The PLANETARY REPORT

Volume XXVII Number 3 May/June 2007

Examining Mars

From The Editor

I admit it—I'm not objective about SETI@home. My feelings for this scientific research project are close to maternal.

When David Anderson and Dan Werthimer, the project's leaders, came to us with their proposal, not everyone here could see what to me was glaringly obvious: even if it was audacious and revolutionary, SETI@home could involve the public in scientific research on the widest scale ever.

So, when the response was leaning toward "No," I declared that "No" was not an appropriate answer, twisted arms every which way, and with a few stout-hearted cohorts found the start-up money. The SETI@home project now acknowledges The Planetary Society's role by calling our group its "founding sponsor."

Of course, when all this started, we had no inkling of how big SETI@home could get, guessing that maybe a few hundred thousand people would volunteer their personal computers to search for a sign of extraterrestrial intelligence—which shows you can sometimes set your expectations far too low. More than 5.5 million people signed up for SETI@home—public participation beyond our wildest dreams.

Now we're seeing another spectacular return on investment in the form of spin-offs. When undertaking any project, one can hope for but not count on spin-offs. Once again, SETI@home exceeded any reasonable expectation. In this issue, you'll read how SETI@home spawned research projects around the world that are now seeking cures for cancer, modeling climate change, and in many other ways working to improve life on Earth.

And The Planetary Society made it happen. We can all be proud.

—Charlene M. Anderson

On the Cover:

The Mars Exploration Rovers, *Spirit* and *Opportunity*, were designed to last three months on the surface of the Red Planet. Three years and more than 180,000 images of Mars later, these hardworking robotic explorers are still making thrilling discoveries. *Opportunity*'s Panoramic Camera (Pancam) imaged these sand dunes at the bottom of Endurance crater on sol (Martian day) 211. Some of these dunes are more than a meter tall from crest to trough. The image is processed in false color for mineral analysis. Image: NASA/JPL/Cornell University

Background:

Once the Mars Exploration Rover *Opportunity* finished exploring Endurance crater, it drove south to examine how the discarded heat shield it had used during landing had weathered. Next to the heat shield was a rock—the only one for kilometers around. *Opportunity* determined it to be an iron meteorite, and although *Spirit* has found two others since then, this is the first meteorite ever discovered on another planet. Image: NASA/JPL/Cornell University

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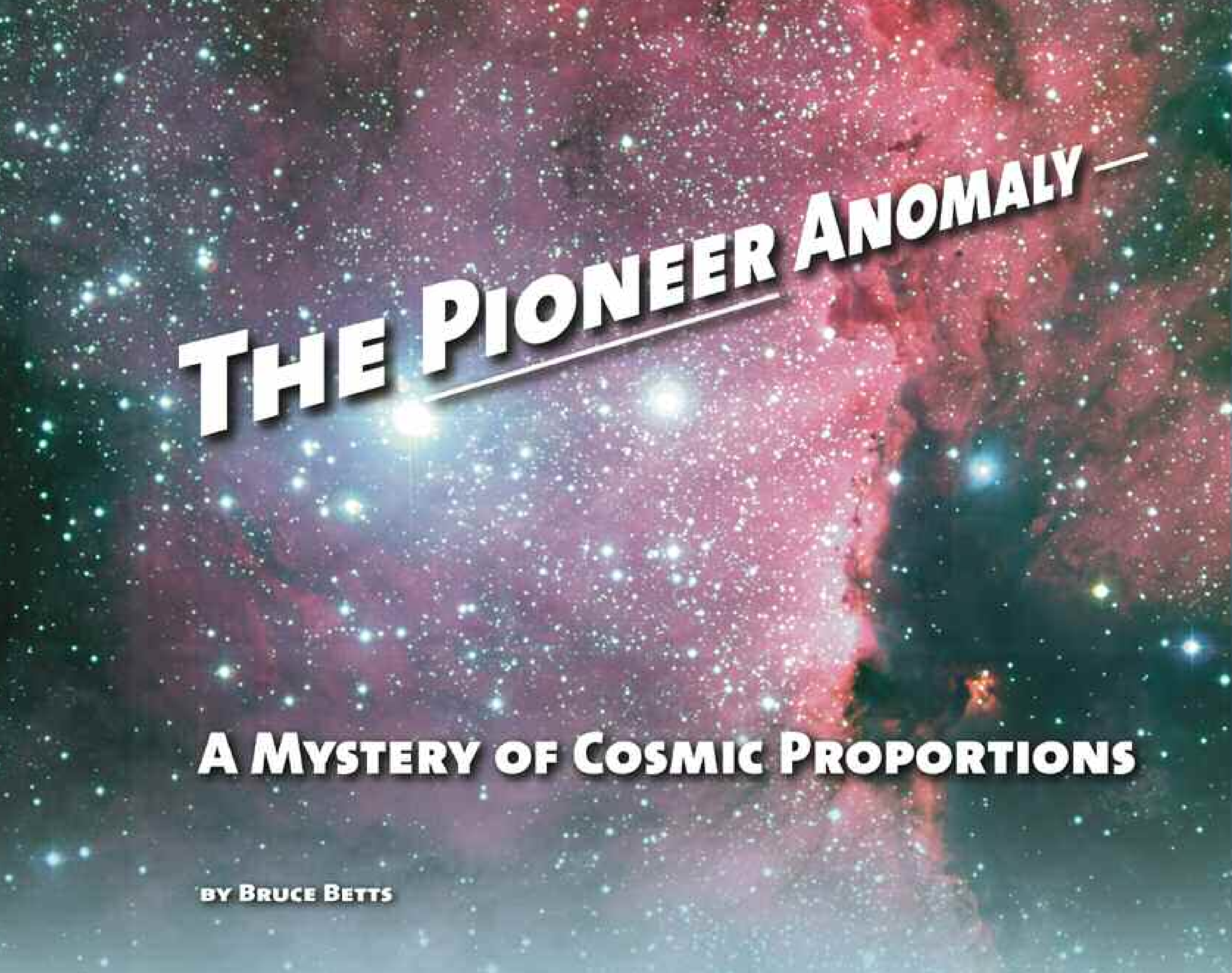


The Pioneer Anomaly—

A Mystery of Cosmic Proportions

by Bruce Betts

No one noticed the clues at first. Then, scientists began to notice that things just weren't right for two Earth spacecraft visiting a dark and nearly deserted neighborhood of the solar system—mysteriously, the spacecraft were slowing down. What cosmic perpetrator was behind this dark deed? To help solve the mystery, Planetary Society members and supporters have helped turn up and preserve more evidence that may lead to the discovery of an everyday answer to this deep space detective story—or may point a finger at a gravitational kingpin never before suspected.

The *Pioneer* anomaly—the slowing of the *Pioneer 10* and *Pioneer 11* spacecraft relative to what would be expected from basic gravitational physics—has turned into a physics detective story. Will it have a surprise ending? We don't know yet, but we are closer to finding out.

What was needed first was more evidence, and Planetary Society members came to the rescue when data from the *Pioneer* spacecraft were in danger of destruction. The next obstacle was that of dealing with 30 years of data collected during a period when computer technology transitioned from punch cards to mainframes to PCs. That has turned out to be a challenging and time-consuming, but surmountable, task. Below is an update on the status of the data recovery and the mystery that is the *Pioneer* anomaly.

A Cold Case

Until The Planetary Society got involved with Slava Turyshev and John Anderson from the Jet Propulsion Laboratory, analysis of the *Pioneer* anomaly was performed with just 11.5 years of *Pioneer 10* data, covering heliocentric distances from 40 to 70 AU (1 AU is the mean distance of Earth from the Sun, about 150 million kilometers or 93 million miles), and with only 3.75 years of *Pioneer 11* data for heliocentric distances from about 20 to 32 AU. For the analysis, researchers used Doppler data—velocity data derived from the Doppler shift of the received frequency of the *Pioneer* signal.

The *Pioneer* anomaly effect is very small, but it is big enough to be well within measurement limits and in fact has now been confirmed by seven independent groups using that original set of data. Its cause, however, remains a cosmic mystery. Is it some aspect of the spacecraft (for instance, heat radiating preferentially in one direction)? Or, less likely but a real possibility with more profound implications, could it be some new subtlety in our understanding of physics? To even begin work on solving the mystery, more data were needed for analyses.

Saving the Evidence

The Planetary Society stepped in and funded the initial efforts to recover and validate as much *Pioneer* data as possible. The data recovered included not only the Doppler data but also information about the spacecraft themselves in what are called Master Data Records (MDRs). The MDRs include temperature measurements of many parts of the spacecraft taken over time, which will be critical to understanding if the anomaly has a thermal cause.

The Doppler data (about 650 files for each spacecraft) were recovered from multiple locations—literally wherever they could be found. The recovery process included reading more than 400 old tapes with JPL navigational data that had been stored in boxes under a staircase, obtaining files held by individuals at JPL, tapping a JPL data archive, and getting files from the NSSDC (National Space Science Data Center). We now have almost 30 years of *Pioneer 10* data (for distances 4.2–82 AU) and 20 years of *Pioneer 11* data (for distances 1–33 AU).

Twists and Turns

In the process of validating the data (making sure it says what it is supposed to say and has not been corrupted), a number of significant challenges have arisen, but these are gradually being worked out. Most stem from the unique challenge of trying to look at data from more than 30 years of a space mission—an unprecedented task. During that time, not only did computers radically change, but so did programming languages, the Deep Space Network, and the people involved. Fortunately, on the last point, several individuals involved with *Pioneer* operations are also involved in the recovery effort.

Among the problems that needed to be discovered and then corrected are the following:

- In some of the files, an extra bit had been added at the end of each 8,044-bit "word." This happened because some of the files had been transferred between different kinds of computers.
- Some of the recovered data were incompatible with current navigation software architecture, leading to problems with radio band identifications.
- During some periods, the data showed the presence of an artifact due to inappropriate data handling.

In combination, these problems meant that experts had to look at each individual file, identify the particular problems associated with it, and make the appropriate fixes.

Picking Up the Trail

Our team has cleaned up many of the early *Pioneer 11* files, enough to begin analyzing them. Meanwhile, the rest of the *Pioneer* files are slowly being turned into useful files that can soon be used to determine the direction of the anomalous acceleration, its variation over time, and any effects near planetary encounters. As with any real mystery, the devil is usually in the details, and in this case, there are tens of thousands of details . . . at the very least.

Slava Turyshev reported on the progress of the *Pioneer* Doppler data retrieval and initial analysis during the Second Pioneer Explorer Collaboration meeting held in Bern, Switzerland in February 2007. The meeting was attended by 35 researchers from Germany, France, Italy, Norway, Portugal, the Netherlands, Canada, and the United States.

Getting Warmer

One of the possible causes of the anomaly is asymmetric thermal radiation from the spacecraft resulting from the placement of the heat sources such as the Radioisotope Thermal Generator power sources and from objects such as the communication dish. Rough models had been constructed in the past, but now the MDRs and their temperature data are being used to create much more detailed models of the spacecraft. These will lead to a much better understanding of what contribution thermal radiation may be making to the *Pioneer* anomaly.

Thanks to Planetary Society members, we are many steps closer to catching the cosmic perpetrator behind the *Pioneer* anomaly mystery. More about the *Pioneer* anomaly as well as details on the data recovery and validation effort are on our website at *planetary.org/programs/projects/pioneer_anomaly/*.

Bruce Betts is director of projects at The Planetary Society.

Just after the launch of* Pioneer 10 *from Cape Canaveral, Florida on March 2, 1972, navigation team members Tony Liu (on the phone) and Phil Laing (reading printout) check out the first navigational data from the spacecraft. Note the punch cards on the desk. Photo: NASA/JPL

Background: Ara OB1, a star-forming region 4,000 light-years from Earth in the constellation Ara (the Altar). *Image: European Southern Observatory*

Searching for E.T. and the Cure for Cancer

The Planetary Society Helps Trigger a Computing Revolution

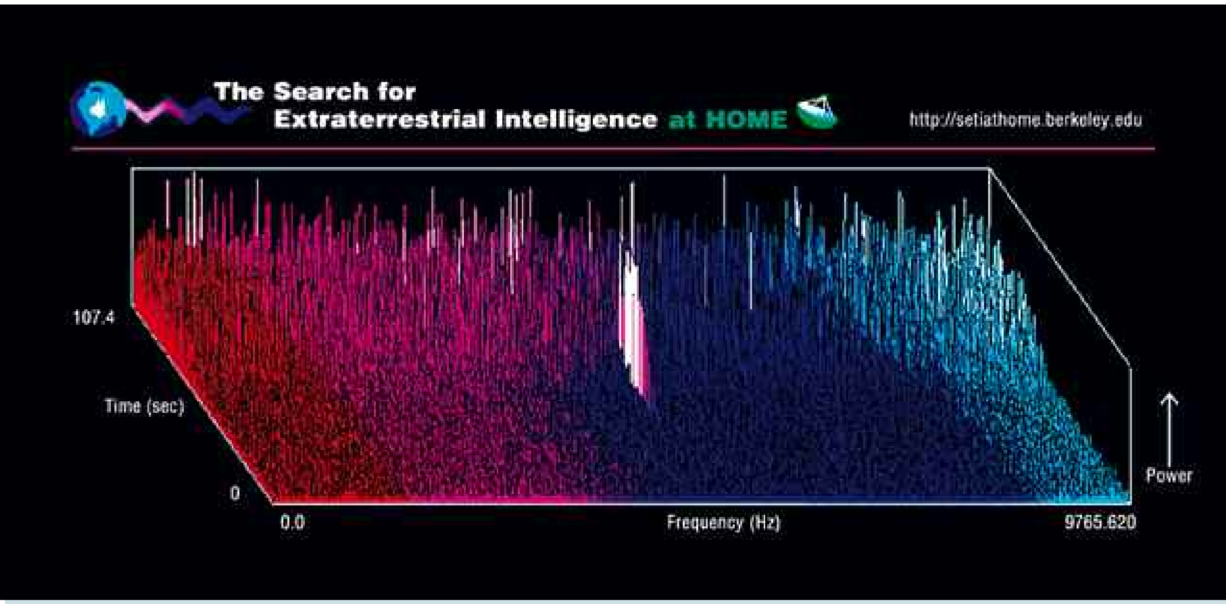
by Amir Alexander and Charlene M. Anderson

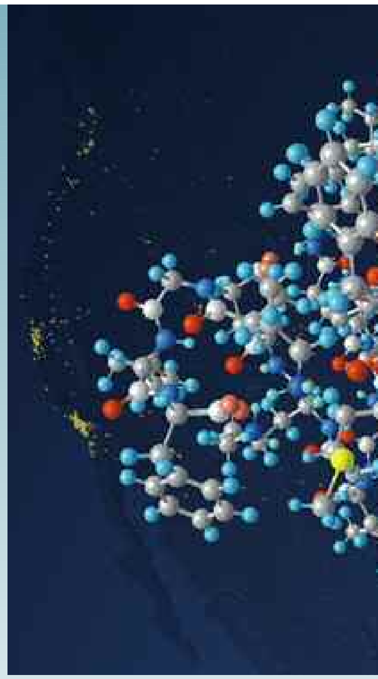
We couldn't say no to the opportunity: being part of an experiment in which members of the public could truly contribute to science and have a chance to make a world-changing discovery. That's what SETI@home promised when David Anderson and Dan Werthimer of UC Berkeley brought the project to The Planetary Society and asked for our help in getting it launched. With our members' support, we leaped on it, and nearly six million participants later, SETI@home is a landmark in the history of scientific computing.

A prime reason we supported SETI@home was the project's potential to advance the Search for Extraterrestrial Intelligence (SETI), an endeavor intimately connected to The Planetary Society since our founding. But there was more to it than that. SETI@home would also pioneer a new mode of computing, in which packets of data would be distributed among a network of personal computers, creating a virtual supercomputer that could dramatically decrease the money and time scientists spend on knotty calculations.

The potential for "spin-offs"—applications that serendipitously follow original research—was obvious from SETI@home's birth, but moving from potential to reality is never guaranteed. One can only hope. In the case of SETI@home, that hope has been realized spectacularly.

In applications ranging from British television to video game consoles, SETI@home spin-offs just keep coming.





This is the original, or "classic," screensaver for SETI@home, the computer-sharing program that launched a revolution in research technology. Now anyone can take part in the search for cures to major diseases or contribute to the understanding of Earth's climate, among many important research tasks. Scientists can crunch their data much faster and more easily thanks to the spare computing power of millions of volunteers' personal computers. SETI@home, the first program of this kind, was made possible in part by Planetary Society members. Image: The Planetary Society

Planetary Society members truly have helped pioneer new techniques in the conduct of science. Our initial investment has returned amazing results that will continue to deliver benefits over years to come.

A Computing Quandary

Scientists conducting complex research projects depend on computers to help them process the masses of data collected by modern instruments. Existing computer technology has constraints: large and fast computers are expensive, and processing time on the few existing supercomputers is scarce. Research groups vie for the precious time available on each machine. Furthermore, some of the most intriguing scientific riddles involve calculations so elaborate and complex that they require not hours or days but years or even decades of computing time to resolve. If science was to make full use of the computing revolution in SETI research, a different approach would be needed.

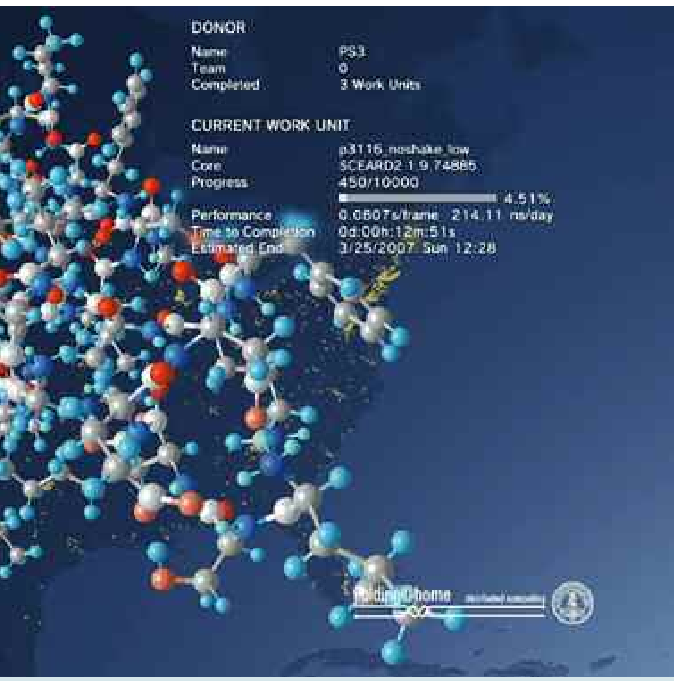
A solution arrived in unexpected form: the Internet. In the 1990s, millions of computers, isolated in offices and homes, became linked to one another through the magic of the World Wide Web. Suddenly, with the click of a mouse, users could instantaneously communicate across borders, continents, and oceans. Could this suddenly interconnected world make it possible for computers to join in pursuit of a scientific goal?

In 1995, in Berkeley, California, a group of scientists decided to find out. The idea, hatched by computer scientists David Anderson and David Gedye, along with SETI scientist Dan Werthimer, was brilliant in its simplicity. Most personal computers use only a fraction of their computing capacity, spending much of their time running screensavers. If those wasted processing CPUs and megabytes of computer memory could be harnessed to process the mass of data collected in the search for extraterrestrial intelligence, the resulting network would dwarf the computing power of the fastest supercomputer in existence.

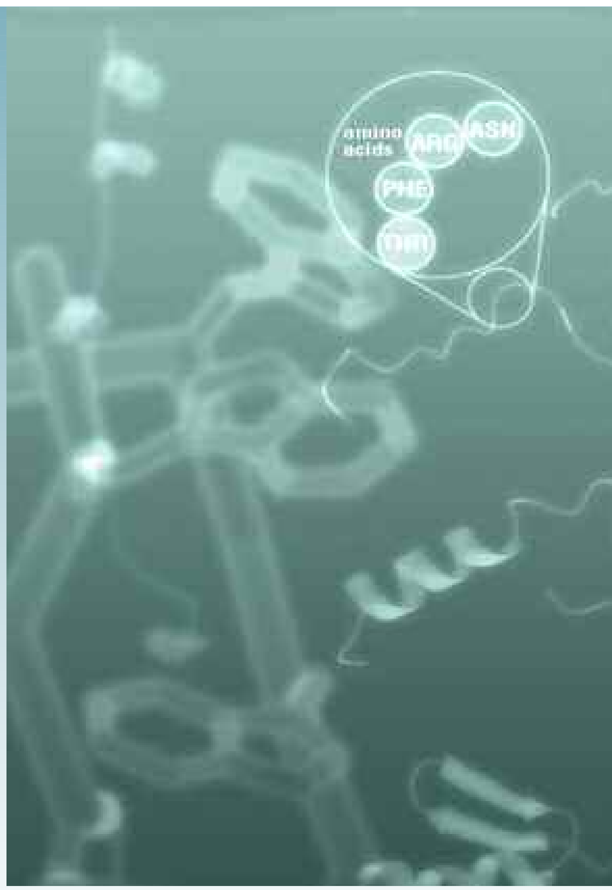
The Birth of Volunteer Computing

The idea was brilliant, but not one for which investors were willing to give money to develop. Anderson and Werthimer beat the bushes looking for startup funds, but aside from a few in-kind donations, no visionary sponsor stepped forward—until they called The Planetary Society. Using the Carl Sagan Fund for the Future and a donation from Paramount Pictures, we provided the first $100,000 needed to get the project under way.

And so SETI@home was born. Launched in 1999, it became an international sensation. Within a few months, millions of personal computers were displaying the dynamic power bar graphics that have become the iconic image of SETI@home. It was a startling success on a scale that even the most optimistic of SETI@home's founders never imagined. SETI@home users made possible the most sensitive search for extraterrestrial intelligence ever conducted; they also demonstrated the power and potential of volunteer computing. SETI@home became—by far—the largest and most powerful computer



The screen of Sony's PlayStation 3 shows the actual folding of a protein model in real time, as it is deciphered by the processor. The image is three-dimensional and can be viewed from any angle. The points of light on the map in the background show where PlayStation 3 units are currently running folding@home.
Image: Stanford University/folding@home



All proteins—the building blocks of life—are formed of long strings of amino acids, but to do their jobs, proteins cannot remain in these simple, necklace-like strands. These strings of amino acids have to "fold" into specific and complex shapes. In order to understand what causes certain diseases, researchers need to construct computer models of this folding process—an impossibly slow procedure until folding@home was developed.
Illustration: Stanford University/folding@home

network ever assembled, accomplishing within months calculations that normally would have taken decades.

Scientists in other fields quickly took note and searched for ways to take advantage of the remarkable resource. A Stanford University group trying to decipher the mysteries of protein folding thought their project was ideally suited for volunteer computing. Proteins are long strings of amino acids—the building blocks of life. To fulfill their functions, proteins cannot remain as simple strings, or "necklaces," but need to fold into specific and complex shapes. One of the most amazing mysteries of life is that proteins perform that task reliably, efficiently, and quickly. Modeling this process on the atomic scale proved to be one of the most difficult challenges of computational biology. Resolving it not only would help scientists better understand the processes of life but also could help fight some of the most crippling diseases afflicting humanity—Parkinson's, Alzheimer's, BSE ("mad cow disease"), and certain types of cancer.

The chief difficulty in simulating protein folding is time, explained Vijay S. Pande of Stanford University. Proteins fold on a time scale of microseconds (millionths of a second), but it takes an average computer about a day just to simulate the folding over a single nanosecond (one billionth of a second). At that rate, it would take almost three years to simulate a microsecond of folding and perhaps a decade or two of computer time to analyze the folding of a single protein. This is hardly a practical way to resolve the problem.

Then came SETI@home, and Pande and his colleagues took notice. Within a year, SETI@home had logged not a decade or two but millions of years of computer time. This kind of computing power would go far toward solving the difficulties in simulating protein folding. After a year designing their own volunteer computing platform, the Stanford group launched folding@home with spectacular results. Within two years, the project's first scientific publication appeared in *Nature*. Although much of the long road to curing disease still lies ahead, as of this writing, the project has resulted in the publication of 49 peer-reviewed articles in established scientific journals.

Folding@home has now reached beyond the community of PC users to volunteers in other regions of cyberspace. In late March, computer gamers using Sony's PlayStation 3 were given the chance to combine entertainment with scientific research by running folding@home on their machines. More than 100,000 users downloaded the folding@home software within two days after it became available, with around 35,000 participating at any given time. The powerful processors at the heart of the game consoles are designed to conduct extremely fast calculations, 10 to 50 times faster than an ordinary personal computer. Thus, although PlayStation 3 consoles account for only one fifth of machines running folding@home, they account for two thirds of the project's computing power.

The Birth of BOINC

Although both SETI@home and folding@home are highly successful and engage many thousands of people and machines around the world, the projects also exposed the limitations of the volunteer computing concept. Each research group, working separately, had to design its own project from scratch, write and test its own software, and purchase and maintain its own servers. This is a challenge even for computer scientists, not to mention for scientists in fields such as biology, physics, or medicine, who might have little knowledge of how to design and operate a computer network. Although both the Berkeley and the Stanford group succeeded in designing and maintaining their respective projects, as long as con ducting a volunteer computing experiment was in itself a major feat of engineering, not many scientists would follow this road.

David Anderson, project director of SETI@home, thought he had a solution. What if volunteer computing was made easy and user-friendly? Then many reluctant research groups could take advantage of its remarkable potential. With this idea in mind, and with the experience of operating SETI@home, Anderson founded the Berkeley Online Infrastructure for Network Computing, known by its catchy acronym, BOINC.

Some of BOINC's Most Popular Projects

Climate*prediction*.net
http://climateprediction.net

ABC@home
http://abcathome.com/

PrimeGrid
http://www.primegrid.com

Riesel Sieve
http://boinc.rieselsieve.com/

Chess960@home
http://www.chess960athome.org/alpha/

Rectilinear Crossing Number
http://dist.ist.tugraz.at/cape5/

SZTAKI Desktop Grid
http://szdg.lpds.sztaki.hu/szdg/

uFluids@home
http://www.ufluids.net/

Unlike SETI@home or folding@home, BOINC is not in itself a volunteer computing research project. It is, rather, an easy-to-use computer code available to anyone who wishes to launch such a project. With relatively minor modifications, the BOINC code can be used for projects in almost any field.

The project to lead the way in launching BOINC was SETI@home. In June 2004, users began downloading the BOINC version, which is more powerful and flexible than the original project. By the end of the year, SETI@home's transition to BOINC was complete, and the project's "classic" version shut down.

SETI@home's conversion was an important milestone because BOINC allows PC users to run more than one project easily on their machines. Any volunteer can, for example, decide to run SETI@home 70 percent of the time and a biology project the other 30 percent. As a result, SETI@home's legions of users are available for other BOINC projects that are just starting out.

Hurricanes are unique in their ability to produce both devastating winds and intense rainfall for hundreds of kilometers around the storm's center, making them some of the most destructive elements in nature. Although the jury is still out on whether climate change is responsible for an increase in hurricanes' number and ferocity, we definitely need improved climate prediction technology to better prepare for these dangerous storms. This image of hurricane Katrina, off the United States' Gulf Coast, was captured on August 28, 2005 by the GOES-12 satellite. Image: National Oceanic and Atmospheric Administration

Soon after, numerous other projects launched their own BOINC programs. Among them was predictor@home, run from the Scripps Research Institute in San Diego. Like folding@home, it investigates protein folding, but whereas the Stanford project attempts to determine the sequence of foldings over time, predictor@home focuses on the internal architecture of the folded protein. Two other BOINC projects use distributed computing to decipher the structure of proteins: Rosetta@home, out of the University of Washington, and Proteins@home, based at the Ecole Polytechnique in France.

Altogether, according to David Anderson, 40 different projects have now joined the BOINC family and use its brand of volunteer computing. Primegrid.com is a privately run mathematical project that searches for very large prime numbers and has already found more than 100 new primes. Einstein@home is based at the University of Wisconsin in Milwaukee and searches for pulsars in the sky based on data from the gravitational wave detectors LIGO and GEO. LHC@home simulates the Large Hadron Collider, a particle accelerator being built at the CERN facility in Geneva, the largest particle physics laboratory in the world. By simulating particles traveling through the accelerator, LHC@home helps with the extremely precise design required for the LHC.

Spinhenge@home
http://spin.fh-bielefeld.de/

SETI@home
http://setiathome.berkeley.edu/

Einstein@home
http://einstein.phys.uwm.edu/

Leiden Classical
http://boinc.gorlaeus.net/

Quantum Monte Carlo at Home
http://qah.uni-muenster.de/

LHC@home
http://lhcathome.cern.ch/

Tanpaku
http://issofty17.is.noda.tus.ac.jp/

Malariacontrol.net
http://www.malariacontrol.net

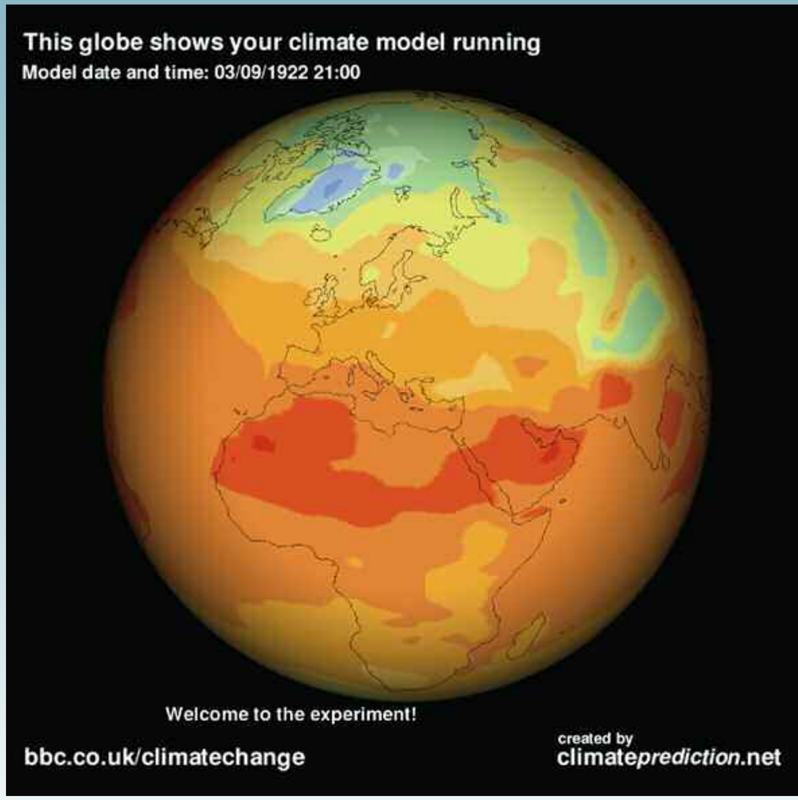
Predictor@home
http://predictor.scripps.edu

Proteins@Home
http://biology.polytechnique.fr/proteinsathome

World Community Grid
http://www.worldcommunitygrid.org/

SIMAP
http://boinc.bio.wzw.tum.de/boincsimap/

Rosetta@home
http://boinc.bakerlab.org/rosetta/



*These globes show examples of climate*prediction.net *screens running cloud (left) and temperature (right) models for February 9 and March 9, 1922* *Images: climate*prediction.*net*

The BBC Comes on Board

The most popular and high-profile project, except for SETI@home itself, is climate*prediction*.net, a BOINC project based at Oxford University and the Open University in the United Kingdom. As its name indicates, climate*prediction*.net investigates one of today's most pressing concerns for both science and public policy: Earth's future climate.

"It all began," explained Co-Principal Investigator Bob Spicer of the Open University, "in the late 1990s when Myles Allen of Oxford noticed the SETI@home screensaver on a colleague's computer." After the concept was explained to him, he began to wonder, "Would it be possible to model the Earth's climate in this way?"

It wasn't easy. Climate models are extremely complex, dividing Earth's surface into small square regions, then dividing these in turn into separate layers of the atmosphere. The model operates over time, taking into account such factors as the increasing effect of human-generated greenhouse gases that can heat up Earth and sulfur that cools the planet by blocking sunlight.

Then there's the effect of the oceans, which account for around 50 percent of any climate change. To further complicate things, the atmosphere and the oceans operate on different time scales: the atmosphere can respond to climate change factors in a matter of days, but the oceans can take centuries to change their patterns. All this makes for a very challenging computational exercise requiring the most advanced and fastest computational resources available.

In September 2003, Allen, Spicer, and their colleagues launched climate*prediction*.net. The first version was simplified and did not account for the oceans. It took on the easier problem of determining what effect a doubling of the amount of carbon dioxide (CO_2) in the atmosphere would have on Earth's climate. Even simplified, climate*prediction*.net was already doing better than competing models: by January 2005, when the first article appeared in *Nature*, climate*prediction*.net had run 2,570 simulations of Earth's climate, compared with only 127 by the supercomputer at the Met Office, the British government agency responsible for monitoring weather and climate.

In the second stage of the project, Oxford and the Open University were joined by a surprising new partner: the British Broadcasting Corporation (BBC). Eager to engage the public in the debate over climate change, the BBC was planning a series of documentaries on global warming and its effect, due to air in 2006. It offered to make climate*prediction*.net an integral part of its plans, promote it in its documentaries, and invite the public to take part. It was an offer that Allen, Spicer, and their colleagues could not pass up.

The new version of climate*prediction*.net, also known as "the BBC experiment," was far more complex than the earlier one. A realistic ocean was now an integral part of the model, and rather than compare distinct states (current levels of CO_2 vs. double those levels), the program followed the evolution of the climate by tracking the contributing factors. Unlike the early version, the new climate*prediction*.net was a member of the BOINC family.

The BBC, meanwhile, did its part. To inaugurate the project in February 2006, it aired an hour-long documentary, titled *Meltdown*, on climate change. The documentary invited people to take part in the BBC experiment, and the project was an overnight hit. Within 10 days of the airing of *Meltdown*, 100,000 people in 143 countries had downloaded the software and were running climate*prediction*.net on their computers. Within a month, that number had doubled.

According to Spicer, climate*prediction*.net demands far more of a computer than does SETI@home. A typical PC can process a SETI@home work unit in a few days, but completing a single climate*prediction*.net simulation could take months. Nevertheless, by the end of 2006, more than 50,000 simulations had been completed and sent back to the project's headquarters. To mark the completion of the BBC experiment, the network aired another documentary, titled *Climate Change: Britain Under Threat*, hosted by respected British broadcaster David Attenborough.

Although the BBC's involvement has ended for now, climate*prediction*.net is still going strong. Its ultimate goal is to run several million simulations to fully explore the effects of all 23 parameters included in the model. "This is genuine science that cannot be done any other way," said Spicer. "It uses a state-of-the-art model, and it feeds into an ongoing public debate."

The Future

SETI@home and climate*prediction*.net offer glimpses of the power and potential of volunteer computing. This technique is providing projects with enormous computing resources and connects science with the public in ways never before possible. Projects such as climate*prediction*.net, said Bob Spicer, "give members of the public a sense of ownership of a genuine scientific project, in which they fully participated." Volunteer computing is what makes it all possible.

Anderson is still looking for ways to improve volunteer computing, including expansion into the computer gaming world. Although he considers this a promising direction, most projects are not as compatible with game consoles as is folding@home. For example, climate*prediction*.net will never run on a PlayStation 3, Anderson explained, because it requires too much memory. Projects like SETI@home probably can run on a game console, though the improvement over conventional computers will likely not be as spectacular is it was for folding@home. Nevertheless, Anderson and his team are in discussions with Sony about launching a PlayStation 3 version of BOINC.

BOINC boasts 40 different distributed computing projects, but Anderson is far from satisfied. He has estimated that "ninety-nine percent of scientists who could profit from volunteer computing are only dimly aware of BOINC's existence." The reasons, he suggested, are not so different from those that prompted BOINC in the first place: scientists in other fields are rarely knowledgeable about computer science, and their IT (information technology) experts often want to retain control of a project, which is not always possible with this new approach. As a result, volunteer computing is rarely considered by researchers.

To overcome these barriers, Anderson is proposing what he calls "virtual campus supercomputing centers" in universities. They would be university-wide volunteer computing centers that would offer hosting services and technical advice to any research group in search of computing resources. The centers would seek out researchers who could make use of their services. A university could appeal to its alumni and ask them to contribute time on their computers to benefit the virtual computing center. Graduates eager to remain part of their alma mater's community and contribute to its scientific prowess would be happy to oblige.

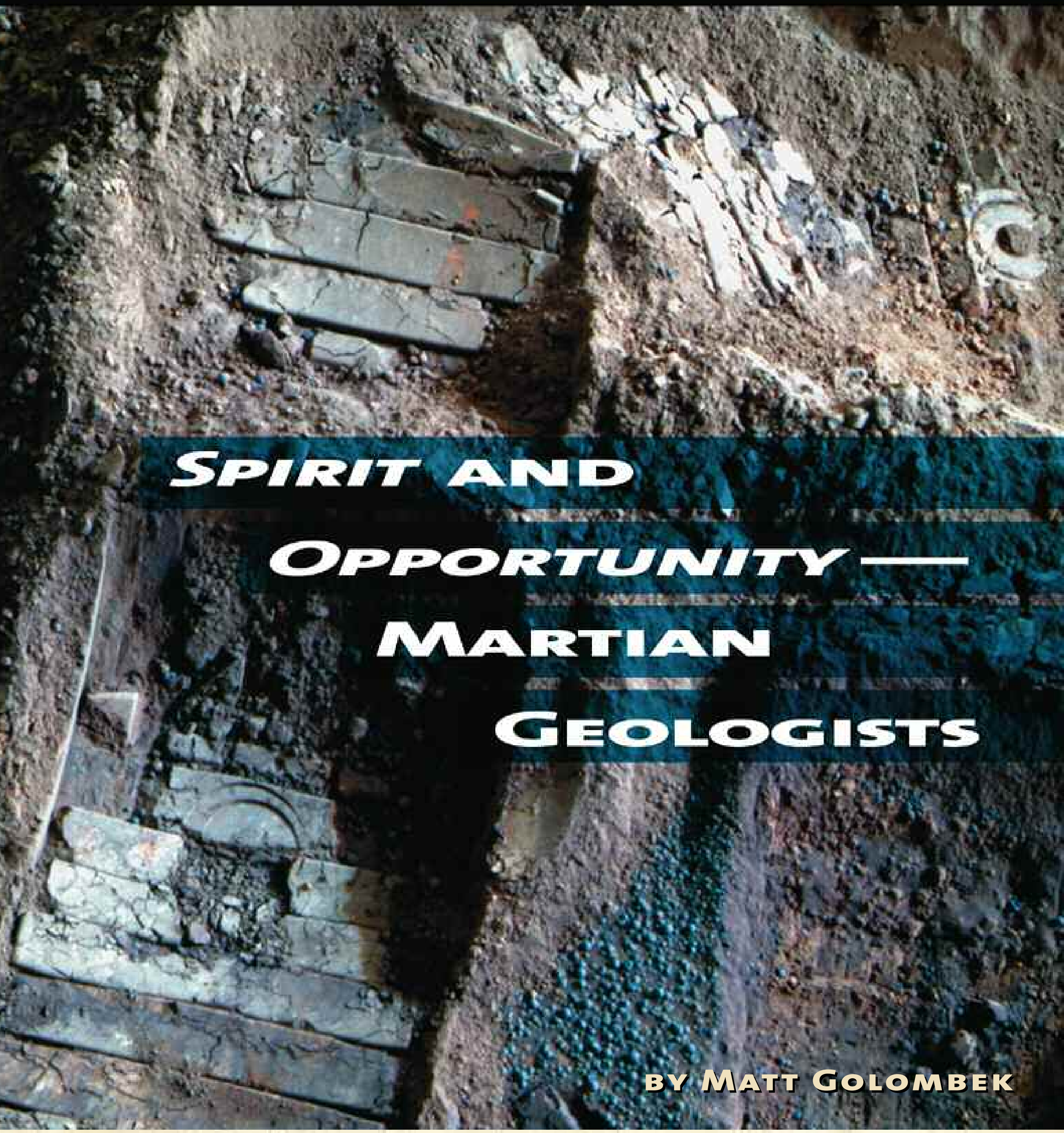
Anderson takes heart from the success of the "World Community Grid"—an IBM-run program that hosts and runs volunteer computing operations for selected scientific projects. In Anderson's vision, the virtual computing supercomputer center will do much the same but on a grander scale. In the future, he hopes, each university campus will have its own center. Somewhere down the line, Anderson believes, a tipping point will be reached, and distributed computing projects will become so common that they will always be considered as a viable option for complex and time-consuming calculations. Then the volunteer computing revolution will be complete.

What of SETI@home, the granddaddy of them all? Eight years after its launch and three years after its conversion to BOINC, the project is still going strong. With hundreds of thousands of users, it accounts for about half of BOINC volunteers. Nowadays, explains Chief Scientist Dan Werthimer, thanks to a new multi-beam receiver at Arecibo Observatory and the project's increased computing power, SETI@home is more powerful and more sensitive than ever before.

As ever more projects follow the path it blazed for volunteer computing and public participation in science, SETI@home continues patiently in its course, crunching data and seeking that signal from outer space. Somewhere in the vast globe-spanning SETI@home network, the elusive sign from E.T. could still be waiting to be discovered.

Was our investment worth it? How can anyone say no? SETI@home and its spin-offs demonstrate The Planetary Society's faith in the future and our belief that by pursuing discovery and understanding of the universe, we can make this small world of ours a better one. Be proud that you helped make it happen.

Amir Alexander is a writer and editor for the Society's website, planetary.org*, and Charlene M. Anderson is associate director of The Planetary Society.*



Spirit and Opportunity—Martian Geologists

By Matt Golombek

Spirit found Gusev crater's sm
Rover (MER) landing site sele
Some of these craters have s
by the science team. Sleepy H
meters in diameter. The dark
the dusty Martian surface du
like impact ejecta, and the a
sized grains have been remo
evidence of erosion or modifi

Left: *Meridiani Planum, near Mars'*
a relatively hazard free region but
posits of a coarse-grained form of
rarely forms in the absence of liqu
imaged at close range by Opportun
from orbit. At bottom center, a clus
wheel tracks in a trench south of E
left are imprints of the Mossbauer

No one was more eager than I was to see the first pictures of Mars' surface after the Mars Exploration Rovers (MERs) *Spirit* and *Opportunity* landed. I had spent the previous three years leading the effort to select safe and scientifically interesting landing sites, and I had specific predictions of how these sites' surfaces would look.

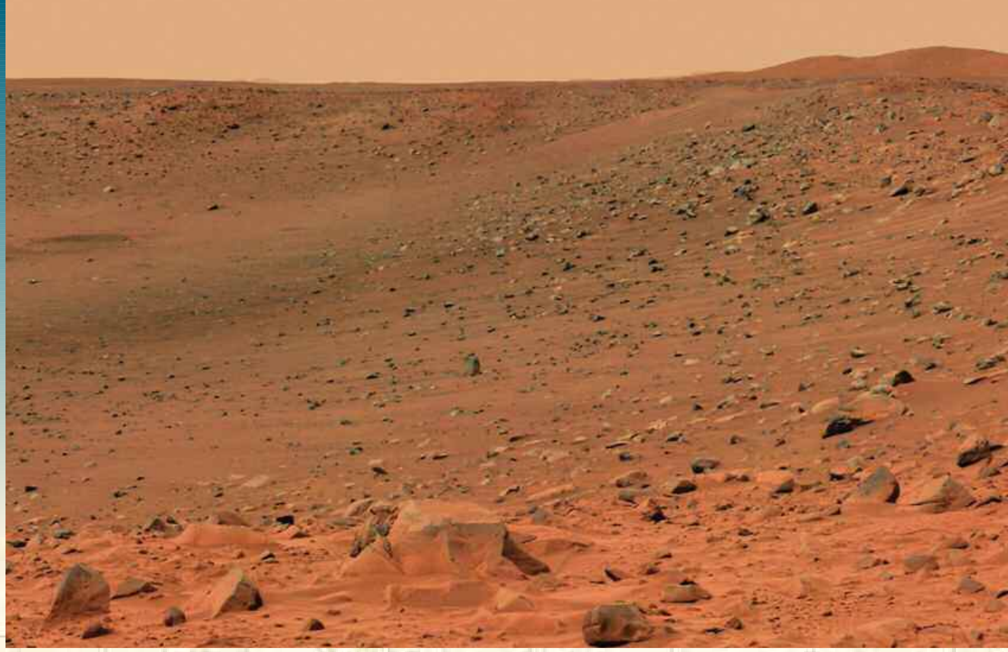
During *Spirit*'s landing on January 4, 2004, I was at the Jet Propulsion Laboratory, wired into a CNN TV reporter's booth, commenting on the landing and first images—but I had no video feed! So I was not one of the first to see the initial images that showed Gusev crater's smooth and dusty surface.

For the landing of *Opportunity* three weeks later, I again provided commentary for the media, but this time I had a tiny monitor in the TV booth to see the first image from Meridiani Planum. Even at its small size, I could see that the first image showed a dark, dust-free surface dominated by dark sand, with bright materials outcropping on the rim of Eagle crater. I expect few were happier than I was to see that both landing surfaces turned out to closely match the terrain our landing site selection team had predicted after exhaustive analysis of remote sensing data prior to landing.

We selected Gusev crater and Meridiani Planum because they appeared relatively safe for the MERs' landing via *Mars Pathfinder*–style airbags. Both also had strong morphological and mineralogical indicators of past liquid water, so they appeared to be good locations to address the science objectives of the MER mission: to determine the aqueous, climatic, and geologic history of sites on Mars where evidence of possible prebiotic or biotic processes might have been preserved.

One of our primary objectives was to look for evidence that liquid water ever flowed on the planet's surface. If Mars ever had water, it is possible that it once had life—and that possibility has raised numerous other conjectures and questions that we hoped to be better able to address.

mooth, flat plain to be very close to what the Mars Exploration
ction team had predicted—flat and peppered with impact craters.
ubsequently filled with soil and sediment and are called *hollows*
Hollow, the light-colored area close to the top of this view, is 20
spots on its floor were created when *Spirit*'s airbags bounced off
ring landing. The dark, angular rocks around Sleepy Hollow look
ea's pebble-rich surface is similar to a desert floor in which sand-
ved by the wind. Gusev's plains surprised the team by showing no
cation by liquid water. *All images: NASA/JPL-Caltech/Cornell University*



Spirit moved on to Bonneville, a relatively young crater (200 meters in diameter) whose dark walls are covered with crumbled, impact-generated basalt ejecta. Because the rover found no water-deposited rocks here either, the MER team pointed *Spirit* at the Columbia Hills (visible at upper right), an older, geologically different promontory about three kilometers (two miles) away. The highest visible peak is Husband Hill.

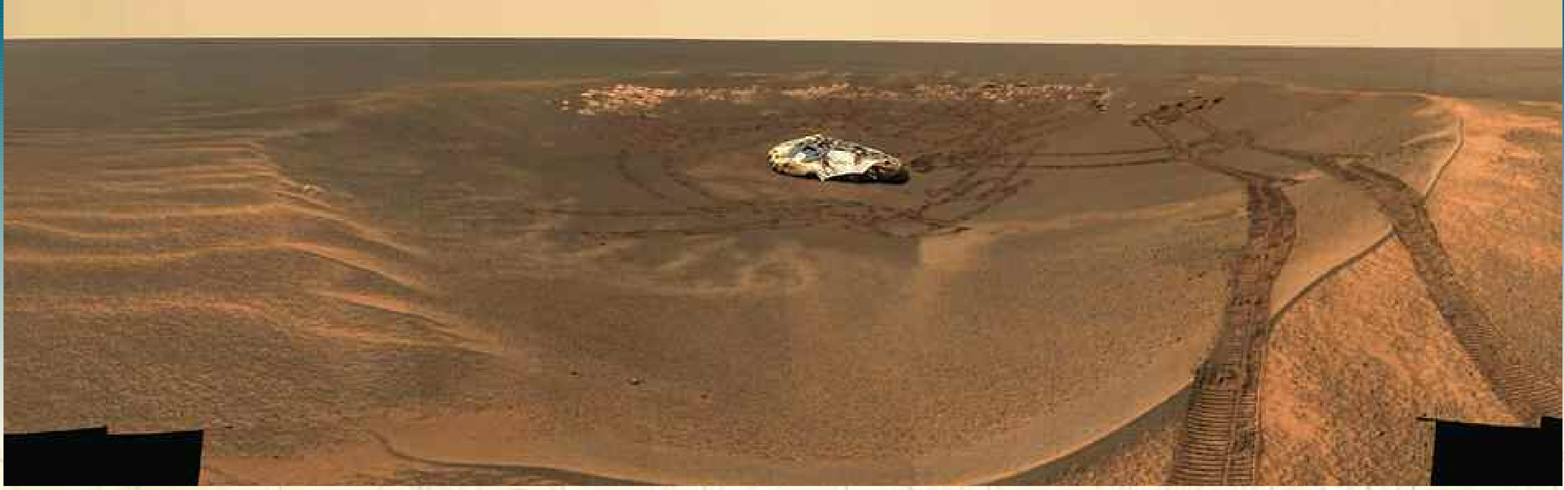
' equator, was chosen as *Opportunity*'s landing site not only because it was
also because observations from orbit showed strong evidence for large de-
the mineral hematite (Fe_2O_3). On Earth, hematite with such large crystals
id water. The little hematite balls (nicknamed "blueberries"), found and
nity, have been confirmed as the source of the hematite signature seen
ster of blueberries (about one millimeter in diameter each) sits between
Endurance crater. The circular imprints in the soil at upper right and lower
Spectrometer face plate.

The Columbia Hills (named in honor of the space shuttle *Columbia* and its crew), to the east of *Spirit*'s landing site, are very different from anything the rover had seen so far. Many of the rocks here are clastic (made of fragments of preexisting rocks), consistent with impact ejecta that has been highly altered by liquid water. On the way down from Husband Hill, *Spirit*'s Panoramic Camera (Pancam) took this false-color image looking down on the "Inner Basin." *Spirit* traversed down the basalt-strewn surface to the 80-meter-diameter circular white deposit called "Home Plate" (at center) before wintering on a north-facing slope just to the top left. Highly vesicular (cavity-filled) basalt called *scoria* and finely bedded ash suggest that Home Plate is a tuff ring or small construct of volcanic ash.

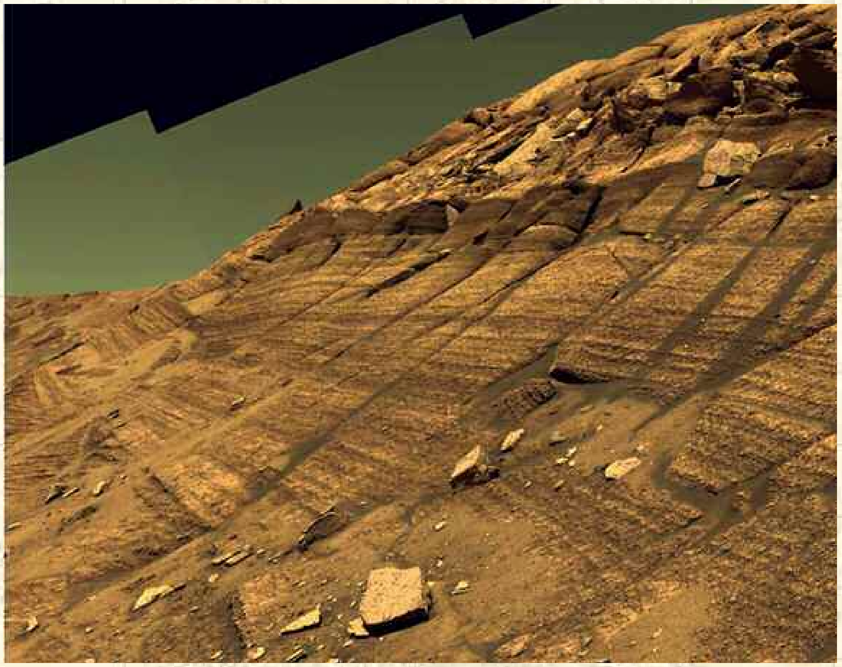
Mars-orbiting spacecraft had suggested that Meridiani Planum has possessed coarse-grained hematite that may have formed via precipitation from liquid water or hydrothermal alteration. The data also suggested that Gusev crater once was a crater lake with interior sediments deposited in water. Although we correctly predicted, from remote sensing data, the surface characteristics that were important for landing safety, our expectations of the geologic materials available for study at the sites were accurate only for Meridiani Planum.

Robotic Field Geologists

Since landing in January 2004, we've all gotten to know the rovers' two landing sites quite well. These mobile robots have been our field geologists—traversing more than 17 kilometers (10 miles) and examining the surroundings as they went. During their journeys, the hardworking rovers have returned compelling evidence that the early environment on Mars was wet and warm. So far the rovers have returned more than 28 giga-



Above: This view of Opportunity*'s lander sitting inside 22-meter Eagle crater is composed of images taken on sols 58-60, after the rover left the crater. The wheel tracks document the rover's exploration during the first two thirds of its nominal mission, when it focused on examining the outcrop at the far rim and the soils inside the crater.*



Right: Endurance, the largest crater close to Opportunity*'s landing site, offered the best chance for scientists to examine crater walls for evidence of outcrop.* Opportunity*'s Pancam took this color view of Burns Cliff inside the rim of Endurance crater on sols 287-294. Detailed stratigraphic analysis of this 10-meter-high rim showed the lower portion to consist of large, windblown cross-bedded layered deposits inclined to the layers above, overlain by a sand sheet (at center) and topped (upper right) by deposits of finely layered cross beds that would have been deposited by flowing surface waters.*

bits of new data, acquired more than 215,000 images and 12,000 thermal spectra, abraded and/or brushed more than 100 rocks, and obtained chemical and mineralogical measurements of hundreds of rocks and soil targets.

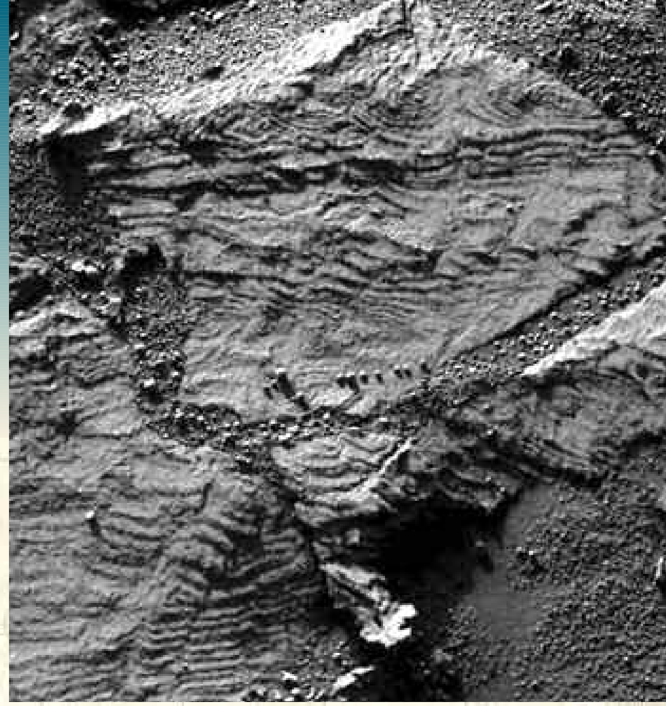
Each rover and its payload partly mimics a human field geologist, who uses his or her eyes and legs, a rock hammer, and a hand lens. With its color, stereo panoramic camera (Pancam) and the Miniature Thermal Emission Spectrometer in place of eyes, it can identify interesting targets and "walk" to those targets on its six wheels. The rovers also carry the Rock Abrasion Tool (RAT), which can brush and grind away the outer layer of rocks. After removing the outer weathering of a rock, each rover can place spectrometers and a Microscopic Imager that is equivalent to or even better than a geologist's hand lens against rock and soil targets. Based on what these devices reveal about the chemical composition, iron mineralogy, and rock texture, the rover can identify the rock type, which tells geologists about the environment and conditions in which the rock formed.

These robots and their human operators here on Earth have explored the Red Planet as never before. The teams surmounted the obstacles of a one-way light time delay of more than 10 minutes and a daily lag between planning observations and carrying them out. Researchers also battled the sheer exhaustion of living on "Mars time" during the first 90 days of the mission. (A Martian day, or sol, is slightly less than 40 minutes longer than Earth's day.) The difficulties of driving and taking measurements on a planet hundreds of millions of kilometers away and returning those data to Earth have been overcome by a committed and determined team of engineers and scientists who have missed remarkably few days over the course of a mission that has exceeded its designed lifetime (90 sols) by a factor of more than 10 (1,100 sols for each rover). Although expectations for the missions were very high before launch, the rovers have been wildly successful by any measure.

Spirit's Journey

In the first three months of the mission at Gusev crater, *Spirit* explored a flat, somewhat rocky plain peppered with impact craters and modified by windblown eolian materials (granules, sand, and dust). Most rocks in this area are dark, fine grained, and pitted. Rock chemistry and iron mineralogy indicate they are olivine basalts, a common volcanic rock that forms by partial melting of the mantle followed by rapid ascent through the crust, to solidify at or near the surface. Dust and soils of the area generally appear similar to soils and dust elsewhere on the planet, and they have collected in craters, called *hollows*, and sorted into wind-formed features such as ripples, drifts, and wind tails. Con-

In Erebus crater, almost four kilometers south of Endurance crater, Opportunity *found finely laminated cuspate cross beds, which again indicated that water once flowed over the surface. This color mosaic of the bright sulfate-rich Olympia outcrop, along Erebus' highly eroded northwestern edge, was acquired on sol 634. Dark basalt sand fills in the cracks around the rocks and has collected in large ripples at upper right.*



Opportunity*'s Pancam also found desiccation cracks in the Olympia outcrop. These cracks indicate periods of drying during the deposition of sulfate-rich rocks. This view of the rock Overgaard shows a finely layered sulfate rock 20 centimeters (about 8 inches) wide with basalt sand and blueberries around it. Layers at the top of the rock are small "festoon" or cuspate cross beds that indicate deposition in flowing water. Angled cracks between layers in the lower part of the rock appear to be shrinkage cracks that formed during the dry periods.*

trary to our expectations, the cratered plains offer no evidence of fluvial or lake processes inside Gusev crater.

Even with *Spirit* at the rim of the relatively fresh Bonneville crater, images revealed a regolith of impact-generated basalt blocks. Given that we found no rocks deposited by water, the science team made the difficult decision to use the rest of the nominal mission (90 sols) to drive across the cratered plains to the nearest location with different material, the Columbia Hills, which is a promontory of older material about three kilometers (two miles) away. Without mobility, it would have been impossible for *Spirit* to have addressed its crucial scientific objective of understanding the role of water in modifying Mars' crust.

After the long traverse across the basaltic cratered plains, *Spirit* reached the West Spur of Husband Hill on sol 156 and began climbing the Columbia Hills. We found that rocks in the Columbia Hills are very different from those of the plains; some outcrops are massive, others are layered, and most have been altered and deeply weathered. Many of the rocks in this area have clastic textures—rock fragments broken from preexisting rock by weathering—of varying composition and mineralogy. Some rocks appear to be relatively unaltered, but most show very high contents of sulfur, phosphorus, and chlorine, suggesting a high degree of aqueous alteration. These rocks are much softer than the plains basalts. Researchers believe them to be mixtures of materials formed by impacts or explosive volcanic eruptions and then subsequently altered by fluids.

We also found loose, fine-grained basaltic rocks on the hills, but their compositions are distinct from the plains basalts, and they exhibit only limited signs of alteration by water. We encountered olivine-rich rocks on the way down from the hills into the inner basin, where *Spirit* traversed an area containing highly vesicular rocks (scoria), to Home Plate, tentatively interpreted as a small volcanic construct formed of ash. Now that Martian winter is over, *Spirit* is continuing to study the rich suite of interesting geologic formations in the inner basin.

Based on the density of craters on the plains where *Spirit* landed and correlations with impact rates on the Moon, where samples have been radiometrically dated, we estimate the cratered plains to be roughly 3.5 billion years old. Because the cratered plains show no evidence of erosion or major modification by liquid water, *Spirit*'s results suggest that the aqueous processes that modified rocks in the Columbia Hills occurred more than 3.5 billion years ago. Since then, the climate probably has been similar to the current dry and desiccating environment, in which liquid water is rarely stable on the surface and surface modification occurs by slow wind processes.

Opportunity's Explorations

Opportunity landed at Eagle crater and quickly returned detailed chemical, mineralogical, and morphological data of the light-colored, layered outcrop near its landing spot. Measurements made at Meridiani Planum during the first few months of the mission strongly supported an ancient salty and acid aqueous environment. Chemical analyses of rocks in the area show that they are rich in sulfur, with elevated amounts of bromine, a particularly water soluble element. *Opportunity* also detected iron minerals—including jarosite, an iron sulfate that forms in very acidic water—and small spherules, nicknamed "blueberries," that are predominantly hematite. The blueberries, which are iron concretions, are further support for past liquid water at this site. After the rock was deposited, water flowed through the rock and deposited the iron that formed these concretions.

Images from *Opportunity* show the rocks to be finely layered. Microscopic images reveal flat, thin voids, which suggest that minerals grew within the rocks and then were dissolved by water flowing through the rocks, leaving the voids we now see. The texture, morphology, and geometry of the bedding show small cross beds (scalloped layers at angles compared with the main layers) that indicate they were deposited in flowing surface water.

After exploring Eagle crater, *Opportunity* traveled about 800 meters east across Meridiani Planum to the larger (150-meter-diameter) Endurance crater. The rover encountered remarkably smooth and flat plains dominated by basaltic sand and hematite granule ripples. It found few outcroppings, which appear to be weak and easily eroded by the sand-blasting effect of the wind.

Endurance crater, the largest crater in the immediate vicinity of *Opportunity*'s landing site, offered the prospect of seeing exposures of outcrop on its walls. In a 10-meter-thick section on the inner rim of Endurance crater, we saw a lower unit of large cross-bedded wind-formed sand dunes overlaid by a middle sand sheet and topped by deposits of finely layered cross beds deposited in the past by flowing surface waters.

This assemblage of chemistry, mineralogy, and sedimentology is common in deposits on Earth that typically form in shallow, salty playas in hot environments where evaporated saltwater leaves behind deposits of salts and sulfates. Winds then extensively rework these deposits into sand dunes and sand sheets, and groundwater of varying chemistry further modifies the deposits. These geologic environments, called *sabkhas*, on Earth can be found in the Persian Gulf, the Gulf of California, and many closed inland basins.

After exploring Endurance crater, *Opportunity* drove south to investigate the heat shield it used during landing. Next to the heat shield, we noticed the only rock seen for kilometers on the plains. *Opportunity*'s investigation of this rock revealed it is a nickel iron meteorite—a very exciting finding, as it was our first discovery of a meteorite on another planet. (Since then, *Spirit* has discovered two others.)

Three kilometers south of Endurance crater, in nearby Erebus crater, *Opportunity* encountered finely laminated cross beds, again indicating past flowing water on the surface. It also found desiccation cracks, which indicate drying periods during deposition.

Opportunity is currently investigating the stratigraphy of the inner rim of Victoria crater, two kilometers (about a mile) south of Erebus. Victoria is approximately 700 meters in diameter and has a serrated rim with intriguing outcrops that *Opportunity* will study for quite some time.

A New Chapter in the Water Story

The rovers' explorations of the Columbia Hills and Meridiani Planum sulfates provide compelling evidence that water existed in the subsurface and occasionally on the surface of Mars in the ancient past. Mapping and measurement of crater densities in Meridiani Planum indicated that these rocks formed more than 3.7 billion years ago. Their composition and location suggest that the environment was warmer and wetter and had a thicker atmosphere at the time they formed. This conclusion is consistent with a variety of geomorphic indicators, such as valley networks, highly eroded and degraded craters and terrain, and layered sedimentary rocks.

Since that distant past, wind activity has dominated at Meridiani Planum and at Gusev crater. Data from both landing sites support a wet and, likely, warm environment prior to 3.7 billion years ago, followed by a major climatic change to the current dry and desiccating environment sometime between approximately 3.7 and 3.5 billion years ago.

The warm and wet environment that existed more than 3.7 billion years ago suggests that Mars was habitable at a time when life started on Earth. The earliest chemical evidence of life on the Earth is about 3.9 billion years old. The most important requirement for life is liquid water; however, the water at Meridiani may not have been particularly conducive to the appearance of early organisms because of its apparent high acidity.

The water-related findings of the rovers prompt compelling questions and conjectures. If liquid water was on the surface of Mars when life began on Earth, could life have started on Mars? Is it possible that life started on Mars earlier than on Earth, when it was more clement than Earth? Mars was subject to early, giant, and possibly sterilizing impacts. Is it possible that its life-forms were transported to Earth via meteorites ejected off the Martian surface? Will life begin anywhere that liquid water is stable, or is it a rare occurrence? Are we alone in the universe? Future landers and rovers in the Mars exploration program will gather the data to help answer these questions.

Matt Golombek is a senior research scientist and the Mars Exploration Program Landing Site Scientist at the Jet Propulsion Laboratory. He is a Science Operations Working Group Chair for the Mars Exploration Rovers and was the project scientist for Mars Pathfinder. *The work described here was carried out by the Mars Exploration Rover project at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.*

World Watch

by Louis D. Friedman

Washington, D.C.—In April, we took our Save Our Science campaign to the U.S. House of Representatives Appropriations Subcommittee on Commerce, Justice, Science, and Related Agencies. The subcommittee, which deals with the NASA budget, invited me to testify as an outside witness on NASA's funding.

Our message is being heard. Four members of the subcommittee attended the hearing—a marked increase over the usual one or two members who show up for such hearings. Representative John Culberson (R-TX) was there to reiterate his support for our proposal for a Europa exploration mission. Representative Adam Schiff (D-CA), whose district encompasses the Jet Propulsion Laboratory, was also present, as were Subcommittee Chair Alan Mollohan (D-WV) and Ranking Minority Member Rodney P. Frelinghuysen (R-NJ). They all spoke in favor of restoring some of the funds that had been cut from NASA's science budget.

In early April, Representative Mollohan joined his Senate counterpart, Senator Barbara Mikulski (D-MD), in a letter to NASA disagreeing with the agency's proposed operating plan for the remainder of 2007. They did not cite the previous science reductions but instead focused on new cuts that eliminate the lunar robotic program, which now will end after next year's launch of the *Lunar Reconnaissance Orbiter*. The administration's Vision for Space Exploration called for a series of robotic missions to prepare the way for human return to the Moon around 2020. Because Congress passed the 2007 budget at 2006 levels, NASA was forced to eliminate about $500 million in programs, among them the robotic lunar landers.

In The Planetary Society's statement to Congress—which you can read in full at *planetary.org/programs/projects/sos/*—we emphasize the contradictions between the Vision for Space Exploration as a guideline and its current implementation. Mars missions were eliminated, outer planets exploration was eliminated, the search for extrasolar planets was eliminated, and now the robotic lunar program is gone. The Vision may be in danger of becoming a rocket program with no destination.

We are interested in your comments. You can write to me with your thoughts at *worldwatch@planetary.org*.

The Moon—Japan may come in first in the "Back to the Moon Sweepstakes": it will be first to the launch pad with *Selene-1* in July or August. The Chinese have indicated they will not be ready to launch *Chang'E-1* before October, and India has predicted a mid-2008 launch for *Chandrayaan-1*. The U.S. *Lunar Reconnaissance Orbiter* is planned to launch in October 2008.

The Planetary Society is working with space agencies and international science organizations seeking to coordinate their lunar activities through the establishment of an International Lunar Decade.

Japan—*Hayabusa*, the intrepid Japanese spacecraft that touched down on asteroid Itokawa in late 2005, is now trying to return to Earth. The mission engineers have devised a trajectory that may allow the spacecraft to make it home, despite the fact that only one of four ion thrusters and one of three reaction wheels are now working. The spacecraft may or may not have collected a sample from Itokawa (see the January/February 2006 issue of *The Planetary Report*), but regardless of that, this mission has been an extraordinary engineering achievement that has yielded remarkable science results. *Hayabusa* has shown that even the solar system's tiniest worlds—Itokawa is less than 500 meters long—are dynamic places with complex geology.

Russia—Russia has accepted a hitchhiker on its planned *Phobos-Grunt* mission—a Chinese Mars orbiter, which will be China's first interplanetary spacecraft. *Phobos-Grunt* (*grunt* is the Russian word for soil) will fly to the Martian moon Phobos, pick up a soil sample, and return it to Earth. It is planned to launch in 2009, although there is some chance of delay until 2011.

The Planetary Society also hopes to hitch a ride on *Phobos-Grunt* with our Living Interplanetary Flight Experiment (LIFE), which would test if microbes can survive interplanetary spaceflight.

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

We Make It Happen!

by Bruce Betts

In 1997, the Society began offering Shoemaker Near Earth Objects (NEO) Grants in honor of planetary geologist Eugene Shoemaker, a pioneer in research on the role of impacts on Earth. To date, the Society has awarded 29 Shoemaker NEO Grants totaling more than $184,000 to observers around the world.

The purpose of the Shoemaker NEO Grant program is to increase follow-up and discovery of near-Earth objects by providing dedicated amateurs, observers in developing countries, and professional astronomers with seed funding to advance their programs. Many continue to discover NEOs, but some of the biggest contributions are in follow-up. If an NEO is discovered, we have no idea what its orbit is, and thus its potential danger to Earth, without many follow-up observations. Our winners use amazing observing setups to do that work, as well as to better characterize the NEOs.

2007 Grant Winners

In March 2007, The Planetary Society cosponsored the Planetary Defense Conference, held in Washington, D.C. Scientists and engineers from a variety of disciplines gathered for a week to discuss all aspects of NEOs, from detection to tracking to deflection. At the conference, The Planetary Society announced its newest round of Shoemaker NEO Grant winners. The observers and their projects were selected from a group of 23 proposals that the Society received from 11 countries on five continents. Here, we present the winners and what they will do with their grants.

Eric Allen from Quebec, Canada will automate the dome of a 0.4-meter telescope so it can be used robotically.

Robert Holmes, Jr. of the Astronomical Research Institute in Illinois will purchase a new CCD camera for use on the institute's 0.81-meter telescope to provide observations of NEOs at magnitudes fainter than 21.

Jean-Claude Pelle's observing location in Tahiti is not only enviable but also scientifically valuable, being in the Southern Hemisphere. Pelle will purchase a new CCD camera for a 0.4-meter telescope.

Donald P. Pray of the Carbuncle Hill Observatory in Rhode Island will upgrade and put back into service a 0.35-meter telescope and will focus on searching for binary asteroids.

Giovanni Sostero represents the Associazione Friulana di Astronomia e Meteorologia in Remanzacco, Udine, Italy. Sostero and his collaborators will purchase a computer to control the CCD camera on their 0.45-meter telescope, as well as a coma corrector and color filters.

Brian Warner of Palmer Divide Observatory in Colorado Springs, Colorado will use the grant to purchase an additional 0.4-meter telescope. He plans to use phase angle observations to measure the sizes of asteroids and better understand their surfaces.

Quanzhi Ye from Guangzhou, China is an 18-year-old college student and the principal investigator of the Lulin Sky Survey. Ye has been awarded a grant to purchase a laptop computer and software to run a 16-inch automated telescope in Taiwan.

Past Winners Rack Up the Stats

Our previous winners continue to be some of the most productive asteroid trackers in the world. Here are samples of some of their recent achievements.

Jana Ticha (2000), 1.06-meter KLENOT Telescope, Czech Republic: In the last five years, Jana's team has discovered three NEOs, obtained 11,225 astrometric (position) measurements of NEOs, confirmed 520 newly discovered NEOs, and recovered 16 NEOs, in addition to obtaining numerous cometary observations.

John Broughton (2002), Reedy Creek, Queensland, Australia: In 2006, John made two comet discoveries, two NEO discoveries, and numerous other observations as part of a survey. In addition, he further developed ScanTracker, a freely available occultation-coordinating software package.

James McGaha (2002), Grasslands and Sabino Canyon Observatories, Tucson, Arizona: In the last seven years, James has reported 5,676 astrometric measurements of NEOs. He has focused on faint and fast-moving objects, including 1,371 observations of newly discovered near-Earth asteroids as well as confirmation of 42 newly discovered comets.

Roy Tucker (2002), Tucson, Arizona: In 2006, Roy obtained 47,000 astrometric observations, including discovery observations of the "G" component of comet 73P/Schwassmann-Wachmann 3.

David Higgins (2005), Ngunnawal, Canberra, Australia:

David’s focus, in collaboration with others, has been on physical observations of asteroids. He has observed 45 objects, three of which were discovered to be binary asteroids.

Peter Birtwhistle (2005), Great Shefford Observatory, Berkshire, England: Extremely faint—magnitude +21—objects are routinely imaged thanks to Peter’s Shoemaker NEO Grant. In the last nine months, Peter has made 60 first confirmations of NEOs.

Our Team of Experts

We are fortunate to have an expert international advisory group to recommend candidates for grant awards. The advisory group includes Planetary Society NEO Grant Coordinator Daniel D. Durda of the Southwest Research Institute; Alan Harris, Space Sciences Institute; Petr Pravec, Ondrejov Observatory, Czech Republic; Tim Spahr, Harvard Smithsonian Center for Astrophysics-Minor Planet Center; and Duncan Steel, Australian Centre for Astrobiology and Ball Aerospace and Technologies Corporation.

The Planetary Society thanks all the grant winners, applicants, and reviewers for helping to create and maintain a vibrant and successful program! Find out more at *planetary.org/programs/projects/neo_grants/*.

Bruce Betts is director of projects at The Planetary Society.

What’s Up?

In the Sky—June and July

Venus dominates the early evening sky, looking like the brightest star in the west. Much dimmer Saturn, also in the western evening sky, grows closer to Venus in the sky until they are less than one degree apart on June 30 and July 1. Both planets get very low in the sky by the end of July. Jupiter rises in the east around sunset and sets around sunrise and looks like a very bright star. Reddish Mars gets higher in the predawn eastern sky during June and July and can be seen very near the Moon on July 9. Mercury is very low in the eastern predawn sky in late July.

Random Space Fact

Walter “Wally” Schirra, who recently passed away, was the only astronaut to fly in all three of the United States’ first human space programs: *Mercury*, *Gemini*, and *Apollo*.

Trivia Contest

Our January/February contest winners are Andrew and Judith McDaniel of Fairfax, Virginia. Congratulations!

The Question was: How many different astronauts lived on Skylab?
The Answer: Nine.

Try to win a free year’s Planetary Society membership and a Planetary Radio T-shirt by answering this question: ***Where in the solar system is the Hellas Basin, also known as Hellas Planitia?***

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, 2007. 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.*

Questions and Answers

On average, how long does a comet take to vaporize, or die out? Is anything left once it does? Have scientists identified any comets that are on their way out or that have expired completely?
—K. Milner
Kansas City, Missouri

In general, comets lose mass when their orbits bring them into the inner solar system. At heliocentric distances of less than 4 AU or so (1 AU is one astronomical unit, the distance between Earth and the Sun—150 million kilometers, or 93 million miles), solar radiation is strong enough to sublimate water ice and other frozen volatiles on or near the comet's surface. As this gas leaves the surface, it lofts dust grains, which are sculpted by gravity and solar radiation pressure into the beautiful dust and gas coma and tail we see from Earth.

We think of a comet's life span in terms of the number of times it has passed close to the Sun (perihelion). A typical comet—about 1 kilometer (0.6 mile) in diameter, in the Jupiter family, with a perihelion distance of 1 AU—is able to survive approximately 1,000 perihelion passages, or about 6,000 years. All comets are much older than this; gravitational perturbations of comets' orbits, most notably by the giant gas planets, have only recently brought the comets into the inner solar system.

We often see comets die by splitting. This can range from the complete disintegration of the nucleus (for example, 1999's comet LINEAR) to separation of major long-lived fragments with their own comas and tails (as in the case of comet 73P/Schwassmann-Wachmann 3). Surprisingly, there is clear evidence that splitting can occur at distances greater than 50 AU from the Sun. A comet has about a 1 in 500 chance of experiencing some sort of splitting event per perihelion passage.

Several hundred known asteroids have orbits that are indistinguishable from short-period comets, and we think that many of these are actually dead or dormant comets. Asteroid 3200 Phaethon was one of the first such objects discovered. Though it has been associated with the Geminid meteor shower, scientists have detected no cometary activity in spite of an orbit that brings it 0.14 AU from the Sun. Phaethon's low albedo and flat spectrum are also consistent with a cometary origin.

Comets with very low and/or sporadic activity might be good candidates for objects that are evolving into asteroids. Comet Wilson-Harrington was discovered in 1949 but has remained inactive since its recovery as an asteroid in 1979. Other low-activity comets include P/2004 TU12 and P/2006 HR30, both of which have exhibited extremely low dust production for their size and heliocentric distance.
—MICHAEL HICKS,
Jet Propulsion Laboratory

Comet McNaught decorates the night sky above Santiago, Chile on January 19, 2007. There are several hundred known asteroids that scientists think are, in fact, dead or dormant comets.
Photo: Stephane Guisard, www.astrosurf.com/sguisard

How thick is the ice on Europa? Has anyone determined how best to drill through it?
—Emer Smith
Altadena, California

The answer to your question has been elusive, and it is highly contentious among scientists. We believe this Jovian moon's icy surface is underlaid by a liquid water ocean within potential reach of terrestrial science. Knowing how thick Europa's ice layer is, and the best means to explore it, requires that we probe it in some way. Ideally, we would make these measurements with a seismometer or hydrophone, but because *Galileo* got no closer than 150 kilometers (93 miles) or so, we have no direct measurement of the ice and must rely on indirect geologic evidence. This usually involves observations of features, the formation of which depends on ice thickness. The answer is complicated further by the fact that Europa's ice shell may have changed thickness several times in the past.

Galileo observed three main features that relate to this question: cycloidal (curved) ridges, lenticulae, and impact craters. The formation of cycloidal ridges best matches the theory of tidal forces operating in a thin shell. How thin is a matter of debate, and it depends critically on the mechanical properties of the ice shell. Similarly, the formation of lenticulae (ovoid-shaped mounds 5 to 20 kilometers, or 3 to 12 miles, across) has been attributed to diapirism. Diapirism, which is seen on Earth, is a process by which layers of salt are squeezed up onto the surface, forming ovoid domes. This interpretation of lenticulae is controversial (but they certainly look that way to me!).

Diapirs can form only if the ice shell is at least 10 kilometers (6 miles) thick. Studies of impact craters (something I am very familiar with) lead to a similar conclusion. Craters on Europa should look like those on Ganymede, and the smaller ones do. Those larger than about 10 kilometers across differ severely from their counterparts on Ganymede. This indicates that the ice layer on Europa is much thinner than the one on Ganymede. The weight of geologic evidence implies that Europa's ice shell is 10 to 20 kilometers thick, but we will never know with certainty until we go back with a mission designed to answer this and other questions raised by *Galileo*'s findings.

Let's assume that the geologic evidence is correct. Penetrating 10 to 20 kilometers of solid ice is not simple. The deepest drill on Earth is only 12 kilometers (about 7 miles) long, and it took scores of support personnel several decades to bore through solid rock in the snowy north of Russia. An alternative would be to melt through the ice with a tethered, radiogenically powered robot. How one would maintain a tether wire 10 or more kilometers long is, well, not my department.

Our best bet would be to find a natural drill such as those that drill from above (very large impact craters) or from below (diapirs) and examine the material they excavate or uplift from the base of the shell. A lander at one of these targets would have the best chance of sampling some of the material in Europa's ocean.

—PAUL SCHENK,
Lunar and Planetary Institute

Factinos

For the first time, water has been identified in the atmosphere of an extrasolar planet (ESP). Travis Barman of Arizona's Lowell Observatory combined new theoretical models with previously published Hubble Space Telescope (HST) measurements to find strong evidence for water absorption in the atmosphere of planet HD 209458b. "We now know that water vapor exists in the atmosphere of one extrasolar planet, and there is good reason to believe that other extrasolar planets contain water vapor," said Barman.

The proximity of most ESPs to their parent star has made detecting water and other compounds difficult. Barman's discovery takes advantage of the fact that HD 209458b, as seen from Earth, passes directly in front of its star every three and a half days. As a planet passes in front of a star, its atmosphere blocks a different amount of the starlight at different wavelengths. The absorption by water in the atmosphere of a giant planet makes the planet appear larger across a specific part of the infrared spectrum compared with wavelengths in the visible spectrum.

Last year, Harvard University student Heather Knutson performed the analysis of visible and infrared HST data that Barman compared with his new models. This comparison led him to the identification of water absorption in a planet 150 light-years from Earth.

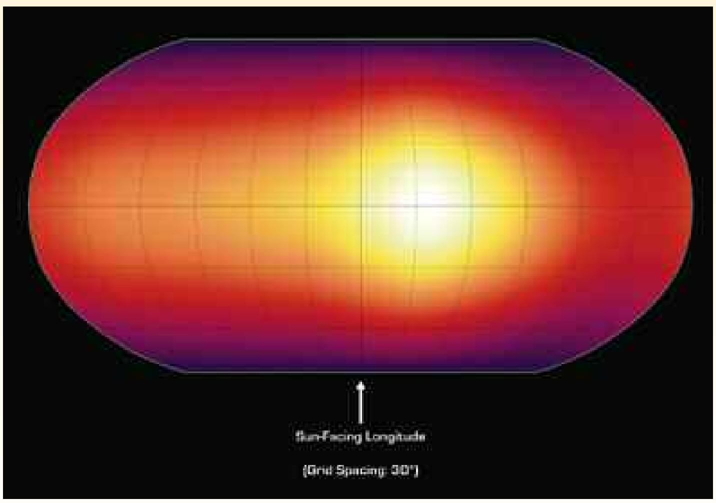
—from the Lowell Observatory

Scientists have created the first-ever surface map of a planet outside our solar system (see image below). The map, which shows temperature variations across the cloudy tops of a gas giant called HD 189733b, is made up of infrared data taken by NASA's Spitzer Space Telescope. Hotter temperatures are represented by brighter colors.

This newly mapped world is what is known as a "hot Jupiter." Gas planets like this orbit their stars at distances much closer than Mercury is to our Sun. Hot Jupiters also appear to be tidally locked to their stars (just as our Moon is to Earth), which means that one side of a hot Jupiter always faces its star.

The map reveals that the planet has a warmer spot on its "sunlit" side, which is always pointed toward its star. In spite of the warm spot, the map tells scientists that temperatures on HD 189733b are fairly even all around. Although the dark side is about 650 degrees Celsius (1,200 degrees Fahrenheit), the sunlit side is just a bit hotter at 930 degrees Celsius (1,700 degrees Fahrenheit). This mild temperature variation is evidence for strong winds that would help spread heat from the hot, sunlit side over to the dark side.

—from the Jet Propulsion Laboratory



Researchers using the Spitzer Space Telescope have mapped temperature variations over the entire surface of HD 189733b, a gas giant planet 60 light-years from Earth. This map, the first ever made of an extrasolar planet, reveals a bright "hot spot" on the side facing its parent star.

Map: NASA/JPL/Caltech/Harvard Smithsonian Center for Astrophysics

Society News

Save the Date!

Join us in New York City on Tuesday, October 19 to celebrate the next Space Age with our 2007 Awards Celebration: Science and Citizenship.

Cohosts Neil deGrasse Tyson and Bill Nye the Science Guy® will toast (and roast) the current state of scientific literacy and the history of the space program as part of an entertaining and enlightening evening program.

The public ceremony will culminate with awards to this year's recipients of the Cosmos Award for Outstanding Public Presentation of Science and the Thomas O. Paine Award for the Advancement of Human Exploration of Mars.

Stay tuned for more details about our winners!

A dessert and champagne reception will follow the awards ceremony. Proceeds from the reception will further the Society's efforts to create an international scientifically literate public.

For more information about the awards ceremony and reception, check our website at *planetary.org* or contact Andrea Carroll, Director of Development, at *andrea.carroll@planetary.org* or (626) 793-5100, extension 214.

—Andrea Carroll,
Director of Development

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—Monica Bosserman Lopez,
Marketing and Interactive Manager

Bill Nye Represents Society in India

Bill Nye the Science Guy® is representing The Planetary Society at the International Astronautical Congress (IAC) in Hyderabad, India in September. Bill will meet with the world's aerospace leaders, who gather annually at this meeting of the International Astronautical Federation. He will expound on the "passion, beauty, and joy (P, B, & J)" of planetary science—including the importance of understanding Earth as a planet.

He will also take part in the Space Generation Congress, held in conjunction with the IAC. The Society is working closely with a network of young professionals and students in a project to study future Moon-Mars exploration.

The Space Generation Advisory Council is seeking delegates from among young people worldwide for the annual Space Generation Congress. We encourage you to contact *www.explorerswanted.com* for more information.

We thank the Weissman Family Foundation for support of this project.

—Louis D. Friedman,
Executive Director

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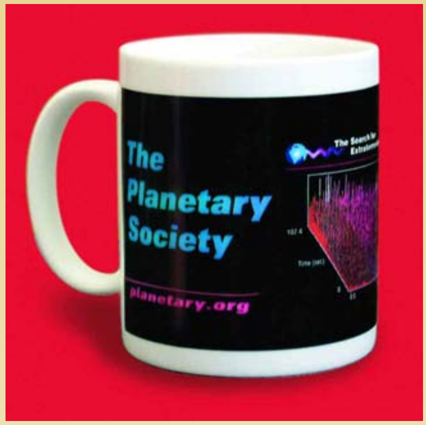

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The search for water and, with it, the search for life is one of the driving forces of planetary exploration. Frank Hettick's *Sister in the Clouds* exemplifies our hopes of finding water worlds like our own orbiting other stars. Frank describes his painting this way: "*Sister in the Clouds* is one of my earlier works—one that I just had to paint. It's a 'dreamy' fantasy piece that inspires feelings of tranquility in the viewer; but as astronomical art, it falls a bit short of being scientifically correct! The sea in the foreground should have much higher and rougher waves due to the tidal effects of this sister world's close orbit."

As a boy growing up in the 1950s, Frank Hettick was inspired by his discovery of Chesley Bonestell's visionary illustrations in *The Conquest of Space*, written by Willy Ley. He is now a member of the International Association of Astronomical Artists. In 2005, he won first place in The Planetary Society/European Space Agency art contest "Imagining Titan: Artists Peer Beneath the Veil." Frank's art can be experienced in person at his own Sky-High Gallery in Crooked River Ranch, Oregon.

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