that I think drives us all is that it isn't about one instrument or two instruments or three, it's the doing of it and the pursuit of scientific objectives," says McCleese. "Each step is then part of a path where, whether you succeed or fail, there is something that follows, and until we get the data from this particular investigation, I think we can't take that next step."

McCleese pauses, as if rewinding through the memories of all the moments, the work, the losses, and that science fair so long ago. "Mars seemed to me to be a place that was ours—accessible," he says. "It never lived in the realm of science fiction for me."

A.J.S. Rayl is a writer and editor for The Planetary Society's website, planetary.org. *You can read her continuing Mars exploration coverage at* planetary.org/mars.

The First HiRISE Images Are In!

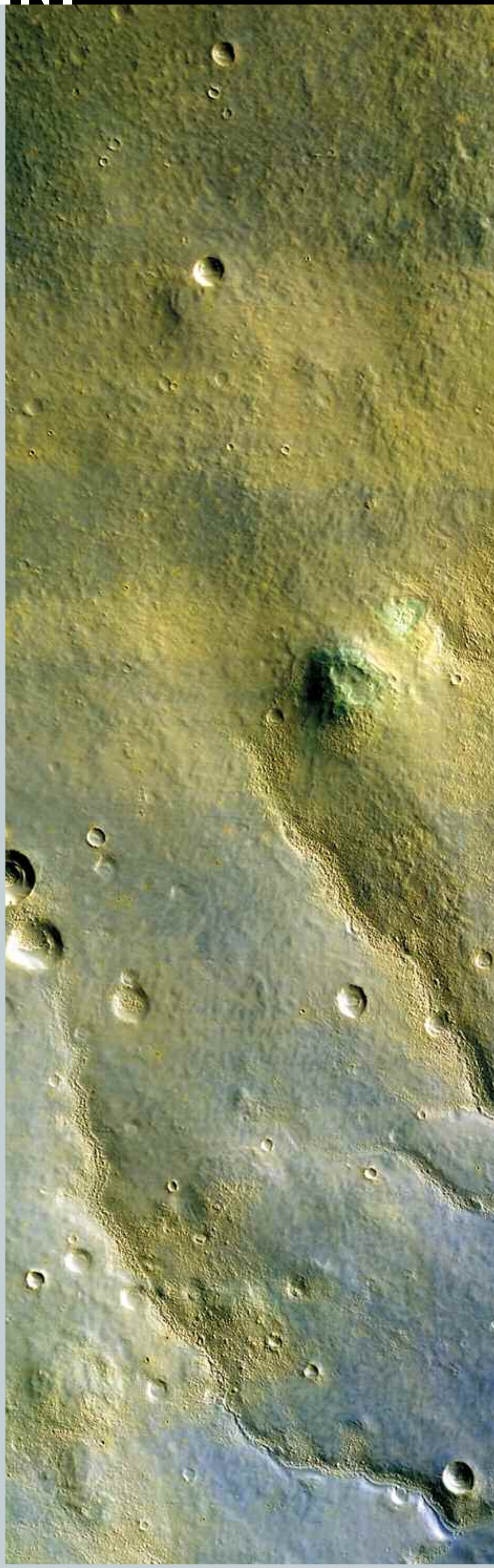
The first test images from the High Resolution Imaging Science Experiment (HiRISE) camera on board* Mars Reconnaissance Orbiter *are in, and they are everything the scientists hoped for. Alfred McEwen of the University of Arizona, the principal investigator of HiRISE, said it was especially good to see them "considering that if you take the speed of the spacecraft over the Martian surface and the altitude and scale it down to something in our experience, it's like photographing grains of sand along a highway going 120 miles per hour." For more information on these images, go to **planetary.org/news/2006/0407_Color_Images_and_Sharp_Details_from.html**



Right, top: This image, the very first taken by HiRISE, was captured on March 24, 2006 from an altitude of about 2,500 kilometers (about 1,550 miles). This view covers an area about 50 kilometers (about 30 miles) wide and about 25 kilometers (about 16 miles) high in Mars' midlatitude southern highlands. The region to the left of the white box is blown up and shown in false color at far right.

Right, bottom: This subset of the broader image above has a resolution of 2.5 meters per pixel. The area shown is about 4.5 by 2.1 kilometers (2.8 by 1.3 miles).

Left: Because HiRISE took this image showing the rim of Argyre, an ancient impact basin in Mars' southern hemisphere, just after sunrise on March 24, only the Sun-facing slopes are well illuminated and much of the scene is in shadow. Hills in the southern part of the image appear to be littered with dark boulders, whereas the lower-elevation plains look much smoother.



Right: Produced in longer-wavelength infrared color, as opposed to the natural color that human eyes see, this image has also been processed to enhance subtle color variations. The brighter, bluer look of the southern part of the scene may be caused by early morning fog in the atmosphere. Large-scale streaks in the northern half are due to the action of wind on the surface. Two greenish spots in the middle right of the image may have an unusual composition and are good future targets for MRO*'s mineral-identifying Compact Reconnaissance Imaging Spectrometer for Mars (CRISM).* *Images: NASA/JPL/University of Arizona*

EXPRESS TO VENUS:

Top: On April 11, 2006, in the European Space Operations Centre's main control room, members of the Venus Express *team stood by, anxiously waiting for confirmation that the spacecraft had entered orbit.* *Photo: ESA, J. Mai*

Above: A short time later, ESA's Director General Jean-Jacques Dordain congratulated Venus Express *Flight Director Manfred Warhaut upon receiving word that orbital insertion was a success.* *Photo: ESA, J. Mai*

Right: Venus Express *in orbit around its target. Venus is shown here without the dense atmosphere that normally hides its surface from view.* *Illustration: ESA*

BY EMILY STEWART LAKDAWALLA

Exactly on time, at 10:07 a.m. Central European Standard Time (8:07 a.m. Universal Time) on April 11, a little kink in a Doppler track signaled the shutdown of *Venus Express*' main engine and its successful capture into Venus orbit. The arrival marked the first time in 14 years that Earth has had a spacecraft in orbit at Venus, as well as the fifth straight success for the European Space Agency's (ESA's) planetary exploration program.

All in all, the event bore many contrasts to the last event I attended at the European Space Operations Centre in Darmstadt, Germany: the landing of *Huygens* in January 2005. The *Huygens* landing was a tumultuous and emotional experience. Nothing like it had ever been attempted before, and it was being attempted not by NASA but by ESA, a much smaller agency with fewer resources and very few previous missions (and no successful landed missions). Many people I talked to before the landing harbored serious doubts that *Huygens* would succeed.

By contrast, *Venus Express*' orbit insertion was almost routine, even for ESA. What made it routine was past experience with a nearly identical spacecraft, *Mars Express*, 2 years earlier. As events unfolded, everything happened exactly as planned; there's not much drama when events match predictions! Furthermore, unlike the lander *Huygens*, *Venus Express* is an orbital mission that could last up to 6 years, producing a volume of data many hundreds or thousands of times what *Huygens* returned. Also, it's seeing a planet in a way that has been done before (though certainly not as well), so the surprises in the results from *Venus Express* will not likely be evident in its earliest data but will instead be revealed in analysis over the coming months, years, and even decades.

There were, however, a few moments of tension in the control room in the middle of the process. For 10 minutes, mission controllers expected *Venus Express*' signal to be silenced as the spacecraft dove behind the planet, thus eliminating contact with Earth. The loss of signal happened exactly as predicted, but 10 minutes later, the signal did not return, leading to 2 minutes of tense silence in the control room. The momentary silence turned out to be a false alarm; the radio dish of the Deep Space Network tracking station in Madrid was sweeping back and forth in the sky to ensure that the signal would be picked up regardless of what had happened to *Venus Express* during the 10 minutes of no contact. Within 2 minutes, the antenna had swept to *Venus Express*' position and reacquired the weak signal exactly at its predicted position and velocity.

ESA credits the heritage of *Mars Express* for the uneventful orbit insertion of *Venus Express*. *Venus Express* was built to nearly the same design as *Mars Express*,

EUROPE SUCCESSFULLY ENTERS ORBIT

with only a few changes to its hardware, software, instruments, and systems. As a result, lessons learned on *Mars Express* could be applied to the Venus mission, preventing problems before they arose. For instance, *Mars Express* went into "safe mode" shortly after launch because ESA mission controllers had built in a too-conservative set of criteria for what constituted an anomalous event on the spacecraft. The safe modes on *Venus Express* have been tailored to more realistic conditions.

Why Return to Venus?

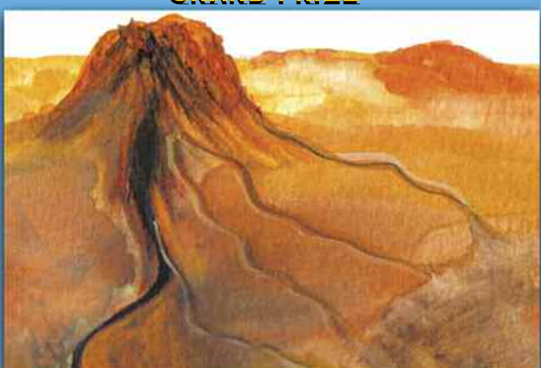
Why did ESA decide to send a spacecraft to a planet that was so thoroughly studied by both the Soviet Union and the United States from the 1960s through the 1990s? The answer is that although we know what Venus is like, we don't know why it is the way it is and why it is not more like Earth. *Venus Express* will study the thick atmosphere of Venus, from the tops of its sulfuric acid clouds to the searing heat and crushing pressure of the air at the surface. Close study of Venus' atmosphere may help us understand what calamities in Venus' climatic history led to the runaway greenhouse effects that make it such a hellish place today.

In fact, the emphasis of the European planetary program has been slightly different from NASA's, with a lot more emphasis on exploring bodies with atmospheres. *Venus Express* joins *Mars Express*, *Huygens*, and several Earth-orbiting spacecraft in ESA's overarching mission to understand the structure and dynamics of planetary atmospheres, data that ESA hopes will be able to return to Earth and contribute to our understanding of our own dynamic climate.

(continued on page 16)

To celebrate the arrival of the *Venus Express* mission at our sister world, The Planetary Society and ESA held an art contest to depict the planet as *Venus Express* would see it from orbit. The Grand Prize went to Tatianna Cwick of Cape Girardeau, Missouri, who entered in the youth category. Tatianna won a trip to Darmstadt, Germany to watch as *Venus Express* arrived at its destination. To see all of the winning entries, go to *planetary.org/explore/topics/postcards_from_venus/*

GRAND PRIZE



Ominous Beauty
Tatianna Cwick, age 17, United States

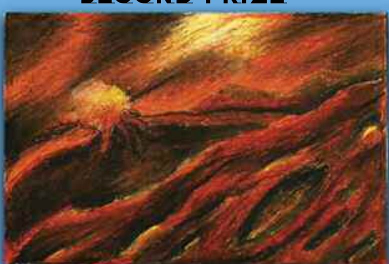
FIRST PRIZE

Hello Venus! Hello Alien!
Yoo-Hong Sun, age 9, Korea

FIRST PRIZE

Venus Burning
Alejandra González Quintana, Spain

SECOND PRIZE



Volcanic Love
Upamanyu Moitra, age 12, India

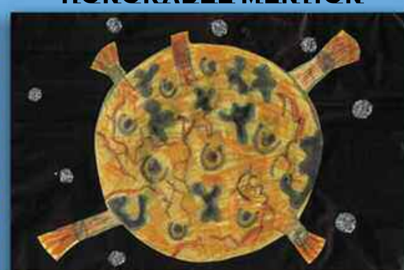
SECOND PRIZE

The Mysterious
Jason Tetlak, United States

THIRD PRIZE

Untitled
Nabila Nindya Alifia Putri, Indonesia

HONORABLE MENTION



The Orange Volcanoes Planet
Lowri Elin Williams, age 8, United Kingdom

Seventeen ESA member states contributed to the *Venus Express* mission, but the spacecraft's success did not come without help from the rest of the international community. The spacecraft was launched atop a Russian Soyuz-Fregat launch vehicle from Kazakhstan, and the real-time Doppler tracking data that permitted the immediate news of the success of the orbit insertion maneuver came from a NASA Deep Space Network station in Madrid.

The Greenhouse Effect

Venus is hotter than it should be. At its distance from the Sun, it receives an amount of solar insolation sufficient to maintain its surface temperature at about the boiling point of water (373 kelvins, 100 degrees Celsius, 212 degrees Fahrenheit). But radio measurements from Earth proved that Venus has the hottest solid surface of any planet in the solar system, at a constant 750 kelvins (480 degrees Celsius, 900 degrees Fahrenheit), day and night. That temperature is hot enough to melt lead and to give Venus' rocks a warm glow.

Where did all the heat come from? The carbon dioxide in Venus' atmosphere is partially transparent to relatively short-wavelength—visible and near-infrared radiation coming from the Sun. That radiation is absorbed by rocks, which then re-emit the radiation at a longer wavelength (called *thermal* or *mid-infrared*). Carbon dioxide is much less transparent to the thermal radiation, so much of the radiation is bounced back to the planet or absorbed and reradiated, in part back to the surface, keeping its energy inside the blanket of Venus' atmosphere. This process is called the *greenhouse effect* even though it's not why greenhouses keep warm.

If Venus ever had any oceans, the greenhouse effect heated them so much that the oceans would have boiled and evaporated long ago. Liquid water is a necessary ingredient in chemical reactions on Earth that trap volatile carbon and sulfur compounds and sequester them in rocks. Without water on Venus, these volatile gases stay in Venus' atmosphere, contributing to a runaway greenhouse effect, in which more heat means more atmosphere, which traps more heat, and so on. —*ESL*

Next Steps for *Venus Express*

The orbit insertion maneuver placed *Venus Express* into a long elliptical orbit with a 9-day period. For a few weeks after arrival, the spacecraft performed several more maneuvers to shrink the size of the ellipse from the original reach of 350,000 kilometers (220,000 miles) to 66,000 kilometers (41,000 miles). In its new orbit, the spacecraft will spend a 4-week period testing the science instruments to make sure they perform as expected. One instrument in particular, the Planetary Fourier Spectrometer, is of real concern: tests performed during the cruise to Venus revealed that while the instrument's sensor is working, its scanning mechanism is stuck in a closed position. The rigors of orbit insertion and warmer temperatures at Venus could have resolved the problem, but only time will tell.

Although *Venus Express*' science orbit is in fact designed for both close, detailed study and distant, global study, the large distances that *Venus Express* will cover during the period between orbit insertion and the science orbit create some unique science opportunities that will not be repeated during the rest of the mission. For example, this will be the only time that the spacecraft camera can capture the entire disk of Venus in a single field of view. Also, the spacecraft will be moving very slowly at its farthest reach from the planet, permitting it essentially to "park" over the south pole, a region that has not been well covered in previous missions. From that vantage point, it will watch the motions of Venus' clouds over the entire 4-Earth-day period that it takes for Venus' atmosphere to circumnavigate the globe.

Just a few days after orbit insertion, the first image was released from the Visible and Infrared Thermal Imaging Spectrometer. Already, this image has revealed interesting swirling dynamics in Venus' upper atmosphere at the south pole, including a polar "vortex." This kind of cloud motion has been observed at Venus' north pole by *Pioneer Venus* and *Mariner 10*, but neither of those missions made many observations of Venus' south pole.

In the end, the science team may get much more time than it bargained for. Because of its uneventful cruise and orbit insertion, *Venus Express* has arrived with a significant margin of extra fuel, which should allow it to maintain its orbit for much longer than the nominally planned mission of 2 Venus sidereal days, or 486 Earth days. The fuel margin allows a possible extended mission of 4.5 to 6 Earth years.

If that holds true, *Venus Express* will be in orbit at Venus for much longer than the 3 years it took to design, build, launch, and deliver the spacecraft to its target—record time for ESA. We have a flawless orbit insertion and a healthy spacecraft; now it's time for the science team to make good on the promise of *Venus Express*.

Emily Stewart Lakdawalla is science and technology coordinator at The Planetary Society. She maintains The Planetary Society's weblog at planetary.org/blog.

World Watch

by Louis D. Friedman

Washington, DC—Planetary Society members have taken action to save the science in NASA's budget by contacting congressional offices to express their support for space science research and missions. Couple this with Society staff and directors' personal interaction with congressional committees and their staffs, and you have an effective campaign. We are already seeing results: the US House of Representatives Science Committee agreed to hold a special hearing on the issue of proposed space science cuts, and Society President Wesley T. Huntress, Jr. was invited to testify.

We have invited members of Congress and their staff to meet with Wes Huntress, Society Vice President Bill Nye, Board member Heidi Hammel, and myself at the end of May, at which time we will extol the value of planetary exploration and specifically seek congressional support for a mission to Europa. We will also present the petitions signed by our members to the Appropriations Committees. Our work is not over: Society members should continue to let their representatives know how strongly they support science in NASA.

To follow the latest news on The Planetary Society's Save Our Science campaign, check our website at *planetary.org/sos/*.

The Moon—The European Space Agency's *SMART-1* is nearing its end. *SMART-1* will soon run out of fuel to maintain control and orbital stability, so ESA has decided to turn its demise into a science experiment by controlling its crash into the Moon. On September 3, the spacecraft will hit at about 2 kilometers per second and should blast out enough lunar rock that the plume will be visible by telescopes on Earth. When the dust has cleared, observers might be able to see the crater left behind by *SMART-1*.

On April 10, NASA announced a lunar impactor mission of its own, to fly as a secondary payload on the 2008 or 2009 *Lunar Reconnaissance Orbiter* (*LRO*). The Lunar Crater Observation and Sensing Satellite will make use of the upper stage of the EELV (Evolved Expendable Launch Vehicle) after it has sent the *LRO* on its way to the Moon. The EELV will be maneuvered to crash into Shackleton crater near the Moon's south pole. A shepherding satellite will fly through the resulting impact plume, looking for evidence of water. A short time later, that satellite will itself crash into the Moon, to be watched by an array of telescopes also seeking signs of water.

Meanwhile, uncertainty racks the rest of the US Moon mission plans. The *LRO* was to have been followed by a large lander sometime around 2012, but those plans are now being called into question because the designed spacecraft seems to have become too large and too expensive.

Human exploration plans are even more uncertain. At the end of April, I attended a 4-day NASA conference that hosted debate and review of lunar mission objectives. For many years, lunar science has been given low priority in science planning, and among proponents of human exploration, the Moon is seen mostly as a steppingstone to Mars. NASA Administrator Mike Griffin, however, has focused the vision on near-term objectives, and there is not yet consensus on what those might be for the Moon.

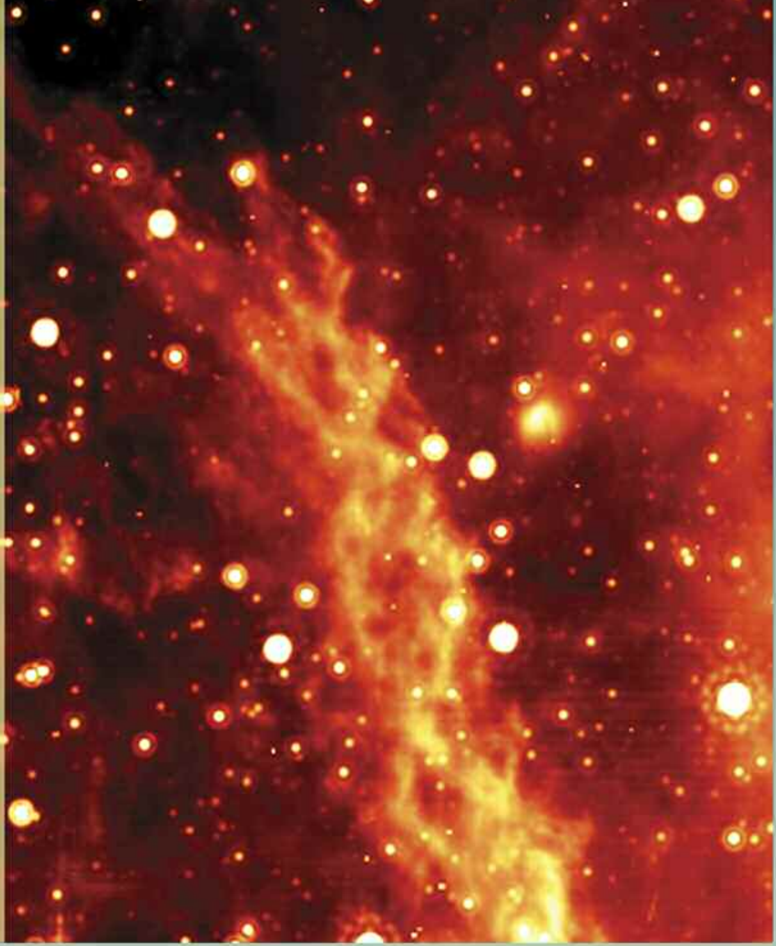
Japan—Following a remarkable success rendezvousing with the near-Earth asteroid Itokawa, the *Hayabusa* spacecraft appeared to have been lost before it could start back to Earth. After 2 months, however, the Japanese space agency team restored communications and regained control of the spacecraft.

The attitude control gas is expended, but the ion engines can be used both to control the attitude and to provide propulsion for the return trip to Earth. The spacecraft team is unsure whether a sample was actually collected, but whatever the final result, the mission has provided great science results and an exciting adventure.

I was invited to a government-run symposium at the Miraikan National Museum of Emerging Science and Innovation in Tokyo to talk about the future of planetary exploration. While in Japan, I had a chance to see the *Selene* spacecraft in its assembly and test area. *Selene* should be an outstanding mission, with a highly capable imaging system and two subsatellites that will provide detailed gravity maps of both sides of the Moon. The *Selene* mission will provide 3-D high-resolution images, chemical and mineralogical maps, and altimetry data.

Japan continues to develop technology for penetrators to fly on the long-awaited *Lunar A* mission. The country also is developing a Venus orbiter mission, called *Planet-C*, and the Japanese and European space agencies are cooperating on the *BepiColombo* mission to Mercury.

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



The Chance and Necessity of Life:

Reflections on AbSciCon 2006

by James D. Burke

In some worlds there is no Sun and Moon, in others they are larger than in our world, and in others more numerous . . . in some parts there are more worlds, in others fewer; some are increasing, some at their height, some decreasing; in some parts they are arising, in others failing. They are destroyed by collision with one another. . . . There are some worlds devoid of living creatures or plants or any moisture. —Democritus, 460–370 B.C.

Hundreds of planetary systems out there! Life's essential molecules drifting in the cosmos! Ancient gems carrying messages from the very birth of Earth! In our laboratories, bits of the Moon, Mars, asteroids and comets, and the dust of bygone stars! Four human artifacts leaving the Sun's domain forever, already reaching interstellar space! Microbes flourishing in subterranean hells! And always the great silent telescopes, the sentinels, watching for the whisper that will change everything.

Astrobiology, once mocked as a science without a subject, is the latest expression of an idea more than 2,500 years old. Maturing rapidly as a vigorous, interdisciplinary potpourri of scientific quests, astrobiology in the United States has exploded out of a few small workshops into the world of budgets, badges, ballots, and bureaucracy. Its latest expression was a lively conference in March 2006 in Washington, D.C. Here, I review that meeting and point to some of its implications.

The sudden prominence of this new pursuit of knowledge is due to an avalanche of discoveries connecting previously isolated endeavors in astronomy, geosciences, and biology. As understanding of galactic, stellar, and planetary evolution has advanced in parallel with understanding of life's processes, it has become clear that these different realms are intertwined. The workings of the cosmos provide habitats, and in turn, life (at least here on Earth) modifies its environments. Everything is evolving as the universe runs along its inexorable course, driven by laws that some minuscule bits of it—humans, so far as we know, alone among animals—have become able to describe.

The Washington conference, called the Astrobiology Science Conference (AbSciCon) 2006, brought together people from many countries and many disciplines ranging from microbiology and geochemistry to astronomy and cosmology. Its premise was that these disparate endeavors are all parts of one grand inquiry, the quest for knowledge of our place in the cosmos, of the history and destiny of our world, and of whether or not we are alone.

In an ironic moment of science's bargain with government, just as astrobiology was beginning to flourish, the US administration cut its funds. This gave a bittersweet taste to AbSciCon 2006. Nevertheless, the meeting was a huge success.

A common bacterium such as *escherischia coli* is a tiny creature. Hundreds of millions of them live in your gut and help to keep you fed and well. (Yet when the Los Angeles drains are overwhelmed by runoff from a winter storm, you had better not surf for a while in Santa Monica Bay.) A typical bacterium contains a complex collection of subsystems called *organelles*. It can move itself around, respond to stimuli, and make descendants. A virus, on the other hand, is much smaller and consists mainly of a package of deoxyribonucleic acid (DNA), the governing molecule of life. In

Scientists using the Spitzer Space Telescope recently detected this elongated, double helix–shaped nebula near the center of the Milky Way. We present this false-color infrared image here just for fun because of its resemblance to a DNA molecule. The researchers think the nebula's twisted shape is due to strong magnetic field lines near the center of our galaxy.
Image: NASA/JPL-Caltech/M. Morris (UCLA)

the aggregate, viruses constitute an enormous mass of biological matter, perhaps comparable with all else alive on Earth.

And guess what? With the new tools of base pair sequencing, scientists have found that the human genome contains many stretches of DNA identical to those of some viruses, strongly suggesting that something resembling a virus may have been the first life-form on Earth. Baruch Bloomberg, former director of the NASA Astrobiology Institute, gave a sparkling talk about progress in understanding and dealing with these microscopic invaders. Almost in passing, as part of his discussion of life in the cosmos, he mentioned a monumental public health success that is happening all over our own planet: vaccination against the hepatitis B virus works. This vaccine is the first antiviral substance to forestall the cancers that can follow a hep B infection. Campaigns are under way in 152 countries.

Other clues to life on the early Earth were the subject of active discussions at AbSciCon 2006. In Western Australia are found zircons dating from more than 4 billion years ago, the Hadean era. At that time, according to the cratering record on the Moon, bodies in the inner solar system were suffering cataclysmic bombardment by orbit-crossing objects. During the deadly hail, perhaps life started more than once, only to be erased by impacts. Perhaps the impacts themselves created hospitable hydrothermal systems whose dissolved chemical traces have survived in the zircons. Eventually, possibly in some hot, acidic waters, life gained a toehold.

Recognizing that possibility, scientists are now looking for clues in strange watery environments on Earth, including Yellowstone's near-boiling springs, deep ocean vents, ice cores, high lakes in the Andes, and the spectacular rust-colored Rio Tinto of Spain. Even in these hellish places, flourishing colonies of microorganisms are found, showing that wherever there is chemical or other energy available, on or in Earth and its oceans and lakes, life may build complex molecules leading to more life.

What about such environments elsewhere? The spacecraft now orbiting Mars and the two rovers wandering on its dusty red surface are showing that that surface is rich in iron, sulfur, and silicates modified by chemistry, possibly in an ancient ocean. Other clues are found in meteorites and in the gases and dust of comets. Together these bits of evidence point to the possibility that life will arise quickly—at least on a geologic time scale—wherever and whenever favorable conditions exist for long enough.

We do not yet know the limits of those conditions and their required durations, but the oldest rocks tell us that not long after the formation of the Earth, life began to leave its traces here.

At AbSciCon, even the Moon, long dismissed from the realm of astrobiology because of its dryness, came in for lively discussion. Several scientists, including Bernard Foing, the irrepressible chief scientist of ESA's *SMART-1* mission now orbiting the Moon, suggested that future missions to the lunar surface should look for ancient samples of the materials that once constituted Earth. They must be there, delivered by the same processes that have brought to Earth meteorites from the Moon and Mars. The problem will be to identify them amid the Moon's mess of impact products. But if any pre-Hadean Earth rocks can be found, they will be hugely valuable because they may still hold clues to a time whose entire record has been erased on Earth.

Meanwhile, in the realm of radio astronomy, two grand pursuits are under way. In one endeavor, more and more complex molecules—140 of them so far—are being found by their spectral signatures in interstellar clouds. In the other line of inquiry, more and more capable telescopes are being built to search for signs of other civilizations in the cosmos.

I and some other AbSciCon participants enjoyed an overnight visit to the National Radio Astronomy Observatory (NRAO) at Green Bank in the wilds of West Virginia. While there, we learned not only about the history and programs of NRAO but also about progress in building the next generation of instruments for SETI, the search for extraterrestrial intelligence, including the Square Kilometer Array of telescopes being assembled in the mountains of northeastern California. (For more on SETI, see The Planetary Society's website at *planetary.org*.)

Highlights of AbSciCon were not only the exciting lectures and atrium discussions among its hundreds of participants; the organizers also provided enjoyable evening events including a reception in the grand rotunda of the Natural History Museum and another at the headquarters of the American Association for the Advancement of Science. That session included a splendid lecture by cosmologist George Coyne, S.J., of the Vatican Observatory.

Coyne always gives fine value in his public lectures. He is good-natured and even-tempered about matters that get other people all riled up. Secure in his faith and wondering at the cosmic marvels revealed by modern science, including his own work, he sees no reason for humans to invent a conflict between science and religion. Why, he asks, should the reality of universal, including biological, evolution demand the nonexistence of a God?

Whatever anyone may think about that, he is persuasive in his argument that much of our petty wrangling is unworthy of a species able to see all the way from the insides of a tiny virus to the edge of the observable cosmos, to imagine and investigate our own beginnings, and to pursue the possible origins and fates of others among the stars—others who may also dream, think, inquire, and come to comprehend the magnificent universe that surrounds us all.

James D. Burke is technical editor of The Planetary Report.

Questions and Answers

When I first heard that there may be planets "wandering" in interstellar space, unconnected to a star's influence, there seemed to be some controversy surrounding the idea. What is the latest thinking concerning these "rogue" planets?
—I. Emerson
Cleveland, Ohio

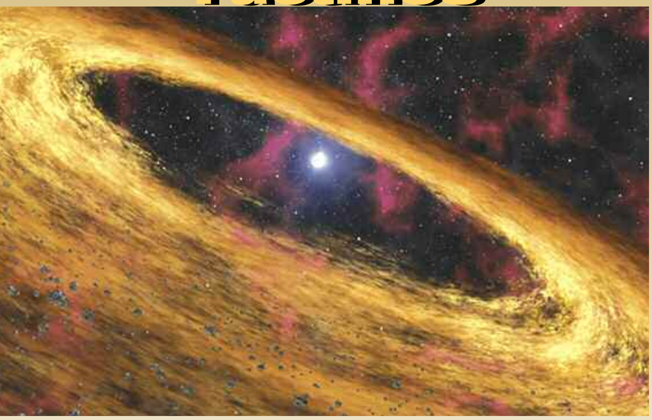
As a planetary system forms, close encounters may take place between growing planets. On occasion, such an encounter can cause ejection of a planet from the system, in just the same way that the encounters of several spacecraft (such as the *Pioneer*s and *Voyager*s) with the giant planets—especially Jupiter—have caused them to leave our solar system.

These rogue planets could exist in interstellar space, but the idea is controversial in two ways. First and foremost, there is no observational evidence for their existence. They would be exceedingly difficult to observe, and the likelihood that one would wander through our solar system is very small. Second, there is an ongoing debate about the extent to which what you see is what you had. In other words, how does the present inventory of solid matter in the outer solar system compare with the total amount of this material at the time that the planets formed? Planetary formation dynamicists have ways of trying to answer this question, but they have not yet reached a consensus.

A completely different take on your question is this: Can nonstellar bodies form directly in interstellar space? These objects could be baseball-sized or the size of Rhode Island, or 30 times the mass of Jupiter. The latter would usually be called *brown dwarfs* and, presumably, have formed the same way that stars form but without sustained nuclear energy.

These bodies have been observed as solitary objects, but most people would not choose to call them planets. The low density of interstellar material, however, makes it unlikely that solid bodies similar to our planets would form directly in interstellar space.
—DAVID J. STEVENSON,
California Institute of Technology

Factinos



A disk of debris surrounding a pulsar (a type of dead star) called 4U 0142+61 has been detected by the Spitzer Space Telescope. This ring of rubble resembles the protoplanetary disks around young stars. *Illustration: NASA/JPL/Caltech*

For the first time, scientists have detected evidence that planets might rise up from the remains of a dead star (see illustration above). Deepto Chakrabarty, Zhongxiang Wang, and David Kaplan of the Massachusetts Institute of Technology used the Spitzer Space Telescope to survey the scene around a pulsar, the shrunken remains of an exploded star, and found a disk of debris expelled during the star's death throes. This dusty rubble could form, phoenix-like, into planets. The pulsar, named 4U 0142+61, is 13,000 light-years away in the constellation Cassiopeia. The team reported on its findings in the April 6, 2006 issue of *Nature*.

This discovery also helps to solve a mystery that unfolded in 1992, when Aleksander Wolszczan of Pennsylvania State University found three planets circling a pulsar called PSR B1257+12. Those pulsar planets, two the size of Earth, were the first planets of any type ever discovered outside our solar system. Scientists have since found indirect evidence that the pulsar planets evolved out of a disk of dusty debris, but, until now, nobody had directly detected this kind of disk.

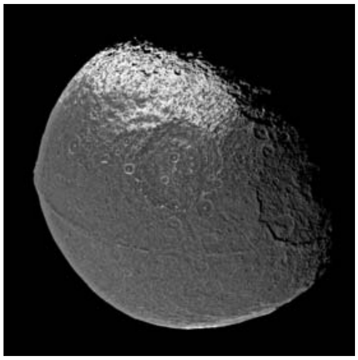
Any planets around stars that became pulsars would have been incinerated when the stars blew up. The pulsar disk seen by Spitzer might represent the first step in the formation of a new, more exotic type of planetary system, similar to the one found by Wolszczan in 1992.

"I find it very exciting to see direct evidence that the debris around a pulsar is capable of forming itself into a disk. This might be the beginning of a second generation of planets," Wolszczan said.
—from NASA/JPL/Caltech

Images of Saturn's rings returned by *Cassini* have revealed unusual propeller-shaped features suggesting that a new class of small moonlets resides there (see images at right). As many as 10 million of these objects could exist within one of Saturn's rings alone.

Cassini scientists found four faint, propeller-shaped double streaks in an otherwise bland part of the mid-A Ring, a bright section in Saturn's main rings. In their March 30, 2006

Surely the simplest explanation for Iapetus' "belly band" is that the dark material covering that hemisphere is extra thick at the equator. It seems to me this could have happened quite naturally if the moon had passed through a gravitationally flattened cloud of such material orbiting in the ring plane. The vast majority of the material would have fallen on Iapetus' equator, with only a thin scattering at higher latitudes. Have mission scientists considered this possibility?
—Gregory Kusnick
Seattle, Washington



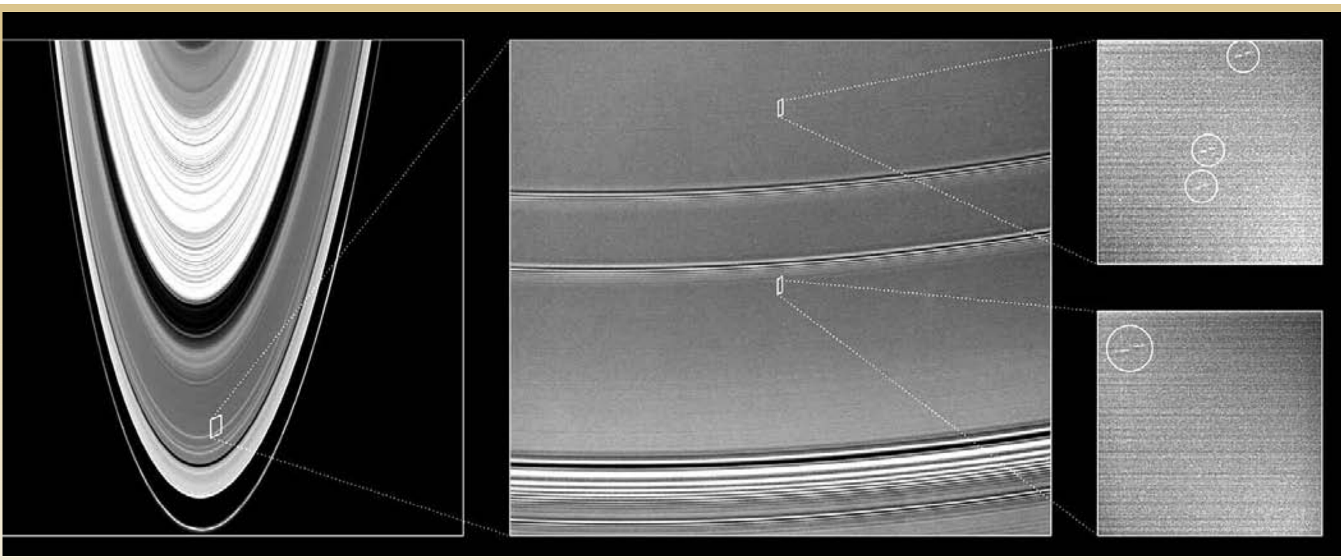
The origin of that mysterious equatorial ridge, nicknamed the belly band, *on Saturn's moon Iapetus continues to puzzle scientists.* Cassini *took the four visible light images that compose this global view of Iapetus on New Year's Eve, 2004.* Image: NASA/JPL/Space Science Institute

The present orbit of Iapetus is very far from Saturn's Roche zone—where ring material can persist without coalescing into moonlets—and therefore Iapetus can't interact with such a finely flattened disk of material. The orbit of Iapetus is inclined as well, so an interaction with a flattened disk of material would not produce the fine ridge we see on its equator, unless that disk is improbably aligned with the orbit of Iapetus. Furthermore, at Iapetus' present location, it would take longer than the age of the solar system to flatten the cloud of material to the required width.

Therefore, considering such a scenario for the formation of the equatorial ridge implies that Iapetus was once in an equatorial orbit much closer to the rings of Saturn, and that this orbit would have been disrupted later. Such a disruption would, in any case, be necessary to produce the moon-ring interaction you suggest. I wrote a paper outlining such a suggestion in 2005 (see it at *http://arxiv.org/abs/astro-ph/0504653*).

The paper's referees pointed out some problems with the theory. The main problem is that there are no large satellites close to the present orbit of Iapetus that could insert it into its present orbit. Without gravitational interactions with such satellites, it would be very difficult to raise the perisaturnium of Iapetus to its present location. Furthermore, it is not clear that in a collision between Iapetus and a ring, the material would accumulate into a ridge. The impacts could have the opposite effect and erode the region near the equator instead.

It might be impossible to prove or disprove orbital migration theories, because we can't be sure about the state of Saturn's satellite system in the remote past. The second question (what happens when a satellite collides with a ring) is perhaps the more interesting of the two; it has not been thoroughly investigated to date. It definitely is a question that can and should be studied.
—PAULO C. FREIRE,
Arecibo Observatory



These three images show the location and scale of the propeller-shaped features in Saturn's A ring. The recently detected features reside in an otherwise bland region of the mid-A ring. Cassini *imaging scientists believe these "propellers" (circled at far right) provide the first direct observation of the dynamical effects of moonlets about 100 meters in diameter. The moonlets lie in the center of each propeller structure.*
Images: NASA/JPL/Space Science Institute

report on the discovery in *Nature*, the researchers said they believe the "propellers" provide the first direct observation of how moonlets of this size affect nearby particles. *Cassini* took the images as it slipped into Saturn orbit on July 1, 2004.

Scientists knew about two larger embedded ring moons such as 30-kilometer-wide (19-mile-wide) Pan and 7-kilometer-wide (4-mile-wide) Daphnis, but the latest findings provide the first evidence of objects of about 100 meters in diameter. "The discovery of these intermediate-sized bodies tells us that Pan and Daphnis are probably just the largest members of the ring population, rather than interlopers from somewhere else," said Matthew Tiscareno of Cornell University and lead author of the *Nature* paper.
—from NASA/JPL/Space Science Institute

Society News

Planetary Radio: The Word Is Out!

The Planetary Society's audio coverage of space exploration has expanded at lightspeed over the last year. More than 75 public radio stations have added the weekly program to their schedules, with more picking it up every week. Listeners also catch the series directly from Earth orbit via XM Satellite Radio. Planetary Radio is in the middle of its second year with this industry leader, which enjoys a fast-growing base of nearly 7 million subscribers.

Each new show can be downloaded from our website, *planetary.org/radio*, but thousands of listeners seem to prefer the convenience of the Planetary Radio podcast. Apple iTunes announced that the half-hour of news, information, interviews, special event coverage, and good clean space fun is one of the most popular science programs in its podcast directory.

Join Emily Lakdawalla, Bruce Betts, host Mat Kaplan, and special guests on their next audio outing.

—Mat Kaplan, Planetary Radio Producer and Host

Create an Enduring Legacy

As you plan your estate, remember that your gift to The Planetary Society can help shape the future of space exploration.

Contact Andrea Carroll, Director of Development, at *andrea.carroll@planetary.org* or (626) 793-5100, extension 214 to learn more about planned giving or to let us know you have included The Planetary Society in your estate plans.

—Andrea Carroll, Director of Development

You Make It Happen!

Who just made possible Earth's first observatory dedicated solely to the optical search for extraterrestrial intelligence?

You—our Planetary Society members around the world. Thank you!

Members, including those of the New Millennium Committee and the Discovery Team, provided the crucial funding that took The Planetary Society's Optical SETI Telescope located in Harvard, Massachusetts from dream to reality. With this new telescope, you are helping to lead the search for extraterrestrial intelligence. (For more information about the telescope, read this issue's "We Make It Happen!" starting on page 4.)

On April 11, 2006, we joined with Harvard University physicist Paul Horowitz and his SETI group to dedicate the observatory. We presented Paul with a plaque that will hang at the observatory. The plaque thanks you—our members. It also thanks two of our members in particular whose major donations enabled us to get this project up and running. Stay tuned for future announcements of member tours to the telescope.

The Planetary Society Optical SETI Telescope is just one more example of what you make possible with your generous support of The Planetary Society. Let us know if you'd like to support this or other Society projects with a major donation or a planned gift. Contact Andrea Carroll at *andrea.carroll@planetary.org* or (626) 793-5100, extension 214.

—Andrea Carroll, Director of Development

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This otherworldly landscape was inspired by the childhood rhyme, "Red sky at morning, sailor take warning/Red sky at night, sailor's delight." *Red in the Morning* depicts the onset of a violently stormy day on an extrasolar planet that looks—except for its two moons—much like our own.

Julie Rodriguez Jones reconnected with two of her first loves—art and astronomy—after a 33-year career at the Lawrence Berkeley National Laboratory. Her artwork is now exhibited around the country and internationally, and she has received many awards and honors for both her astronomical art and her paintings of flowers.

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