The PLANETARY REPORT

Volume XXV Number 5 September/October 2005

Mars Analogs

A PUBLICATION OF THE PLANETARY SOCIETY

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From The Editor

The damage that Earth inflicts on her inhabitants—horribly demonstrated by Hurricane Katrina and the December tsunami—reminds us what fragile creatures we are, lucky to survive at all on this dynamic, dispassionate ball of rock hurtling through space.

Our exploration of other worlds has taught us that the potential for planetary catastrophe is always with us. On Mars, we've seen planet-rending gouges cut by catastrophic floods. Every world of rock and ice bears the scars of encounters with comets and asteroids.

Within the blink of an eye—geologically speaking—Earth will heal her shallow, insignificant wounds from wind and water, but the damage to her human inhabitants will linger for what is, to them, a very, very long time.

The question is raised: what can we do to prevent other, even greater, catastrophes? In New Orleans and around the Indian Ocean people are pursuing early warning systems and better means of flood control. Such things can and should be implemented. But we need also to look outward, into the solar system; for example, some potentially lethal rock may be heading for us now. A planetary perspective—that gift of the space age—can help us prepare for and possibly prevent an impact that could doom human civilization. This is what The Planetary Society works toward, even as we mourn our losses and look to the future.

—*Charlene M. Anderson*

On the Cover:

Though Chile's Atacama Desert is more thoroughly etched by past water than is the surface of Mars, it compares strikingly well with images from Mars at a variety of scales. This image of an intermountain drainage basin looks superficially similar to the walls and floor of Mars' Valles Marineris. Images: Jacek Wierzchos, University of Llieda (top) and ESA/DLR/FU Berlin (G. Neukum)

Contact Us

Mailing Address: The Planetary Society, 65 North Catalina Avenue, Pasadena, CA 91106-2301
General Calls: 626-793-5100
Sales Calls Only: 626-793-1675
E-mail: *tps@planetary.org*
World Wide Web: *http://planetary.org*

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Members' **Dialogue**

Try Saving *Voyager*

In both *The Planetary Report* ("World Watch" in May/June 2005) and in letters to the membership, Louis Friedman notes the threat of NASA shutting down the monitoring of *Voyager* and states that the amount of money saved will be "very small—millions."

If that is true, why don't we pass the hat and take the mission over from NASA? This was already done successfully in the case of SETI, which is now privately run. The Society's recent solar sail mission also involved raising millions of dollars.

It would be huge feather in The Planetary Society's cap to take over the *Voyager* mission's monitoring. Perhaps it could still be funded partly by the government—for example, via a direct grant from the National Science Foundation.

This country doesn't need another special interest group—which we are—clamoring for more money for its pet projects. If we believe in the value of *Voyager*'s remaining mission, we should put our money where our mouths are.

—JOHN CSEREP,
Valparaiso, Florida

It would be great if The Planetary Society could take over Voyager *operations, but there are two main problems with this idea. First, several million dollars are not easy for us to come by. Second, whoever operates the spacecraft requires the use of the unique tracking facilities of NASA's Deep Space Network (DSN).*

Our largest project ever was the $4 million solar sail, and the lion's share of the project's funding came from a major commercial sponsor. We hope to interest private sponsors in trying again with the solar sail. But raising private funds for space science and exploration has proved difficult. Nevertheless, we are open to trying, and if someone wants to fund Voyager *operations, we want to talk to them. Then we'll consider the question of the DSN.*

—Louis D. Friedman,
Executive Director

A Better Design

I've been following NASA's humans-in-space program since its inception, and what a bucket of problems it has been.

First and foremost, NASA exchanged Wernher von Braun's liquid-fueled Saturn 5 for the shuttle—a big mistake. Saturn 5 was the smoothest and most powerful rocket ever launched in the United States. Next, we Americans allowed politicians to replace a great rocket with a far lesser one. Those who controlled the shuttle's development went for quick and cheap. We've already lost 14 astronauts, proving that the shuttle is a poor design.

I want you to use your influence to the fullest to convince Washington and NASA that their next human orbiter must be designed and built far, far better than what we now have. They should get away from solid-fuel boosters. The strong vibration and shaking they cause while burning is most likely at the root of the insulation loss on the liquid-fuel tank. They need to go back to the multinozzle, liquid-fueled booster. This design puts the crew's compartment above the rocket, not right next to the explosive fuel.

—GRADY J. PADGETT,
Felton, California

Don't Drop the Ball

Now the "ball is in NASA's court" regarding setting the stage for the necessary steps to be taken to deflect asteroid 2004MN4 from ultimately hitting Earth (see "We Must Decide to Do It!" in the July/August 2005 issue of *The Planetary Report*). Isn't it still up to folks like you, other related groups, and scientists all over the world to press NASA and Congress to act on this situation and prevent them from "dropping the ball?"

As Rusty Schweickart pointed out, in an earthquake-induced tsunami, there is really no way to predict when this would occur. But regarding an asteroid of this kind hitting Earth, we know where the body is in its orbit, and we can calculate the timing of its passage to near 100 percent accuracy. So why not try to save this planet from such a hit, if we can possibly do it?

—MIKE MARTINEZ,
Hudson, Wisconsin

Errata:

Some of our July/August 2005 issues have an error on page 16 ("We Must Decide to Do It!"). The second photo caption should read "56 feet" instead of "56 miles."

In the author identification for that article, the year *Apollo 9* flew should be 1969.

—Editor

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

We Make It Happen!

Solar Sailing: The Story Isn't Over

On June 21, 2005, The Planetary Society attempted to fly the world's first solar sail to prove this never-before-tested space propulsion technology. But the launch vehicle failed, and our Cosmos 1 *spacecraft never got its chance. Here is the latest update from project director and Planetary Society Executive Director Louis Friedman.*
—Bruce Betts, Director of Projects

The End of *Cosmos 1*; The Beginning of the Next Chapter

by Louis D. Friedman

Cosmos 1 was—and is—a great effort, and one we are proud The Planetary Society tried to do. Our independent grassroots organization built and launched a spacecraft whose technology promises to one day open up interstellar travel. We shared the adventure of space exploration and captured the hearts of millions worldwide. To get as far as we did was—by itself—a great accomplishment, and The Planetary Society board, staff, and technical team, together with our partners at Cosmos Studios, are dedicated to trying again.

With our members' support, we are raising funds to build and fly another solar sail, and we are seeking new sponsors. We are evaluating technical options, and we are committed to finding a launch vehicle that won't fail us next time. Our Russian colleagues at the Lavochkin Association, who built *Cosmos 1*, and the Institute for Space Research (IKI), who were in charge of the electronics, are doing their best to help us, while taking into account the hardware, software, and intellectual investment we have already made.

We retain high confidence in our technical team because, as far as we know, our spacecraft would have worked. Nevertheless, we are taking a few months to do a "lessons learned" evaluation and put together a plan for our new attempt to fly the world's first solar sail spacecraft.

What's Up?

In the Sky

Mars, glowing orange, grows brighter through September and October until it gets closest to Earth on October 29 and 30. Though it is not as bright or close as it was in its 2003 close approach, this is still an excellent time to see the Red Planet. It will be brighter than the brightest star. It rises in the early evening in the east and sets near dawn in the west.

Venus is the brightest starlike object in the sky, in the west after sunset. Jupiter is below Venus during September and then slips behind the Sun. An annular solar eclipse on October 3 can be seen from northern Africa and southern Europe, and partially seen from the rest of Europe, Africa, and western Asia. A partial lunar eclipse on October 17 can be seen from areas in or bordering the Pacific.

Random Space Fact

In terms of diameter, Mars is about half the size of Earth and twice the size of the Moon.

Trivia Contest

Our May/June contest winner is Marvin "Chip" M. Sawyer, Jr. of Burlington, North Carolina. Congratulations!

The Question was: Comets often have two distinct, significant tails. What are these called?

The Answer: The dust tail and the ion tail.

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

Who discovered Saturn's moon Titan?

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 December 1, 2005. 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.*

Report on the Volna Failure and the Loss of *Cosmos 1*

We now have new information on what most likely happened to *Cosmos 1*. Although we do not know for certain, it looks like the spacecraft never separated from the rocket or made it to orbit.

The Volna rocket's first-stage shut down prematurely when its core engine turbo pump assembly malfunctioned. Telemetry data show that the assembly vibrated abnormally at a frequency consistent with its rotor failing. Earlier Volnas, although extremely reliable, had experienced similar problems. A design upgrade had been made on some Volnas to correct the problem.

Unfortunately, our rocket was not among those that were upgraded.

The final report from the Makeev Rocket Design Bureau, the Volna's manufacturer, describes telemetry covering just less than 6 minutes of flight over the Barents Sea. The main engine of the first stage stopped at 83 seconds, but steering engines (used for roll-pitch-yaw control) continued firing for an additional 50 seconds. At that point, the rocket had an altitude of 75 kilometers (45 miles). With its motors shut down, the rocket continued in parabolic free-flight, and about 5 minutes into the flight and at an altitude near 30 kilometers (18 miles), the data show deceleration from the atmosphere until, about 1 minute later, the rocket plunged into the sea.

The Makeev team concluded that the first-stage engine failure was random and "that it cannot be systematized in terms of error-free running periods during the Volna service life." That is, they say that no prediction can be made about when the turbo pump problem will occur on future Volna flights. Nonetheless, the report continues, "the first stage engine failures resulted from the design features of the engines that were manufactured without regard for the Design Documentation upgrade intended to improve engine reliability."

Within a few hours after launch, it appeared that portable tracking stations in the Kamchatka Peninsula and Majuro in the Marshall Islands, as well as the Panska Ves ground station in the Czech Republic, had received signals that correlated with the scheduled times of transmission from the spacecraft. How could this be? It might have been that the first stage of the rocket had separated and it fell alone into the sea, while the rest of the rocket stages worked and carried *Cosmos 1* into a very low Earth orbit. Makeev could not tell us otherwise at the time.

After closely examining the signals in the weeks that followed, we eliminated the Panska Ves signal (it turned out to be of the wrong frequency) and the Majuro signal (which detailed analysis showed was probably radio-frequency interference). The Kamchatka data, however, remained strongly suggestive of a spacecraft signal. It was only after the IKI team failed to reproduce the signal's characteristics on the ground, and an American group we put together showed that the data could not match reasonable Doppler levels, that we lost hope in the possibility that the spacecraft ever reached orbit.

Leaving no stone unturned, the IKI team continued to listen from a tracking station in Tarusa, Russia, and we continued to analyze putative signals until we could finally conclude that it was unlikely that any signal came from the spacecraft.

We now have the final Makeev report in hand, plus additional analyses from our Russian colleagues at IKI and American colleagues of The Planetary Society. We are comfortable with the conclusion that *Cosmos 1* never made it to orbit because the launch vehicle failed. But we are not comfortable with the reason it happened: the Volna selected for our payload had not been upgraded to correct a known failure mode. We will not fly on a Volna again. We've learned that lesson—and it was certainly a hard one. We are now ready to find a new launch vehicle, establish better launch vehicle interfaces, and try again to fly the first solar sail spacecraft.

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

DRY EARTH, WET MARS

Chile's Atacama Desert interests scientists because we find there Mars-like soils: virtually undetectable levels of life, very low organics, and the presence of some chemical reactivity. The NASA program Astrobiology Science and Technology for Exploring Planets (ASTEP) funds ongoing research in the Atacama Desert. This year The Planetary Society cosponsored the Atacama field expedition, sending Troy Hudson, a graduate student from Caltech working on concepts for future Mars exploration, on the expedition to apply his skills and methods to this Mars-like desert. Here is his report.

—Chris McKay, Planetary Scientist,
NASA Ames Research Center,
Member of The Planetary Society Board of Directors

"One of the extraordinary things about life is the sort of places it's prepared to put up with living. Anywhere it can get some kind of a grip . . . life will always find a way of hanging on in somewhere. It will even live in New York, though it's hard to know why."

Even though I'm a confirmed lover of big cities and New York ranks among my top three, I found this quotation from Douglas Adams's novel *Mostly Harmless* to be apropos of what we're doing here in the Atacama Desert of northern Chile. I and about 20 other scientists have come to the driest place on Earth to look for life. I, in particular, am looking for water. It seems a bit foolhardy on the surface, but actually it makes a lot of sense—in a Douglas Adams sort of way, perhaps as a case for the Holistic Detective Agency.

Most places you go on the surface of this ball of rock, 70 percent of which is covered with ocean, you're going to find water pretty easily. The average column of atmosphere, from the top of the stratosphere down to the surface at this latitude, contains about 5 centimeters (about 2 inches) worth of water if you rained it all out at once. Any soil you're likely to dig up, from a backyard garden or in the middle of the Mojave Desert, is going to have some water in it. The ability of soil to retain water is what allows plants and animals to survive and grow, even in the desiccating months between desert rains. But in a

BY TROY HUDSON

LARGE BOULDERS ARE STREWN RANDOMLY AROUND THE FLOOR OF CHILE'S ATACAMA DESERT FLOOR AMID ROCKY RIDGES AND FLATS OF FINER-GRAINED MATERIAL. UNLIKE THE SURFACE OF MARS, THERE ARE NO APPARENT IMPACT STRUCTURES THAT MIGHT HAVE BEEN RESPONSIBLE FOR THROWING THESE ROCKS ABOUT.
IMAGES: JACEK WIERZCHOS (LEFT) AND JPL/NASA

place where it never rains, in a place where the most moisture one ever sees is in occasional morning fogs that burn off immediately after sunrise, in a place where there's no visible life at all, looking for water is logical precisely because there's so little of it.

Chile and Astrobiology

Scorching deep-sea vents, stratospheric dust particles, acid mine drainage, nuclear reactors, millennia-old permafrost, circuit boards in spacecraft on the Moon—viable microbes have been extracted from all these environments. The places where life really toughs it out are understandably hard to get to. By comparison, the Atacama Desert seems benign and hospitable, and here you find one of the best natural laboratories for studying life on the edge. It doesn't seem that harsh on the surface; you could walk here from a major city, and with adequate stocks of food and water, you could be quite comfortable camping out for months. But the lack of available indigenous water, and possibly other factors like soil chemistry, make the Atacama one of the only natural places on Earth's surface where even bacterial life is patchy. Occasional fogs bring in short-lived surface condensation, and that seems to be enough for a few kinds of bacteria. But the bacteria are not ubiquitous.

A sampling at one site will reveal a density of about 10,000 microbes per cubic meter (which is very small for a soil), but move 10 feet to your left, and you may not get a single blip on any available detector. The patchy distribution of life is not random. It may have something to do with soil chemistry and toxicity, or it could be a remnant from a time when the area was not so dry. This is less likely, because the Atacama is one of the oldest deserts on Earth, dating from around 10 million years ago.

Chris McKay of the NASA Ames Research Center, a colleague and former boss of mine, has been hunting life in extreme environments for most of his career. Ice-covered lakes in the Canadian Arctic; the Dry Valleys of Antarctica; the acidic, iron-rich waters of the Rio Tinto, Spain . . . these are some of the most extreme locales on Earth's surface, and Chris and other astrobiologists have made it their business to probe and understand the secrets of the microbes that make their homes there. Over the last seven years, with an increasingly complex arsenal of equipment and a growing army of experts, Chris has led geo- and astrobiologists to an old agricultural station (yes, they tried to grow things here) at Yungay, near the town of Antofagasta, Chile.

The Atacama Desert of northern Chile is only 100 kilometers (62 miles) from the vast reservoir of the Pacific Ocean, but in more than 100 years of human habitation and use, no rain has ever been observed here. There are no plants in the central Atacama. No cacti, scrub brush, succulents, mosses, or lichens provide visual relief from the jagged rocky ground that stretches for hundreds of square kilometers. Nitrate and copper mining, and their promise of wealth, attracted those who settled here. The wind patterns that prevent rain in the central desert also forbid relief for the coast. Below the high front range, within sight of the sea, the hill slopes appear utterly barren; mosses or lichens are the most common types of life.

Why life exists here as it does is a question being tackled from many different directions. Different sites are sampled for elemental, chemical, and organic constituents; uncontaminated culturable samples are taken; and even satellite observations are being compared with "ground-truth" samples. In addition to probing the "why," some people here are making use of the simple fact that life here is just sparse . . . as sparse, perhaps, as one might find on a place like Mars. A collaborative effort between the Jet Propulsion Laboratory (JPL), Scripps Institute of Oceanography, and UC Berkeley are here testing the Mars Organic Detector (MOD). The elaborate setup of precision laboratory equipment, covering an area the size of a ping-pong table, looks incongruous in a building that is little more than a slab of concrete with exposed drywall, a tin roof, and no windows. But attach to that assemblage of custom equipment a couple of laptops, a vacuum pump, and some gas-powered generators, and you're ready to look

In the makeshift laboratory, Andrew Aubrey examines the vortex cooler on the sublimation oven, part of the Mars Organic Detector, a high-precision soil organic extraction and detection system. It took about 3 days to fully assemble and test the instrument.

The infrared camera, soil thermal probe, and meteorological instruments are deployed well before sunrise in an attempt to catch any predawn dew that might gather on the desert's bone-dry ground.

On the Atacama Desert's floor, a loose surface layer of sub-centimeter stone and dirt aggregates covers a much more coherent, cemented layer with very low permeability. This crust, which ranges from a few millimeters to several centimeters in thickness, may present a very high barrier to the movement of liquid or gaseous water.

Troy Hudson pours paraffin around the contact hose of a soil permeameter. The instrument's silver reservoir and "float" force a stream of air at a constant pressure into the ground through a surface paraffin plug. The rate of air flow indicates the soil's resistance to fluid movement.

The paraffin plug around the contact hose must be complete, or air from the reservoir will escape in unknown ways. With a complete circular plug, the flow of gas can be modeled and the soil's physical properties can be determined.
Photos: courtesy of Troy Hudson

for amino acids. If trials here prove the concept, scientists obtain funding, and engineers miniaturize all the components, you could see the next generation of this thing rolling across the Red Planet in 2009.

A Challenging Environment

Searching for life, extant or past, is big business these days, as is finding potential habitats. If life isn't found in a place where our expectations tell us it's possible, that's big news. The common thread tying together all life as we know it is water, and water is my specialty.

Chris invited me on this trip because my thesis research at Caltech focuses on the stability and evolution of subsurface ice on Mars. In a vacuum chamber at JPL, I simulate Martian surface conditions of temperature, pressure, and humidity and study how water vapor diffuses (moving from high to low concentration) and advects (moving from high to low pressure) through porous media like soil on Mars' surface. The Atacama, though obviously different from Mars in temperature and pressure, is similar in its dryness, very low organic content in the soil, and high concentrations of salts that form crusts and barriers to water motion. This probably is the most Mars-like soil I'll see until I go to the Red Planet myself.

This June, we have more people than ever, including, for a time, a five-person film crew from Discovery Canada. Most people at the station follow a typical daily cycle. The less hardy folk and those who must suckle from Mother Internet on a daily basis drive in from their Antofagasta hotels, arriving to much activity around 10 a.m. The station-sleepers await the arrival of their colleagues for their own sake, but also for the food and, most important, the vehicles they bring. Lesson learned: rent more trucks next time. This lesson was reinforced by the unfortunate traffic accident that deprived one of our number of his driver's license and vehicle for several days.

A few people have dead time as they wait for their transportation, but we all find ways to occupy ourselves. For the first four days, the MOD team worked diligently to assemble their apparatus, a task complicated by the unavailability of high-power generators. Typically, there's at least one vehicle at the station for emergencies, but that rule occasionally gets bent, usually to accommodate a water run. All drinking water comes from bottles, but wash and toilet water is brought in by the barrel from a nearby filling station. Thirty meters below our feet, through concrete-hard salt pan, runs the water table draining the Andes over the horizon to the east. A well at the station was used previously, but the town of Antofagasta apparently has only four generators big enough to operate the water pump, and they were all in use this month.

Fog

A nighttime fog so dense and frequent that it's been given a name, the *camanchaca*, occasionally makes its way inland as far as the deep desert. About an hour and a half before sunrise, when temperatures reach their nighttime lows, the fog layer can collapse and create enough dew that it completely wets the upper millimeter of the soil. It's not much, but it's the most this place ever sees. By an hour after sunrise, the dew burns away, and the desert returns to salty, hard-packed dryness. Over a daily cycle that sees variation in ambient humidity, temperature, and sunlight intensity, and may or may not experience a condensation event (fog or dew) at night, the water content of the soil will change dramatically. Certain soils could act like sponges, sucking up whatever moisture the Atacama environment could deliver to them at night and remaining bone dry from the perspective of a thirsty microbe, only to completely expel this water in the early morning heat, which offers no reprieve. Other soils, due to compositional or geometric differences, may hover on the edge of saturation and become bacteria-scale catch basins during and immediately following condensation.

It's hard to predict, from evening conditions, if there will be a fog event the following morning. In anticipation of those events, I spent several nights in the back seat of a small pickup truck out at a field site prepared to catch a rare bit of wet soil. The setup of the IR (infrared) camera, KD2 soil thermal properties meter, atmospheric temperature/humidity logger, and requisite generators, tripods, and accessory equipment takes about half an hour.

The camera can take a time-lapse series of stills at any interval I choose to set, and the logger operates continuously. But the KD2 is manually controlled, and taking samples for gravimetric water content must be done by hand. It took a night or two, but I trained myself to sleep for 45 minutes, take data and samples for 15, and go back to sleep again. An hour after sunrise, when things start to heat up, I head back to the station to turn over my vehicle and get some real rest. A midmorning nap precedes a couple hours of sample examination for water content using a water potential meter, processing of the time-lapse footage, and correlation of the thermal properties data with the temperature and humidity data.

Three Techniques

Ideally, I would sample the surface crusts and the loose soils beneath them for water every hour for several days, at least one of which would include a fog event. This data set would be supplemented with atmospheric temperature and humidity measurements, soil surface temperature measurements, and measurements of the thermal properties of the surface crust and subsurface sand. (Nature operates on her own schedule, and though the camanchaca fog is more common in winter, it still occurs irregularly, and, unfortunately, I did not experience one during this field trip.)

I have three ways of measuring water in a soil. The first, gravimetric water analysis, is a simple subtractive technique: I measure the mass of the raw sample, then heat it in an oven until all the water is driven off; the difference in the starting and ending masses is the total initial water mass. The second technique involves measuring a soil's thermal properties. Heating a needle driven into the soil generates a heat pulse that propagates outward, and the needle cools at a rate governed by the thermal conductivity and diffusivity of the medium.

The third technique involves water potential. In order of decreasing availability to biological processes, water can exist in a soil as a pore-filling liquid, as adsorbed molecules on the surface, or as chemically bound hydroxyl groups. This availability can be quantified as water potential, the strength with which water is bound to a substance. To measure this potential, the water in a soil equilibrates with a small amount of gas above the sample at a known temperature, and then a hygrometer determines the humidity of that gas. As the soil gets drier, the more loosely bound water leaves first, and the potential (defined as zero for free water) becomes more negative.

The three techniques have their pros and cons. Gravimetry, the most accurate for determining total water content, is essentially a destructive technique, and some of the water measured may not be available to biology. Thermal properties measurements are repeatable but need calibration via gravimetry anyway, and they don't say anything about how tightly the water is held. Water potential directly reveals the degree of water availability but is strongly affected by temperature and composition, and it is perhaps the most indirect technique, requiring soil water/vapor equilibrium. Also, gravimetry and water potential analysis disrupt the soil, so the same undisturbed soil cannot be sampled twice.

If we could say that all the soil in a given square meter is physically, chemically, and biologically homogeneous, using all three techniques would be easy, and we could directly apply all the results. But we still don't have an idea of the scale of the biological patchiness, and even physically the soils vary on centimeter scales, so one has to be very careful about generalizing.

For this field trip, general data were collected, but the most valuable information concerns how to conduct better experiments next time. If this trip is repeated, I'll need to train myself to spend several full days getting 45-minute naps, or develop an automated soil-sampling mechanism. Perhaps I could collaborate with some of the JPL rover designers working on the sample return mission.

IR Camera

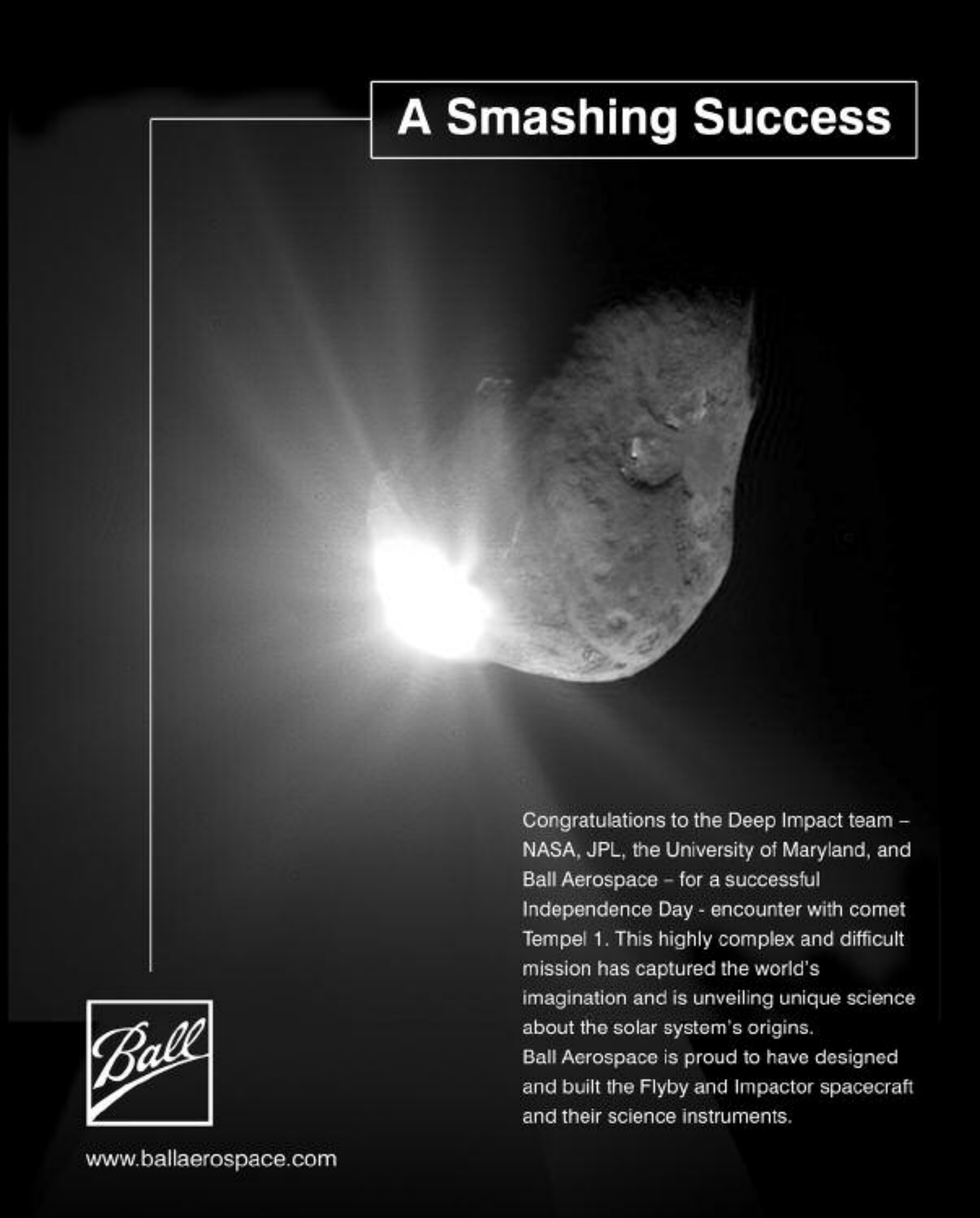
An infrared (IR) camera developed by JPL's Microdevices Laboratory might eventually help reveal the scale of significant variation in soil water content. Until recently, most IR cameras that could operate in the near-infrared range (0.9 to 3.0 microns) required cryogenic cooling, which makes field use cumbersome. This new camera uses a new CCD (charge-coupled device) material, requiring only solid-state cooling, so it's easy to deploy and operate. Water molecules have a very strong infrared absorption at 1.45 microns, so if we look in that region, anything that's wet should appear darker than surroundings that are drier.

This camera could be set up to observe a soil during a fog event and the following sunrise, and it could reveal small-scale differences in soil water retention over time. However, this application and this field trip are recent developments, and the camera is not yet equipped to do this well. The camera is broad band (0.9 to 1.7 microns) and therefore collects a lot of photons outside the water band, resulting in contrast differences between light and shadow that overwhelm water absorption signals. For future deployments, a set of narrow-band–pass filters and some artificial illumination for predawn imaging will be acquired. This is exactly why we build prototypes—to see what works and what doesn't and how things can be improved a step at a time. To learn this, I tested the camera on several occasions, leaving the station at around midnight to set up camp alone and await the sunrise.

Out here in the desert, away from the people at the station, I begin to understand how desolate it is. I'm the only multicellular life for tens of miles. Current astronauts and future explorers of Mars and the Moon will come face to face with an even harder, more extreme truth, a still more absolute form of loneliness and isolation. A place like the Atacama would be a good training ground. You need only change the color of the sky, and you could convince yourself, looking in any direction, that you're looking through the eyes of the *Spirit* or *Opportunity* rovers on Mars.

Troy Hudson is a graduate student in Caltech's Geology and Planetary Sciences Department under his adviser, Oded Aharonson. Troy's research focuses on the evolution and stability of Martian subsurface ice and its exchange with the atmosphere.

The view after sunset, looking westward from one of the sample sites. Not a single sign of macroscopic life appears anywhere.
Photo: Troy Hudson


A Smashing Success
Congratulations to the Deep Impact team – NASA, JPL, the University of Maryland, and Ball Aerospace – for a successful Independence Day - encounter with comet Tempel 1. This highly complex and difficult mission has captured the world's imagination and is unveiling unique science about the solar system's origins.
Ball Aerospace is proud to have designed and built the Flyby and Impactor spacecraft and their science instruments.
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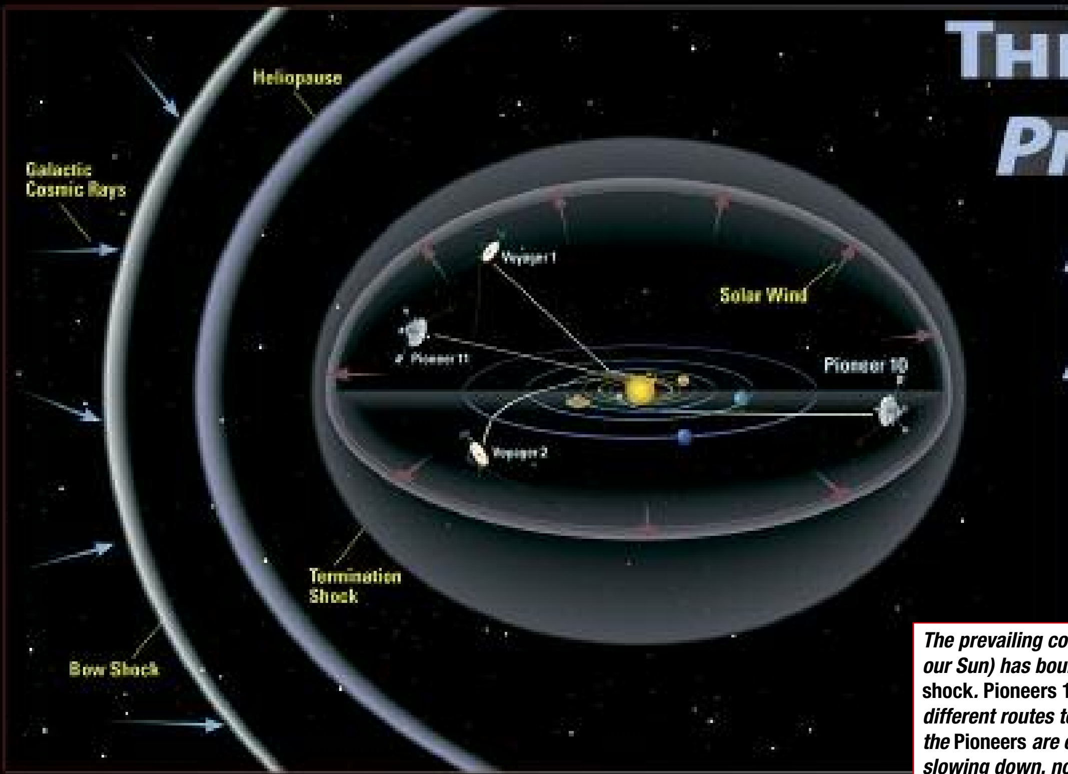


The Pioneer Anomaly: A Deep Space Mystery

The prevailing concept of the heliosphere (the region influenced by our Sun) has boundaries called the **heliopause** *and the* **termination shock. Pioneers 10** *and* **11**, *as well as* **Voyagers 1** *and* **2**, *are taking different routes to these outer edges of our solar system, but only the* **Pioneers** *are experiencing a minute but completely mysterious slowing down, now called the* **Pioneer** *anomaly.*
Illustration: NASA Ames Research Center

BY BILL NYE

Right now, there is something just plain weird going on in space. *Pioneer 10* and *Pioneer 11*, two spacecraft that were launched in the early 1970s to explore Jupiter and Saturn, are hurtling out of our solar system. But wait—they're hurtling not quite as quickly as we would expect. As we measure their positions from here on Earth, either something is slowing them down, or something else is making them appear to slow down. Either way, we have a real mystery on our hands—well, in our data. It could change the world . . . no kidding.

This error or difference in the positions of the spacecraft compared with where we would, at first, expect them to be is called the *Pioneer anomaly* [uh-NAHM-uh-lee]. In Latin or Greek, anomaly means irregularity.

As you become involved in this story, I hope you're more than just a little surprised by the *Pioneer* anomaly. After all, you know a lot about gravity. You move around in a gravity field here on Earth. If you've seen tides, you've observed the interaction of at least four gravity fields: the Earth's, the Moon's, the Sun's, and that of water itself. You probably throw and catch balls. You haul things up stairs, ramps, and ladders. You might coast, roll, or ski down a few hills. Maybe you surf down the face of a wave. You've even observed the gravity of dust on a shelf. As a thinking Earthling, you know a great deal about one of the fundamental forces in the cosmos. Not bad. You're so used to it that it may seem routine, like nothing special. You and I, however, are living at a time when the evidence for an astonishing discovery might just be emerging: in deep space, gravity might not work the way we currently think it does. Here's why we wonder . . .

Something Weird That Way Goes

We haven't had signals from the radios on board *Pioneer 11* since 1995, and we haven't heard from *Pioneer 10* since 2003. When last heard from, *Pioneer 10* was headed out of the solar system on a path on approximately the same plane as Earth's orbit, with *Pioneer 11* going north or "above" the orbit of the main planets. After completing their missions at Jupiter and Saturn, the spacecraft began to make their way out of the solar system, but they have not been behaving as expected. Both *Pioneer 10* and *Pioneer 11* seem to have slowed down, by just about the same amount, for no reason that we can understand. We have tracked *Pioneer 10* for nearly 30 years now, and over that time the spacecraft is short by some 400,000 kilometers (250,000 miles, roughly the distance from Earth to the Moon) from where we would expect.

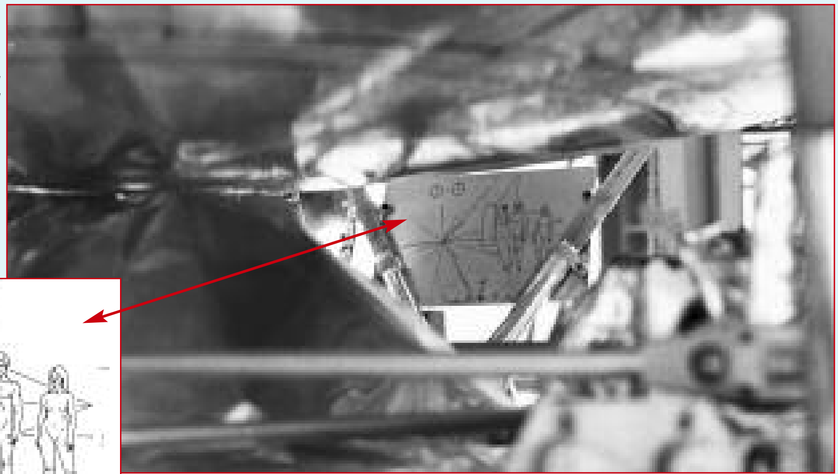
It's weird. Are you with me? It's a weird thing that both spacecraft seem to be slowing down at exactly the same rate, and in exactly the same way. Granted, compared with the billions of kilometers that they've already traveled, even 400,000 kilometers isn't much. But this is rocket science, after all, and every single thing should add up.

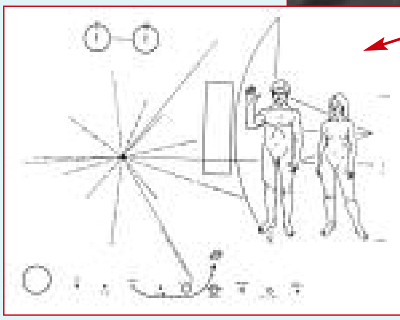
One of the astonishing and wonderful things about being in outer space, whether you're wearing a tight, close-to-your-nose space suit or riding along on a huge, comfortable planet like ours, is that everything moves with almost no friction. This is what Isaac Newton, and you and I, call the property of *inertia*. If something is going one way, it keeps going that way, unless it is acted upon by some force.

Imagine jumping onto a backyard slippery slide kept

MYSTERY

Right:* *The plaques attached to* Pioneers 10 *and* 11 *were the first "interstellar greeting cards" to leave our star system. These gold-anodized aluminum plates, etched with vital information about the humans who sent them, were attached to the spacecrafts' antenna support struts in a spot that would shield them from erosion by interstellar dust. *Photo: NASA*





Left:* *The* Pioneer *plaques were designed to explain when the spacecraft were launched, from where, and by what kind of beings, to any inhabitants of deep space who might find them millions of years from now. *Illustration: NASA*

wet by a garden hose. Get a good running start, because you'll be sliding nonstop for 30 years! It would be an especially long slide, say 8 billion kilometers. Actually, it would be infinitely long. That's the way things move in what we call *inertial space*. Now, our *Pioneer* spacecraft are moving through inertial space, aren't they? And there's nothing to slow them down, right? Or is there? A double coincidence?

What could it be? A fuel leak from one of the very small hydrazine thrusters? They're supposed to be turned off. A broken piece of spacecraft flung off by accident in the wrong direction? (Imagine standing on skates and swinging a bowling ball—a small bowling ball—and it slips from your grip. You'd slide somewhere, maybe just a little.) Either of these could cause an anomaly—but twice? Would both spacecraft break apart, or be leaking, in exactly the same way, from exactly the same place, in the same direction, and at the same rate? It could happen, one might suppose, but it just doesn't seem right.

Scientists have tried every sort of explanation and performed every sort of investigation they can think of. What about sunlight pressure, the pressure that will drive a solar sail? What about the solar wind's streaming particles? Ocean tides shifting the receiver dishes of the Deep Space Network? The software that converts tiny radio time and frequency signals into a meaningful place in space, much like a GPS on Earth? They've gone over that countless times. Nope. It seems to be something we don't understand at all; this is something outside our experience, something weird.

Or Something New in Space?

How about this? Suppose there is some sort of matter, some sort of stuff in deep space that we can only imagine, or maybe more accurately, we haven't yet imagined well enough. And this stuff is slowing the spacecraft down—just that much (hold your fingers really close together as you read this).

Well, what is this stuff? Some people suggest that it's part of a new theory, the theory of *mirror matter*, particles that exist just because other, regular matter particles exist, like the ones that make up you and me. Or maybe it's part of dark matter, invisible particles that for some reason we can't see. They don't reflect light; they're dark. I like to call them "darkons," particles of dark. Oh, all this is big fun, but no one knows . . . at least not yet.

When the *Pioneer* ships were set sailing into the cosmic dark, people mounted a gold plaque on each one showing pictures of us humans and a way for a clever civilization to figure out where the spacecraft came from. None of us will ever see them again, but the idea that we can send messages to some intelligence out there is something to think about. Whoever they might be, if they can find and read the *Pioneer* plaques, they probably know all about this unexplained happenstance, this anomaly. They might wonder if we also know.

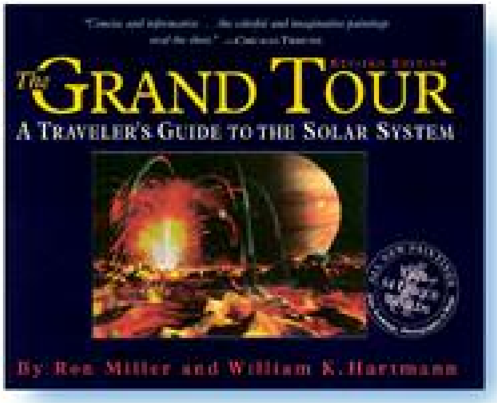
You and I may be living at a time when the *Pioneer* anomaly leads us humble humans to a new, maybe completely new, understanding of the cosmos and our place in it. You may be the one who makes this discovery. Mirror rays? Mirror-ons? Darkons? Invisiblons?

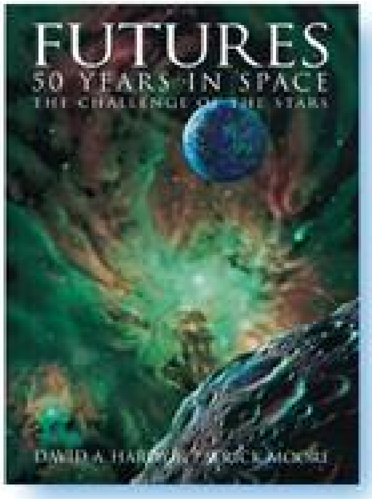
Whoever figures this out could change the world. One of the fundamental ideas in science is that whatever happens here on Earth, whatever phenomena control our world, should work the same way everywhere in the universe. It would be a tall order for scientists to figure out these fundamental rules of nature, but we're trying. This tiny backward force, or deceleration, of only 0.0000000008 meters per second every second (8×10^{-10} m/sec^2, if you like that kind of notation), barely measurable by us here on Earth, may be evidence of something that will, someday, make our world completely different.

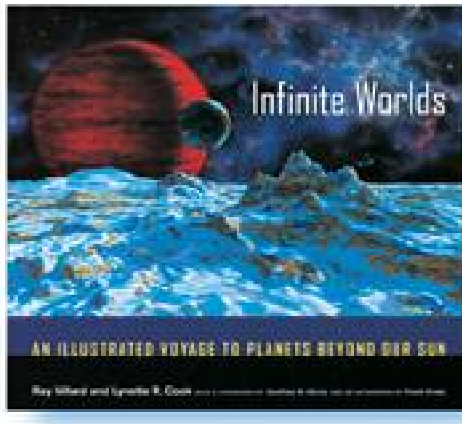
Keep watching this space, and we at The Planetary Society will do our best to keep you in touch with the deep space of the *Pioneer*s and what's up, up there.

Bill Nye is vice president of The Planetary Society.

OUT OF THIS WORLD BOOKS







The Grand Tour:
A Traveler's Guide to the Solar System
By Ron Miller and William K. Hartmann
Workman Publishing, 296 pp., $19.95, paperback (3rd rev. ed.)

Futures: 50 Years in Space,
the Challenge of the Stars
By David A. Hardy and Patrick Moore
HarperCollins, 110 pp., $24.95, hardcover

Infinite Worlds:
An Illustrated Voyage to Planets Beyond Our Sun
By Ray Villard and Lynette R. Cook
University of California Press, 272 pp., $39.95, hardcover

Thank heaven for the artists and writers who reveal space to us! Not only do they produce fascinating documents of our explorations, but these gifted seers also keep us several steps ahead of the game with their visions of worlds we can only imagine at this point in our celestial travels.

These three books—all written for a wide audience and illustrated by masters of their craft—will surely play a part in inspiring the next generation of space artists and explorers.

The latest edition of *The Grand Tour*, a beloved space art classic, is more spectacular than ever with 160 new paintings, plus drawings, maps, and copious, up-to-date spacecraft images. This lavishly illustrated book is divided into three sections: "The Major Worlds," with text on each planet's characteristics; "Selected Smaller Worlds" such as moons, comets, and asteroids; and the brief "Beyond the Solar System," which focuses on planets in orbit around nearby stars.

Revised and updated based on data from groundbreaking missions such as *Voyager 1* and *2, Magellan, Galileo*, the Hubble Space Telescope, and *Mars Global Surveyor*, this guide provides a comprehensive view of how far our explorations have taken us since its first edition in 1981. Hartmann's traditional paintings and Miller's computer-generated artwork add a stunning visual context.

The Grand Tour is a completely engaging introduction to the alluring collection of individual worlds that populate the inner borders, and the "nearby" outskirts, of our solar system.

Futures is not only an expertly illustrated history of space exploration but also a continuation of the teamwork between an accomplished space artist and well-known popular astronomer—an alliance that dates from the beginning of the space age. David Hardy and Patrick Moore met in 1954, when Hardy illustrated Moore's book *Suns, Myths and Men*.

This stunning, large-format book begins with an overview (1954 to 2004) of how space exploration, and our own view of what space is like, changed in the last half of the 20th century. The 21 chapters progress from each of the planets in our solar system to the Milky Way and an assortment of stars and to topics concerning deep space. Other chapters discuss technologies such as space stations, interstellar travel, and communication.

Hardy and Moore have produced a unique book that brings together their combined wealth of experience and expertise in revealing the wonders of the cosmos and conveying the excitement of exploring them.

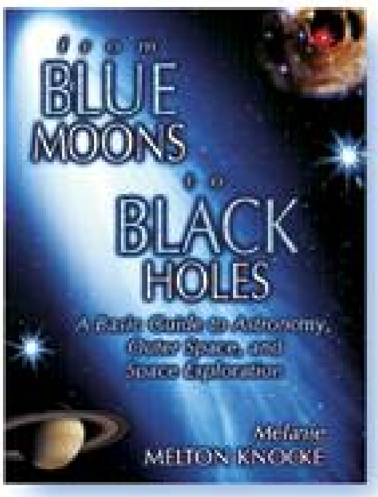
Ten years ago, we could only speculate about planets orbiting Sun-like stars outside our own solar system.

Today, detections of extrasolar planets have become a regular phenomenon. This strange parade of alien planets is unbelievably diverse in terms of the sizes, orbits, and general characteristics of its members. Although it will be years until we have actual spacecraft images, *Infinite Worlds* gives us an idea of what these mysterious bodies will look like.

Ray Villard, the news director for the Space Telescope Science Institute, and Lynette Cook, a prolific illustrator of extrasolar planets, have put together a comprehensive tour of the strange planets that have been detected around other suns in our galaxy. Cook created many new paintings especially for this book, and Villard's elegant text describes the state of planet-hunting science today and imagines where it will take us in the future.

Infinite Worlds is a perfect addition to the library of anyone who wonders what strange planets inhabit the mysterious, far reaches of our galaxy and beyond.

—Donna E. Stevens, Associate Editor of The Planetary Report



From Blue Moons to Black Holes: A Basic Guide to Astronomy, Outer Space, and Space Exploration
By Melanie Melton Knocke
Prometheus Books, 313 pp., $19.00, paperback

People interested in astronomy who haven't taken a science class since high school often are intimidated by the subject matter, fearing that if they brave the dark waters of even a popular-level account of astronomy and cosmology, they might drown in the overwhelming complexity of stellar spectra and singularities. Melanie Melton Knocke's *From Blue Moons to Black Holes* goes a long way toward calming those waters. It's an introduction to astronomy and space exploration that achieves something all too rare in science writing: explaining the basics without talking down to the reader.

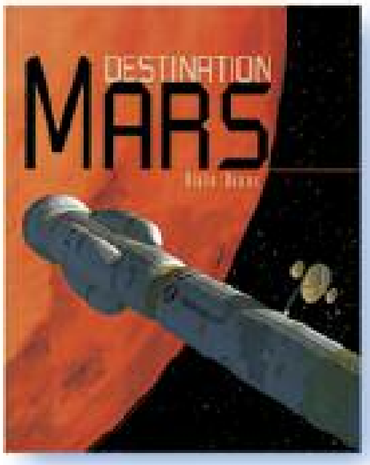
The book is organized into three parts. The first covers basic astronomy in a question-and-answer format. The questions posed are the kind people new to astronomy commonly ask: Do people in different parts of the world see the same stars at the same time? Could a human travel through a black hole? Why is Mars red? A short summary answer is provided, followed by a more detailed discussion. For those who want to explore the sky with more than their eyes, how to buy and use a telescope also is explored.

The second part is essentially a set of reference tables listing basic astronomical facts, such as the distances, sizes, and moons of the planets of our solar system; dates of meteor showers and eclipses; names of the brightest and nearest stars; and something quite useful in the Internet Age: an extensive list of astronomy- and space-related websites.

The third part is a history of human and robotic lunar and planetary exploration (spacecraft that solely orbited the Earth are not included). It's astonishing to see just how many missions have been sent to other worlds in the 40-plus years since the first lunar probes.

In addition to concise and readable prose, the book includes a number of illustrations of concepts for which, as is quite common in astronomy, a picture is worth a thousand words. A set of color plates features some of the most dazzling astronomical images of recent years, taken by instruments ranging from amateur telescopes to the Hubble. These days, images taken by "amateurs," like the picture of the Eagle nebula by Jack Newton, are often hard to distinguish from the work of professionals!

Knocke has written a comprehensive, accessible introduction to the wonders of the cosmos that a wide range of readers can learn from and enjoy. Anyone interested in getting started in astronomy as a hobby, as well as younger people who may be considering space science as a career, should have this book. So go ahead, imagine putting on your space suit, and step into the cosmic ocean. With Knocke as your guide, even the deeper waters are just fine.
—Andre Bormanis, Writer and Producer for the CBS Television series Threshold



Destination Mars
By Alain Dupas,
illustrated by Ron Miller
Firefly Books, 167 pp., $29.95, hardcover

This coffee-table book is a nice addition to the personal library of anyone interested in the future of humans in space. It is especially good as a family resource presenting the rationale and lure of Mars exploration. The historical context for Mars exploration is well presented, along with a summary of such exploration to date and how robotic explorers prepare the way for future human expeditions.

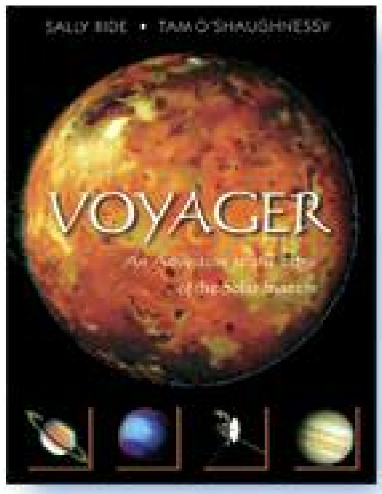
Ron Miller's art is a major contribution—alone worth the price. With its many pictures of the Moon and the planets, of engineering achievements in spaceflight, and of scientific discoveries, the book becomes a great object for browsing as well as reading. But Dupas' and Miller's real contribution is their enticing presentation of ideas for future human exploration—getting to and then living on Mars. This is now the official "vision" of the American space program, as well as goals in the space programs of Russia and Europe.

No attempt is made to critically examine some of the different ideas about future solar system exploration (e.g., use of lunar resources, building an orbital colony, getting rich on asteroidal materials). Instead, the author cleverly works them in to present a bit of everything for our consideration of what and how to explore. Among the dozens of short chapters are "Into the Solar Wind," "Meeting with an Asteroid," and "Life on the Way to Mars." There is (very) brief background on rockets, the space shuttle, space stations, exploration of the outer planets, extraction of resources for fuel and life support on Mars, habitats, rovers, and nuclear propulsion.

Nicest of all is the connection made to the search for extraterrestrial life and the human desire to spread life throughout the solar system.

The book is only $29.95, and for $100.00 or so the art could have been reproduced at much higher quality. Miller's art and the photos of solar system exploration would justify it. At its actual price, everyone can afford the book and have ready answers for friends and relatives who ask, "Why should we send humans to Mars?"
—Louis D. Friedman, Executive Director of The Planetary Society

Reaching for the Moon
By Buzz Aldrin,
with paintings by
Wendell Minor
HarperCollins, 40 pp., $15.99, hardcover



***Voyager*: An Adventure to the Edge of the Solar System**
By Sally Ride
and Tam
O'Shaughnessy
Sally Ride Science Publishing, 40 pp., $20.00, hardcover

Two of America's most famous astronauts, Buzz Aldrin and Sally Ride, have produced two very nice children's books. Aldrin's is an autobiography, whereas Ride's (with coauthor Tam O'Shaughnessy) chronicles the *Voyager* spacecraft and their journey to the giant planets.

Aldrin's autobiography chronicles his life from his youth to the Air Force, to his Ph.D. studies at MIT, to his astronaut years. The book is illustrated with paintings but no photographs. The paintings are beautiful but make the story seem a little more like fiction than the reality it is.

Aldrin's life is a tale of successes. Within the text, Aldrin's characteristics are specifically pointed out as examples to children. Determination, strength, focus, and excelling at academics and sports are all good lessons drawn from the book. Another is independence, an excellent quality, but the story of Aldrin riding his bike alone 20 miles to cross the George Washington Bridge and stories of sneaking into movie theaters send mixed messages in today's age, at least from a parental perspective.

Aldrin's book will be interesting for older children, younger children interested in space, and adults. I highly recommend this tale of a true American hero for its recounting of a historic event, its character lessons, and its tie to the inspiration of space. Perhaps most intriguing, readers find out where the famous nickname "Buzz" came from.

Ride and O'Shaughnessy have put together a beautiful introduction to the *Voyager* spacecraft, their visits to the giant planets, and the planets themselves. Stunning *Voyager* images of Jupiter, Saturn, Neptune, and Uranus; their rings; and many of their moons are woven into a narrative that follows the spacecraft from one planet to the next.

The book contains a surprising quantity of text, making it very informative but perhaps a challenge for very young readers. The images, however, as well as the text, are appropriate for nearly all ages.

I am a stickler for technical accuracy, and I believe the authors did an amazing job, particularly compared with the typical children's books on the planets. There are a few minor omissions (the biggest being lack of discussion of the solar system's largest moon, Ganymede, among descriptions of the many other interesting Jovian moons). One or two captions are misleading, but that is in a book filled with illustrations.

The revisions in this second edition update our understanding based on further analyses of *Voyager* data and on the *Galileo* and *Cassini* missions. The latter updates are covered mostly in one page at the end and are rather thin, but these missions were not the focus of the book. No egregious errors in the *Voyager* text show conflicts with current understanding provided by later missions and telescopic observations.

As part of my review, I read both books with my 4-year-old and 7-year-old sons. The 7-year-old was particularly engaged, craving information. The books were on the long side for the 4-year-old (not a criticism, because neither claims such a young age range). I very much enjoyed watching my boys soaking up information about two of the greatest voyages of human history: those of *Apollo 11* and the *Voyager* spacecraft.

—Bruce Betts, Planetary Society Director of Projects and Science Editor for The Planetary Report

World Watch

by Louis D. Friedman

Cape Canaveral, Florida—With a beautiful launch on July 26, the US space shuttle returned to flight. Cameras positioned along the shuttle fuel tank captured stunning views of the launch, which appeared, at first glance, to have been perfect. Detailed examination by these same cameras also caught images of foam debris falling off the external tank. Fortunately, none appeared to hit the orbiter, but NASA immediately grounded the shuttle fleet again once it became obvious there was an unsolved problem. As we go to press, the duration of the suspension of shuttle flights is not certain.

Washington, DC—The US Congress continues to give strong financial support to NASA, but nonetheless, budget pressures are squeezing the space agency. The dominant source of pressure is the space shuttle: its return to flight is more expensive than anticipated. There are other pressures as well—NASA Administrator Michael Griffin is accelerating development of the Crew Exploration Vehicle and is trying to maintain a robust science program all while starting work on the Vision for Space Exploration, which would send human explorers back to the Moon and on to Mars.

These pressures have led to cutbacks in the Mars exploration program. The *Mars Telecommunication Orbiter* for 2009 has been canceled, and work has stopped on development of a sample return mission and on all Mars programs in the Exploration Office, which is charged with implementing the new human spaceflight vision. Near-term Mars missions are not in danger—the *Mars Reconnaissance Orbiter* successfully launched in August, and the *Phoenix* lander is set to go in 2007. The 2009 *Mars Science Laboratory,* however, may slip 2 years.

Most congressional consideration of NASA comes in the appropriations bill, which provides funding for the NASA budget. Simultaneously, the authorization process provides authority to spend money for NASA's different programs. For the last 5 years, Congress has failed to pass an authorization bill, and thus congressional guidance has come through the appropriations process. For fiscal year 2006, it appears that an authorization bill will be passed.

As I write this, the Senate Authorizing Committee has proposed language that would prevent NASA from retiring the shuttle as planned in 2010. The version of the bill circulating in the House of Representatives has no such restrictive language, so a conference committee must resolve the issue—probably in September, after summer recess. The Planetary Society opposes this restriction, because shuttle retirement is key to advancing the new exploration policy for human spaceflight.

Thus, although the new exploration vision is strongly supported in Congress and NASA appears to be on course to be given full funding, the endeavor is in danger of being thwarted, both by a refusal to let the shuttle retire as planned and by deemphasis of Mars exploration as the driver behind the human exploration vision.

Bonn, Germany—Germany has decided to join other European countries in funding the European Space Agency's new space exploration program. This is expected to enable Europe to follow up the very successful *Mars Express* orbiter with a lander called *ExoMars* in 2011.

Originally, *ExoMars* had been planned with US cooperation, but European officials have stated that the International Traffic in Arms Regulations in the United States (see World Watch in the July/August 2005 issue of *The Planetary Report*) prevent such cooperation from proceeding. There is growing interest in Europe in cooperating on a proposed Russian Phobos Sample Return mission that has just received initial funding.

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

Marketplace

Society News

Upcoming Events in Your Area

The Society's staff and volunteers will be representing us at various space-related events over the next few months. We hope you can attend one!

On September 27, the Society's Bay Area Volunteer Network invites you to a lecture by Chris McKay, planetary scientist and astrobiologist from NASA Ames Research Center. He will present "Titan Through the Eyes of *Huygens*: A Quiet Little Place with a Nice Atmosphere." On October 8, come hear Rick Grammier, *Deep Impact* project manager, speak about the *Deep Impact* mission in the Mountain Theatre on beautiful Mt. Tamalpais in the San Francisco Bay Area.

Longtime members and volunteers John and Genevieve Goss let us know about the Virginia Association of Astronomical Societies Annual Convention in Roanoke, Virginia. Because John will be busy as one of this year's organizers, we are looking for volunteers to staff a table at this event. Please contact Vilia Zmuidzinas at *tps.vz@planetary.org*.

For the fourth consecutive year, Regional Coordinator José Roberto de Vasconcelos Costa will be speaking about, and representing, The Planetary Society at the 8th ENAST Conference held in Curitiba, Brazil.

Check out our Events Calendar at *www.planetary.org/html/society/calendar.html* for these and other events in your area. If you know of any upcoming space-related programs in your area, please let me know.

—Vilia Zmuidzinas,
Events & Projects Coordinator

Don't Miss Our Next Age of Exploration

You're invited to The Planetary Society's 25th Anniversary Awards Dinner on Saturday, November 12, 2005. We will mark Our Next Age of Exploration with an evening of space explorers and entrepreneurs, celebrities, great food, and stargazing, all at the world-famous Santa Anita Park, about 14 miles northeast of downtown Los Angeles. Proceeds from this event will benefit The Planetary Society—and, through our organization, the Next Age of Exploration.

At the dinner, we will present two prestigious awards—to author, poet, and playwright Ray Bradbury, the Thomas O. Paine Award for the Advancement of Human Exploration of Mars; and to director James Cameron, The Planetary Society's first Cosmos Award for Outstanding Public Presentation of Science.

For more information, or to purchase tickets, log onto our website at *planetary.org/2005awardsdinner*. Individual tickets for the Awards Dinner (with VIP reception) can be purchased for US$250 online or by telephoning 626-793-5100. Various sponsorship opportunities are also available. Please call me at 626-793-5100, Ext. 214 or e-mail me at *andrea.carroll@planetary.org*.

—Andrea Carroll,
Director of Development

Questions and Answers

How did Titan retain such a thick atmosphere while other large moons in the outer solar system—such as Ganymede—did not?
—William V. Stine
Fairfax, Virginia

Scientists are still wrestling with the "origin of atmospheres" question, but observations by *Galileo, Cassini,* and *Huygens* have provided important insights. We believe that in Titan's distant past, an atmosphere of nitrogen was formed by the action of the Sun's ultraviolet photons on ammonia. The planetesimals that formed Titan also delivered ammonia to Saturn's largest moon.

On the other hand, unlike Titan, Ganymede may not even have acquired ammonia, or other volatiles needed to form an atmosphere in the first place. This is because the planetesimals that formed Ganymede were warmer, being close to the Sun. Laboratory measurements show that at those temperatures, planetesimals do not trap ammonia efficiently.

There is another significant factor in this retention story. Even if some atmosphere began to form on Ganymede, it must have been quickly stripped away by high-energy charged particles. That's because Ganymede lies well within Jupiter's powerful magnetosphere. Again, Titan lucked out, as it finds itself only occasionally inside Saturn's magnetosphere. But even then, the removal of the atmosphere from Titan would be minimal because Saturn's magnetosphere is relatively benign compared with Jupiter's.

—SUSHIL ATREYA,
University of Michigan

I understand that Io has significantly less ice than the other Galilean satellites. Could that be due to the heat of its constantly erupting volcanoes?
—Allison Durney
San Francisco, California

Io is indeed very different from the other Galilean satellites because it lacks water—something we knew from telescopic observations before any spacecraft ever visited the Jovian moon. And Io's rate of eruptive activity is so prodigious that the moon could have recycled itself tens of times over the age of the solar system. The key question for this moon's dryness is whether water was present at all when Io formed, or if the satellite's active volcanism drove the water out after some time.

Infrared observations of Io show a weak absorption feature at the 3.15-micron wavelength that might be due to tiny quantities of hydrated minerals, hydroxides, or even water. According to Bob Carlson, principal investigator of *Galileo*'s Near-Infrared Mapping Spectrometer (NIMS) team, if the absorption is due to water, it is at an abundance of 4 parts per million or lower. In comparison, the other Galilean satellites are water-rich worlds.

An important result of spacecraft and ground-based observations is the discovery of progressive enrichment of water in the Galilean satellites as they move out from Io (which is closest to Jupiter) to Europa, Ganymede, and Callisto. This has prompted solar system modelers to assume that there was a temperature gradient in the subnebula surrounding Jupiter, from which the satellites formed.

In 1982, Jonathan Lunine of the University of Arizona and David Stevenson of the California Institute of Technology (Caltech) put forth a model of the Jovian system in which water does not condense at Io's distance from Jupiter. According to this model (and other theories), Io most likely formed in a region depleted of water. Therefore, current thinking favors the view that Io has always been a "dry" world.

—ROSALY M. LOPES,
Jet Propulsion Laboratory

As Cassini *approached Titan (far left) on August 21, 2005, it captured this natural-color view of the smog-enshrouded Saturnian moon. The images that went into making this natural-color view of Jupiter's moon Ganymede (left) were taken by* Galileo *on June 26, 1996. Although Titan and Ganymede are both large moons, many factors—such as chemistry, temperatures, and their parent planets' magnetic fields—are responsible for the fact that Titan has a thick atmosphere and Ganymede does not.*

Images: NASA/JPL/Space Sciences Institute and NASA/JPL

Factinos

A new member of the solar system, dubbed 2003 UB313 for now, has been discovered. The orbit of this far-flung world passes inside that of Pluto, but it is tilted almost 45 degrees relative to the plane of the solar system, whereas Pluto's is tilted only 17 degrees. Because 2003 UB313 is larger than Pluto, it may qualify as a planet. An official name for 2003 UB313 awaits approval by the International Astronomical Union.

Illustration: Gemini Observatory/Association of Universities for Research in Astronomy

A 10th "planet" has been discovered in the outer regions of our solar system. Mike Brown of Caltech found the new world using the Samuel Oschin Telescope at the Palomar Observatory in Southern California. The new body, temporarily called 2003 UB313, is a typical member of the Kuiper belt, but its sheer size (larger than Pluto) means it might be classified as a planet.

The planet is now about 97 astronomical units (an astronomical unit, or AU, is the distance between the Sun and Earth—150 million kilometers or 93 million miles), making it the farthest known object in the solar system.

Brown made the discovery on January 8, 2005 with Chad Trujillo of the Gemini Observatory and David Rabinovitz of Yale University. Brown and Trujillo first photographed the planet on October 31, 2003, but the object was so far away they couldn't detect its motion until they reanalyzed the data in January this year. The scientists spent the next seven months studying 2003 UB313 to better estimate its size and motion. "We are 100 percent confident that this is the first object bigger than Pluto ever found in the outer solar system," said Brown.

The International Astronomical Union is considering classifying this object as a planet.
—from Caltech and the Gemini Observatory

Maciej Konacki of Caltech has discovered a gas giant planet with three suns in the constellation Cygnus. Konacki found the planet orbiting the main star of the close-triple star system HD 188753. The three stars are about 149 light-years from Earth and are about as close to one another as our Sun and Saturn. The planet is slightly larger than Jupiter and, because it has to contend with the gravitational pull of three stars, it promises to challenge our current understanding of how planets are formed.

Until now, scientists have generally avoided searching for planets around close-multiple star systems, both because current planet detection techniques fail for such complex systems and because theories of solar system formation suggested that planets were very unlikely to form in such environments. But Konacki developed a novel approach that allows him to precisely measure velocities of all members of close-binary and close-multiple star systems. He used the 10-meter Keck I telescope in Hawaii to search for planets in such systems. The planet found in the HD 188753 system is the first one from this survey.

Konacki says, "How that planet formed in such a complicated setting is very puzzling. I believe there is yet much to be learned about how giant planets are formed." He reported his findings in the July 14, 2005 issue of *Nature*.
—from Caltech

The first triple-asteroid system has been detected in orbit around the Sun in the main asteroid belt between Mars and Jupiter. Frank Marchis of the University of California, Berkeley, and his colleagues at the Observatoire de Paris found two small asteroids orbiting a larger asteroid (known since 1866 as 87 Sylvia). Because 87 Sylvia was named after Rhea Sylvia, the mythical mother of Rome's founders, Marchis named the twin moons after those founders, Romulus and Remus. The researchers reported their discovery in the August 11, 2005 issue of *Nature*.

Sylvia's moons have nearly circular orbits in the same plane and direction (prograde) as the Moon's orbit around Earth. Sylvia's smallest moonlet is Remus, which is only 7 kilometers (4.4 miles) in diameter. Romulus is about 18 kilometers (about 11 miles) across. One of the largest known bodies in the main asteroid belt, Sylvia is about 280 kilometers (175 miles) in diameter. It is located about 3.5 AU from Earth.

By observing the moonlets' orbits, Marchis and his colleagues were able to precisely calculate the mass and density of Sylvia, finding it to be a "rubble pile" asteroid. Scientists presume that these loose aggregations of rock form when one asteroid smashes into another, disrupting one or both of them. The moonlets probably are orbiting debris left over from such a collision.

The researchers made their discovery with the infrared camera on one of the European Observatory's 8-meter telescopes (Yepun) at Cerro Paranal, Chile.
—from the University of California, Berkeley

THE 2006 PLANETARY SOCIETY CATALOG

"Is Anybody Out There?" Poster
This astounding image, obtained by the Two Micron All Sky Survey, reveals only a fraction of the 400 billion stars in our own Milky Way galaxy. 39" x 16" 1 lb.
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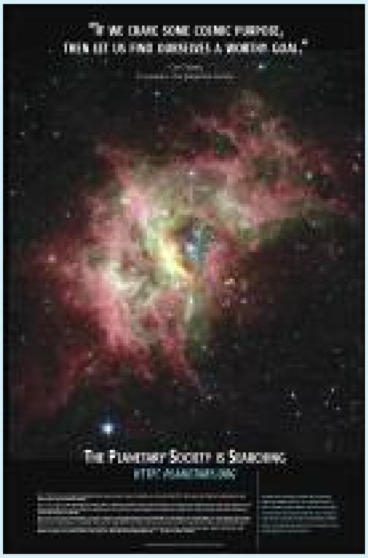

Nebula Poster
This awe-inspiring image from NASA's orbital Spitzer Space Telescope shows a false-color infrared view of nebula RCW 49—a birthplace for many hundreds of new stars and likely many thousands of planets.This stunning poster features one of Carl Sagan's poignant statements: "If we crave some cosmic purpose, then let us find ourselves a worthy goal." 22" x 34" 1 lb.
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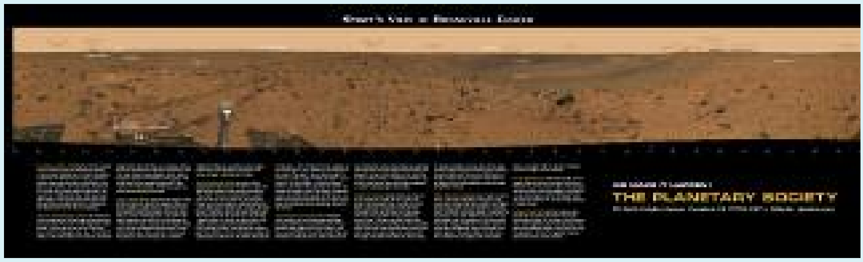

Spirit's View at Bonneville Crater Poster On January 3, 2004, *Spirit*, the first of two complex rovers, hurtled toward the Martian atmosphere and bounced down onto the dusty surface. Sixty-seven days after landing, it reached the raised rim of Bonneville and used its panoramic camera to capture this 360-degree view of its new surroundings. 10" x 39" 1 lb. **#350 $13.50**

Mars in 3-D Poster Put on your red/blue glasses and step onto the Martian surface, where *Mars Pathfinder* still rests today. Red/blue glasses included. 12" x 39" 1 lb. **#306 $13.50**

Pale Blue Dot Poster
In February 1990, *Voyager 1* looked back at its home planet for the first time. The image of Earth as a tiny bluish dot inspired Carl Sagan to write one of his best-known essays, which starts off his book *Pale Blue Dot*. The poster features Carl's timeless words and the full frame of the profound image captured by *Voyager 1*. 12" x 30" 1 lb. **#326 $10.00**

Surf Titan T-Shirt
A Planetary Society classic—we first introduced this shirt after *Voyager* passed by Titan, revealing hints of a methane ocean. Now that *Cassini-Huygens* has arrived for a closer look at the mysterious moon, we decided to bring this old favorite out of retirement. This shirt is long-sleeved with "The Planetary Society" printed on the left sleeve. Adult sizes: S, M, L, XL, XXL 1 lb. **#593 $20.00**

Future Martian T-Shirt
The future is full of possibilities, and today's Earth child just might be a future Martian.
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"Is Anyone Out There?" T-Shirt
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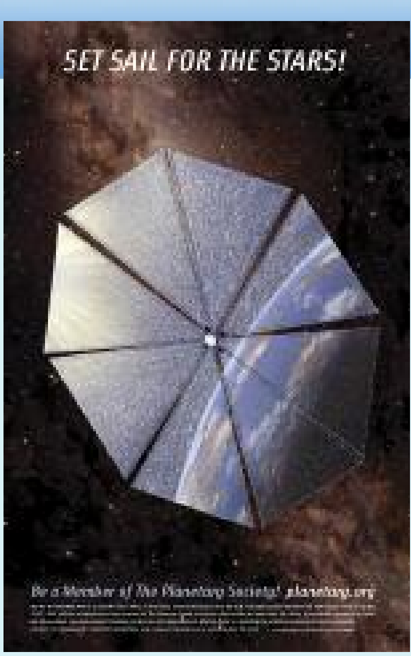

Set Sail for the Stars! Poster
A solar sail takes off in flight, leaving its home planet behind. In the distance, the Milky Way beckons. This stunning illustration created by Rick Sternbach captures both the elegance and the promise of solar sailing, the only known technology that may one day take us to the stars.
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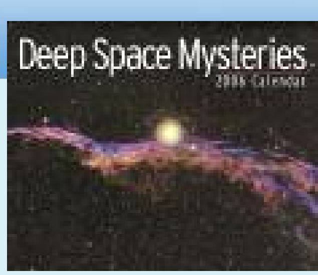

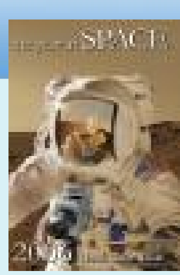

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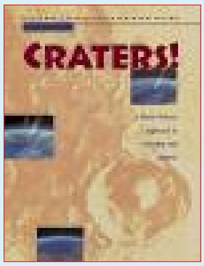

***Craters!* A Multi-Science Approach to Cratering and Impacts**
By William K. Hartmann with Joe Cain. Produced by The Planetary Society and the National Science Teachers Association, *Craters!* explains how comets and volcanoes have affected Earth's history. It includes 20 ready-to-use, hands-on activities and a CD-ROM (Windows and Macintosh compatible) filled with more than 200 images. For grades 9–12. 224 pages (softcover). 2 lb. **#109 $24.95**

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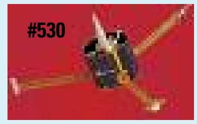

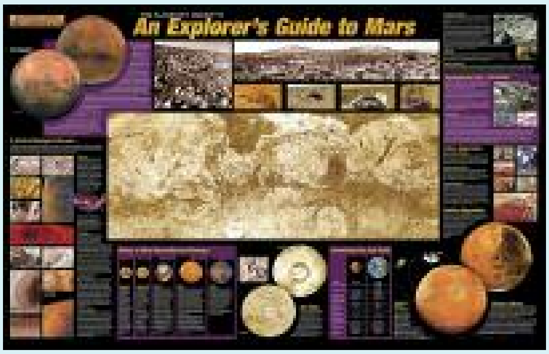

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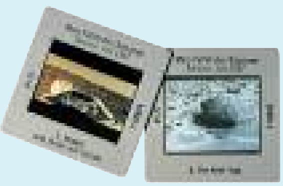

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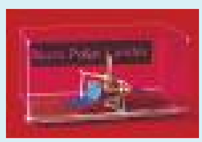

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Anatoly Gordienko, 5th year student of the National Aerospace University n.a. N.E. Zhukovsky, Kharkov, Ukraine

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THE PLANETARY SOCIETY
65 North Catalina Avenue
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