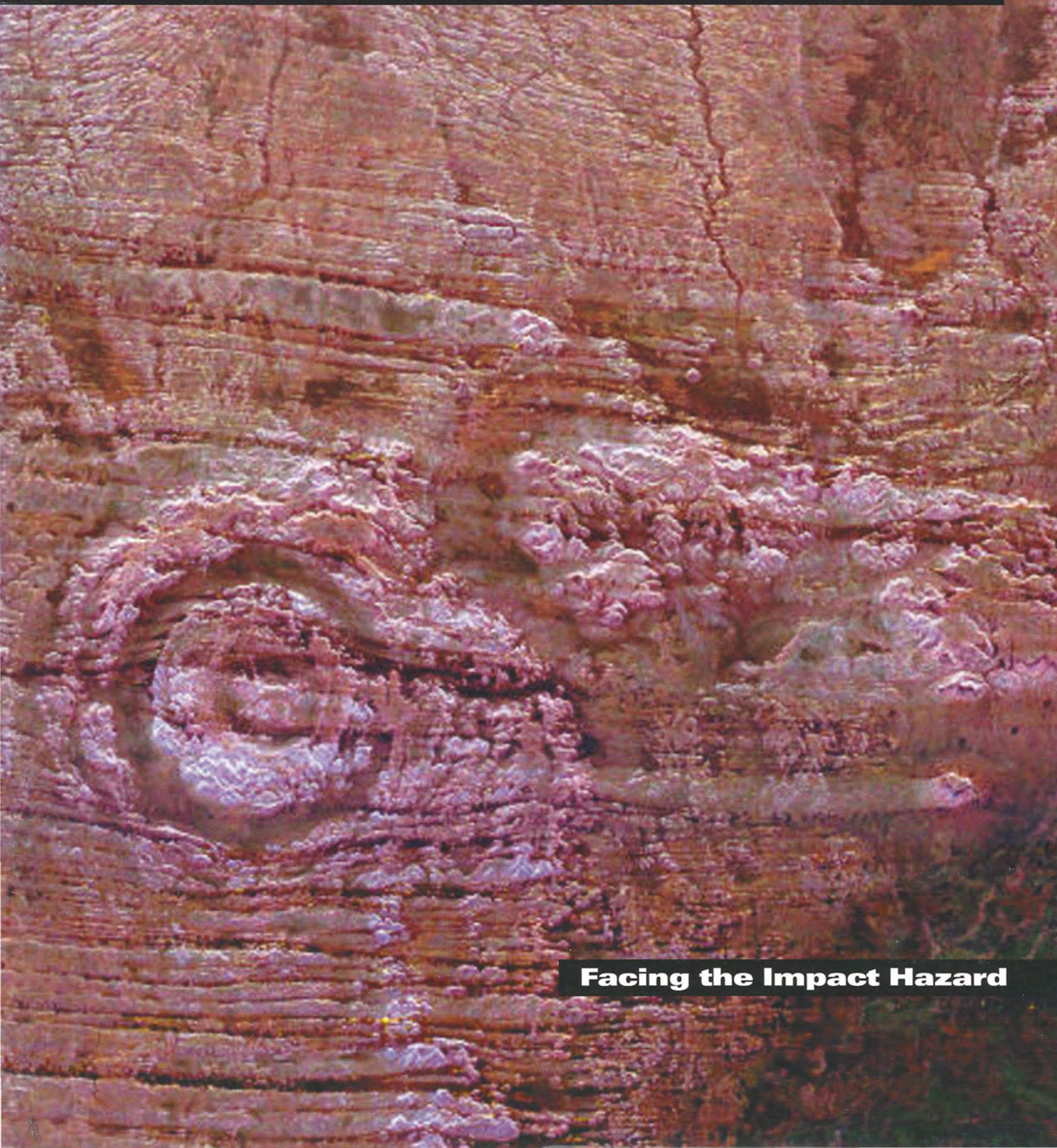
The
# PLANETARY REPORT

Volume XX Number 3 May/June 2000



Facing the Impact Hazard

**On the Cover:**

Might these faint circles be the scars of past blows to Earth's face? The concentric ring structure left of center is the Aorounga impact crater in northern Chad. Scientists are using radar imagery to study the possibility that Aorounga is part of a "crater chain" formed several hundred million years ago by pieces of an asteroid or comet. A second crater appears to sit in the middle of this picture, and the dark, partially circular trough at right of center could be a third. The area shown is 45 by 40 kilometers (28 by 25 miles) in size. This image, captured in 1994 by the Spaceborne Imaging Radar-C/X-Band Synthetic Aperture Radar onboard the space shuttle, penetrated the Sahara's sand to reveal these otherwise invisible geologic features. Image: JPL/NASA

# From The Editor

"It was the best of times, it was the worst of times." Recent events in the space program and in The Planetary Society have put me in a Dickensian frame of mind: *Mars Climate Orbiter, Mars Polar Lander*, both *Deep Space 2* probes, all lost due to simple mistakes and misjudgments piling up on each other. An election-year Congress with a few members who smell blood and see easy prey in NASA. Problem after problem in finishing the long-delayed space station. If we dwell on such things, it does indeed seem to be the worst of times for space exploration.

But consider a few happier thoughts: *Mars Global Surveyor* continues to send us some of the most spectacular and informative findings ever returned by a planetary mission. NEAR *Shoemaker* is orbiting a near-Earth asteroid, teaching us in detail about the small objects that share our solar neighborhood. And there are many missions still to come.

At The Planetary Society, we are being presented with exciting opportunities every day: new members and friends, extrasolar planet projects, exciting new ways to reach the public, growth in the Search for Extraterrestrial Intelligence, and new partnerships with research institutions and corporations. So much is being offered to us, and we have so much to look forward to. I prefer to think that we are just entering the best of times.

*—Charlene M. Anderson*

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*The Planetary Report* (ISSN 0736-3680) is published bimonthly at the editorial offices of The Planetary Society, 65 North Catalina Avenue, Pasadena, CA 91106-2301, 626-793-5100. It is available to members of The Planetary Society. Annual dues in the US are $25 (US dollars); in Canada, $35 (Canadian dollars). Dues in other countries are $40 (US dollars). Printed in USA. Third-class postage at Pasadena, California, and at an additional mailing office. Canada Post Agreement Number 87424.

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A Publication of
THE PLANETARY SOCIETY

# Members' Dialogue

### Faster, Better, Cheaper . . . Pick Two

I have read Tom Heinsheimer's letter to Members' Dialogue in the March/April 2000 issue of *The Planetary Report* and have the following comments to make.

Looking at the financial situation for this type of science, and the reluctance of the American Congress to fund such endeavors, it will probably take some 20 years, as he is suggesting, if NASA does it alone.

However, I believe that his second point is the key to make this thing move forward. It could be done faster should NASA, the European Space Agency (ESA), and the Russian and Japanese space agencies participate. The European Union is setting aside several billions of euros for science and applied research, and it would probably not be impossible, or improbable, for NASA plus ESA (and others) to join forces and get humanity to Mars 10 years or so earlier. It is much more likely that humankind will get to Mars faster with a joint program than if the USA does it alone.

Furthermore, any coordinated program of that sort makes for a more united world, which will thrill the public in a lot of countries and increase the support for science in all of the participating nations. It will also expand humanity's vision beyond planet Earth itself.

—ROGER NORDIN,
*Antofagasta, Chile*

After reading a recent issue of *The Planetary Report* where many comments were offered asking members of The Planetary Society not to be disheartened or discouraged regarding the recent series of NASA failures and to maintain their enthusiasm for the vision of eventual colonization of Mars, I felt moved to offer a comment, specifically regarding the failure of the *Mars Climate Orbiter* (*MCO*).

I am as supportive and enthusiastic as anyone about our continued exploration of space, including human missions (preceded by lots of robotic missions, please). I am still enthusiastic and dedicated. However, I have one other emotion when it comes to the apparent reason for the *Mars Climate Orbiter*'s failure: I am angry!

How could the fouling up of English and metric units happen in this day and age? This is an unforgivable error at this stage of the evolution of engineering and science. When I started my engineering career, we were expected to hand our design calculations to one of our peers for a complete going over. Depending on the complexity of the design, this could involve several days and often meant taking it home for an application of midnight oil. It was expected, and it was built into the schedule and the budget. No design supervisor would consider sitting down for a design review if the peer review hadn't taken place. I never heard of an error of the type mentioned in connection with the *MCO* making it out of the design department. And even if it had happened, there were plenty of other reviews down the line that would have caught it!

There are too many "mutual admiration society" comments in the face of this kind of snafu. We need more "tell it like it is" comments. I offer this one.

—PETER W. KALIKA,
*Simsbury, Connecticut*

Several articles in the March/April 2000 issue of *The Planetary Report* make me uncomfortable as a member of The Planetary Society. The writers' unified and recurring tactic was to downplay the losses of the Mars program and focus on how to feel proud of our past successes and press on with renewed vigor.

Granted, no member would deny the importance of generating more public interest or recruiting new Planetary Society members in support of our cause, and no one would prohibit the use of persuasive language in doing so. [But] I would much rather see the problems of "faster, better, cheaper" adequately addressed, debated, and resolved than listen to the "rah rah" platitudes of a mutual admiration society. Patting ourselves on the back won't propel us forward.

—ROBIN McLEOD,
*Ailsa Craig, Ontario, Canada*

The correct expression is: "faster, cheaper, better—pick two out of three." If you want it faster and cheaper, it will be unreliable. If you want it faster and better, it will be more expensive. If you want it cheaper and better, it will be slower.

In the 1970s, NASA ran the *Apollo*, *Voyager*, and *Viking* programs choosing "more expensive." What Dan Goldin has given us in the 1990s is unreliable. In the present political climate more expensive is not an option (except for the International Space Station, where politics trumps good sense). Technology matures so rapidly that a delay can mean a much more sophisticated mission for the same cost.

I suggest you push for cheaper, better, slower as the most appropriate of the three choices.

—FRANK WEIGERT,
*Wilmington, Delaware*

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OPINION:

# Astronomy: Eyes Wide Shut

**by David Jewitt**


***Our planet has been battered countless times by asteroids and comets that frequent our neighborhood. If they hit in the right place, and if they are large enough, they can bring untold death and destruction to our defenseless world. It has happened before.***

***In the past decade, we've captured many images and learned a lot about asteroids and comets—and have found none that is threatening. However, scientists report that there are almost a thousand NEOs larger than a kilometer (0.6 miles) in diameter—and at the current rate of discovery it will take 20 years to find 90 percent of them. Here is a sampling of close (but safe) encounters we've had with these little pieces of our solar system. Clockwise from top left:***

*1. On August 28, 1993* Galileo *captured images of asteroid 243 Ida and its tiny moon Dactyl. This enhanced color composite was created from the sequence of pictures in which Ida's satellite was originally discovered.* Image: JPL/NASA

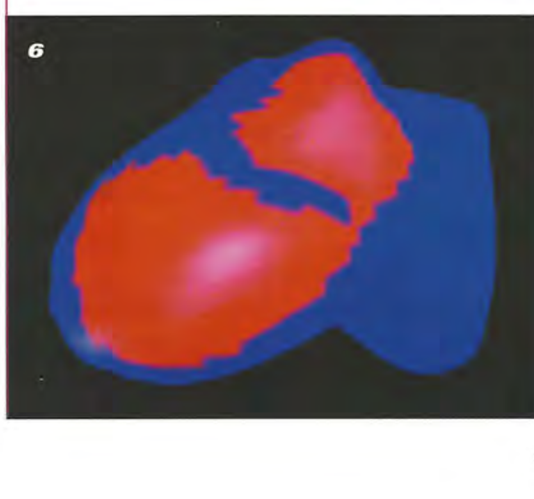
*2. This is the first image mosaic taken of the main-belt asteroid 253 Mathilde. NEAR* Shoemaker *captured this shot on June 27, 1997 as it first approached Mathilde. Most of the asteroid is shadowed here because the Sun was behind it at the time.* Image: JHU/APL NASA

*3. In the spring of 1997, comet Hale-Bopp became a lovely fixture in Earth's skies. This photo was taken from southern Arizona on the evening of April 9.* Photo: Ken Matesich

*4. Just one year earlier, comet Hyakutake paid Earth a visit. Shigemi Numazawa took this picture from Kami-hayashi, Japan with his high-speed Schmidt camera on March 20, 1996.* Photo: Shigemi Numazawa

*5. If an incoming object is small enough, like the tiny grains of comet debris that produce meteor showers, it will simply burn up in Earth's atmosphere. This dramatic example of a Leonid meteor was photographed on November 18, 1999 near Degali, Norway.* Photo: Arne Danielsen

*6. This computer model of Eros was built using data from NEAR* Shoemaker*'s X-ray/gamma-ray spectrometer. The red areas represent minerals that "glowed" in response to two solar flares this past March (see page 17 for more information).* Image: Goddard Space Flight Center/NASA



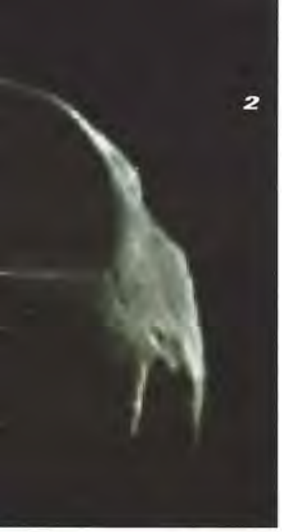

Astronomers like to forget that the roots of their subject lie in ancient superstitions about the influence of the cosmos on everyday affairs. In fact, astronomy and astrology were closely intertwined as recently as four centuries ago, when Tycho Brahe laid the foundations of modern astronomy while simultaneously maintaining a lucrative business in personal horoscopes. Modern astronomers generally scoff at such superstitious beliefs, so it is somewhat ironic that science has in the past few decades uncovered compelling evidence for celestial interference in terrestrial matters.

It is now clear that asteroids occasionally wander from the main belt beyond Mars because of chaotic instabilities caused by Jupiter. Some of these errant asteroids strike the Earth with terrible consequences. Rabinowitz et al. report that the number of threatening near-Earth objects (NEOs) larger than 1 km in diameter is only half the previous estimates. But we still have no effective means of detecting them all, and no form of self-defence.

The Earth bears the scars of previous encounters with NEOs. Hundreds of impact craters, some the size of small American states, have been discovered on the surface of our planet. Each was produced by a devastating explosion that must have been fatal to life in the surrounding areas on scales from local to global (Figure 1, page 5). The Cretaceous-Tertiary mass extinction of 65 million years ago seems to have been triggered by the impact of an asteroid 10 km in diameter. Ten thousand people killed by 'falling stones' in Shanxi Province, China, in 1490 were possibly the victims of a much smaller and thoroughly fragmented projectile. Still more recently, on 30 June 1908, 1,000 square kilometres of Siberian pine forest in Tunguska were blown flat by a 10-megaton atmospheric blast caused by a 70-metre asteroid.

The gradual acceptance of the evidence for impacts by asteroids (and comets) has led naturally to questions about the magnitude of the threat posed by NEOs to life on Earth. Rabinowitz and colleagues provide the most recent and best controlled estimate of the number of large, potentially Earth-threatening NEOs.They report that there are nearly 1,000 NEOs larger than 1 km in diameter and that, given the present rate of discovery, it will take 20 years for 90% of these objects to be found. Should we worry?

The answer depends on the number of fatalities to be expected, but also on personal assessments of risk. The number of NEOs found by Rabinowitz et al. is within a factor of two of previous estimates based on less-controlled samples, so published estimates of impact mortality are essentially unchanged. Considering events of all energies there is about 1 chance in 20,000 of being killed







by an impact during the course of a human lifetime, similar to the likelihood of being killed in an airplane accident. The perception of risk from impacts is smaller than for being killed in a plane crash because planes crash at a steady rate with (relatively) few deaths per event, whereas lethal impacts are rare but kill a lot of people. At the very least, the potential consequences of impact are large enough to cause concern.

In the past decade, thanks to several reported near-miss encounters with small objects, the impact threat has become a subject of intense interest to the general public (spawning the popular movies *Deep Impact* and *Armageddon*). In 1994, the United States House Committee on Science and Technology went so far as to order the US space agency NASA to "catalogue within 10 years the orbital characteristics of all (Earth-orbit-crossing) comets and asteroids that are greater than 1 km in diameter". This particular cut-off diameter was picked in part because 1-km NEOs are thought to be the smallest objects capable of wreaking global havoc (for example, by disrupting the climate and shutting down photosynthesis). Smaller objects cause regional damage but would be unlikely to precipitate a major extinction like the Cretaceous-Tertiary event.

Last summer, astronomers devised a new risk-assessment scale, similar to the Richter scale used for earthquakes, to help the public understand the hazard posed by a given NEO. The so-called Torino scale ranges from zero (no chance of a collision) to 10 (certain collision causing global devastation). No known NEO has yet had a Torino number greater than one. This is just as well because we presently have no coherent plan of action should a real threat arise. The simplest option—massive evacuation of the impact site—would be impractical because of the positional uncertainties and large numbers of people involved, and would be ineffective because the damage from large NEOs will be global. One option that has been discussed is the thermonuclear destruction of the incoming NEO (a bad idea because the shower of debris produced by the exploding NEO might be as damaging as the initial object, and would be radioactive). Given enough time, the NEO might be deflected from an Earth-intersecting path by a series of smaller explosions, or by attaching rockets or solar sails that use radiation pressure from the Sun.

The focus on NEOs larger than 1 km ignores the threat from smaller but much more numerous objects. The Earth's atmosphere offers little protection against objects larger than 100 metres in diameter. These smaller objects outnumber NEOs larger than 1 km by a factor of 100, so they are much more likely to strike in our lifetimes. There is a 1% chance that the Earth will be struck by a 300-metre NEO in the next century. Such an impact would deliver a withering 1,000-megaton explosion and cause perhaps 100,000 deaths. If the impact occurred in or near a densely populated region—the eastern seaboard of the United States, for instance, or Western Europe or coastal Asia—the fatalities could easily rise into the tens of millions.

Neither can we take refuge in the fact that 70% of the Earth is covered by oceans. Impact-induced tsunamis could wipe out coastal cities over a wide area. So, to have practical value, surveys should not be limited to the (observationally easy but numerically rare) 1-km NEOs, but should instead catalogue objects at least down to the few-hundred-metre size range. What is needed is a more ambitious survey to completely identify the population of small, potentially threatening NEOs.

The strategy for such a survey has been explored by Alan Harris of the Jet Propulsion Laboratory. He argues that the whole sky must be surveyed on a monthly basis with a sensitivity about 100 times greater than current NASA-sponsored surveys. How can this be done? A large (6-8-metre) telescope is required, with a wide field of view tiled with CCD (charge-coupled device) optical detectors and connected to a massive computer array capable of meeting the huge data-processing demands. The technology exists, and tentative designs are beginning to appear. Such a telescope, which would have many applications in other branches of astronomy, is projected to cost about $100 million (about half the price of a Jumbo jet). What is missing is any sign that such a facility will be funded by governments and their agencies. Perhaps astronomers can attract the interest of private donors in the search for threatening NEOs. If not, it seems we will have to face the asteroidal impact hazard with our eyes wide shut.

*David Jewitt is a professor at the Institute for Astronomy, University of Hawaii.*

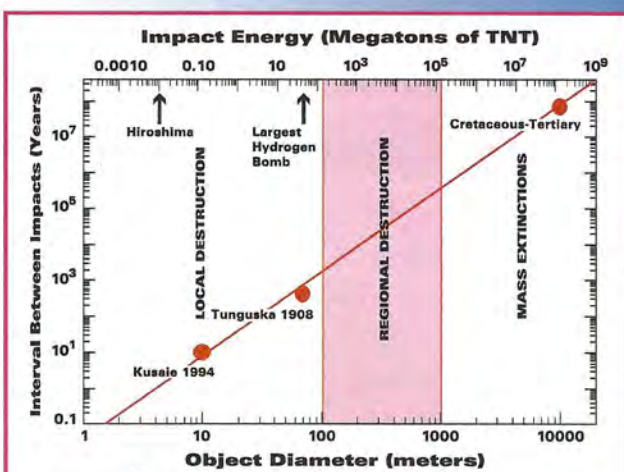



**Figure 1: Previous impacts by near-Earth objects (NEOs).**

*Graph: David Jewitt*

# SHOEMAKER GRANTS:
# A Little Money, Lots of NEOs

In December 1997, the predawn sky over the Arctic blazed with the unexpected, widely seen flash of an incoming object. This is how the Greenland fireball might have appeared to those who watched it burn up in Earth's atmosphere. Painting: Don Davis *by Daniel D. Durda*

The spectacular success of the NEAR mission to Eros has given us a close-up view of just one of the many thousands of near-Earth objects (NEOs) that orbit the Sun in the vicinity of our planet. The latest estimates indicate that there are about 500 to 1,000 near-Earth asteroids larger than 1 kilometer (0.62 miles) across and more than 100,000 objects larger than 100 meters in diameter. The impact of a 1-kilometer asteroid on our planet would have global environmental and economic consequences, while the impact of a 100-meter object could devastate a modern city.

Nearly 500 NEOs have been discovered so far, only a small fraction of the number of objects large enough to cause significant damage here on Earth after the inevitable celestial traffic accidents. Government support for NEO search and follow-up programs has improved a bit in the last couple of years, and the rate of NEO discoveries recently has dramatically increased. Still, the total number of professional astronomers surveying the sky for potentially hazardous NEOs remains rather modest, and those involved in the search can barely keep pace with the need for follow up and further study of newly discovered NEOs (to understand their physical characteristics, such as shape or composition).

In 1997, The Planetary Society began the Gene Shoemaker Near-Earth Object Grant program in honor of planetary geologist Eugene Shoemaker, who pioneered our understanding of the role of impacts on Earth and who dedicated much of his life to NEO research. The purpose of the Shoemaker NEO Grant program is to increase the rate of discovery and follow-up studies of NEOs by enabling dedicated amateurs, observers in developing countries, and professional astronomers who, with seed funding, could greatly increase their programs' contributions to critical NEO research. The 1997 recipients of Shoemaker NEO Grants were Gordon Garradd of Australia, Kirill Zamarashkin of Russia, Walter Wild of Chicago, Illinois, and Bill Holiday of Corpus Christi, Texas. In 1998, the Society awarded grants to Stefan Gajdos of the Slovak Republic, Paulo Holvorcem of Brazil, and Frank Zoltowski of Australia.

## Awarded Money at Work

Since being awarded a Shoemaker NEO Grant in 1998, observers at the Modra Astronomical Observatory in the Slovak Republic, led by Stefan Gajdos, have redefined their NEO observing program. The team is now focusing on confirmation and astrometric follow-up observations of newly discovered NEOs that are deemed high priority by the IAU (International Astronomical Union) Minor Planet Center. With the Shoemaker NEO Grant, Gajdos' team has established a wireless Internet connection, allowing rapid communication with the Minor Planet Center and their listing of high-priority NEOs. With computer hardware and software upgrades, Gajdos' team made nearly 500 astrometric measurements of more than 100 objects, including their independent "discovery" of the Aten asteroid 1999 SN5. Gajdos reported on his team's progress and results at the Workshop on International Monitoring Programs for Asteroid and Comet Threats (IMPACT), held July 1 to 4, 1999 in Torino, Italy. He was invited to give a further presentation at the UNISPACE III Conference in Vienna, where he spoke on "The Role of Small Observatories in the International Coordinated NEO Effort."

South of the equator, at the Universidade Estadual de Campinas in Brazil, Paulo Holvorcem has finished installation of a new robotic telescope mount and a new 12.5-inch telescope dedicated to NEO discoveries and follow-up observations. Collaborating with observers in Oregon and Arizona, Holvorcem has field-tested his automated telescope-pointing and asteroid-detection software and is now ready to observe in Brazil. Observations from south of the equator fill a particularly important niche in NEO discovery and follow-up, because most of the large, government-funded programs to detect NEOs are run from Northern Hemisphere observatories. Follow-up observations in the Southern Hemisphere give us longer arcs for calculating orbital paths of newly discovered NEOs, aiding in the recovery of these objects years later.

## Notes From a NEO Hunter

**by Frank Zoltowski**

*The following is from an e-mail to Shoemaker NEO Grant Coordinator Dan Durda, February 15, 2000.*

I had to close up shop in Australia when my job went away in October and moved to the Albuquerque, New Mexico area to take up a position with a small high-tech company. One of the criteria for where I wanted to live was based on keeping up with my asteroid observations. I purchased a home in Edgewood, about 20 miles east of Albuquerque. The drive to work can be a bit long, but I have fairly dark skies from which to observe.

To test the capabilities of my setup in New Mexico, I chased up a 20.5 plus magnitude Spacewatch NEOCP object on two nights (the second fainter than magnitude 21; quite good results for a 12-inch scope). The object was 2000 BF19, which later made headlines for a few days as a possible Earth impactor. Since the object was at my detection limit and, more important, the weather was not very friendly, I could not make any more contributions to 2000 BF19.

A week later, Andrea Boattini posted a message on the Minor Planet mailing list which was rather scathing about the press releases on 2000 BF19. I have to agree with him on many points; one is that very little or no recognition is given to the "little guy," even for significant contributions made at small amateur sites. I really can't complain because I had my "15 minutes of fame" in Australia for my observations of 1999 AN10.

It is fun to think back on it. At the time it was a bit of a pain. I got about two hours of sleep between two 12-hour work shifts because of radio interviews. Had to maintain tact on national TV (*Today Show*). Maybe it's time the little guy, of which there are many, who chases asteroids for the love and fascination, got a bit of recognition. It is well deserved.

*Frank Zoltowski, amateur astronomer, was a 1998 recipient of a Shoemaker NEO Grant.*

*Author Dan Durda is also a space artist whose work has appeared in* The Planetary Report *several times. In* Happy Birthday-2028, *he depicts asteroid 1997 XF11 as it may look passing very close to Earth on his 63rd birthday.*

*Painting: Dan Durda*

Frank Zoltowski made news in Australia last year with important observations of the asteroid 1999 AN10. Discovered by the LINEAR program, 1999 AN10 at first appeared remotely capable of impacting Earth decades in the future. Zoltowski's follow-up observations played a crucial role in refining calculations of the asteroid's orbit and allaying concern over a future impact. Zoltowski continues his observations from near Albuquerque, New Mexico, where he concentrates on fainter and somewhat faster-moving NEOs. The AP-7 CCD he now uses, purchased with the help of Shoemaker NEO Grant funding, allows him to make observations of objects that are not getting sufficient follow-up (because they are too faint for most amateur observers to detect). This year, Zoltowski has already made confirming observations of a new comet discovered by the LINEAR program and followed up the Spacewatch discovery of asteroid 2000 BF19, which made news early this year when it, like 1999 AN10, appeared to have some chance of impact in the future.

## Call for Grant Applications

The Planetary Society invites applications for a new round of Shoemaker NEO Grants to fund observational programs, NEO research programs, and projects that develop international collaborative research. The grant program is coordinated by Daniel D. Durda, an asteroid researcher at the Southwest Research Institute in Boulder, Colorado. An international panel of researchers will advise the Society in awarding the new grants.

The panel includes Richard Binzel, Massachusetts Institute of Technology; Andrea Caruzi, Instituto di Astrofisica Spaziale; Brian Marsden, Harvard-Smithsonian Center for Astrophysics; Alain Maury, Telescope de Schmidt-Observatoire de la Côte d'Azur; Syuichi Nakono, Japanese astronomer; and Jorge Sahade, La Plata Observatorio Astronomico.

The selection committee will consider projects that enhance the rate of discovery and/or follow-up observations of NEOs or advance knowledge of the physical properties of NEOs. Applications from anyone anywhere will be considered. Approximately 5 grants will be awarded, with average grant amounts ranging from about $3,000 to $10,000.

For further information, applicants for Shoemaker NEO Grants are encouraged to visit the Society's NEO website at **planetary.org**.

The deadline for applications is September 1, 2000. Send your application to:

**Shoemaker NEO Grant Program**
**The Planetary Society**
**65 North Catalina Avenue**
**Pasadena, CA 91106-2301**
**USA**

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*Daniel D. Durda is a planetary scientist at the Southwest Research Institute in Boulder, Colorado, where he studies the collisional evolution of asteroids. A pilot, cave diver, and space artist, Dr. Durda is also the Coordinator for The Planetary Society's Shoemaker NEO Grant program.*

# Amateur Astronomers Answer the Call

by Brian Marsden

Perhaps a dozen amateur astronomers or groups of amateurs around the world are nowadays regularly reporting follow-up observations of newly discovered NEOs, both asteroids and comets. They are quick to act on the notifications of new NEO candidates, posted on the Minor Planet Center's NEO confirmation page (**http://cfa-www.harvard.edu/iau/NEO/ToConfirm.html**). Amateur astronomers are sometimes the first to make NEO observations after the night of discovery, and their persistence on subsequent nights frequently speeds up the process of making the formal announcement of a confirmed NEO on a Minor Planet Electronic Circular. They may savor for a moment seeing their names as contributors on that first circular, but they keep performing follow-up during the ensuing weeks and months. Thanks to their work, we can get to know a new NEO's orbit well enough to "recover" it (predict where and when it will next appear) in subsequent years. Such a recovery can be key in demonstrating that a particular NEO presents no threat to Earth in the foreseeable future.

Among the amateur astronomers receiving a Shoemaker NEO Grant during the first two grant cycles, Gordon Garradd, Paulo Holvorcem, and Frank Zoltowski continue to be highly dedicated contributors. It is no accident that these observers were living and working in the Southern Hemisphere when they received their awards. The lack of professional programs in that half of the world continues to be a serious problem, and their contribution has been enormous.

Few will forget how Zoltowski made a skillful recovery of the infamous 1999 AN10 in May 1999, when it was well south of the Sun and becoming visible again after a three-month hiatus. A prediction had appeared in the media of a possible Earth impact by this object in some four decades. Zoltowski's recovery observations indicated a substantially increased impact probability, showing that a prerequisite close-approach to Earth in 2027 was still "on." Two months later, identification of 1999 AN10 in Palomar Sky Survey images from 1955 removed the possibility of danger for at least the next century, but this recognition would have been well nigh impossible to make in the absence of Zoltowski's May recovery.

Holvorcem, an observer in Brazil, used his Shoemaker NEO Grant to upgrade his telescope aperture from 20 to 36 centimeters (from 8 to 14 inches). This upgrade necessitated a break in his observing, but Holvorcem was not idle during this time. He kept in the game by measuring the images obtained by an observer in Oregon. Adding to the geographical irony, Garradd, who has for many years made key observations in New South Wales, Australia—first with a 25-centimeter (10-inch) and later a 45-centimeter (18-inch) telescope—spent two months in late 1999 observing from Arizona!

For the next round of Shoemaker NEO Grants, we continue to need applicants from the Southern Hemisphere! We also need some from the north, of course, and it is probably important to emphasize the need for larger telescopes, in the 60-centimeter (24-inch) class and larger. Larger telescopes are especially helpful for recovery activities; many of the new discoveries, particularly by Spacewatch, are fainter than before.

Larger telescopes help in distinguishing comets from asteroids, often part of the follow-up process. Comets may go unrecognized in discovery images because discovery imaging uses short exposures to increase sky coverage. To establish an object as an active comet, it is becoming more and more necessary to use long exposures with large telescopes.

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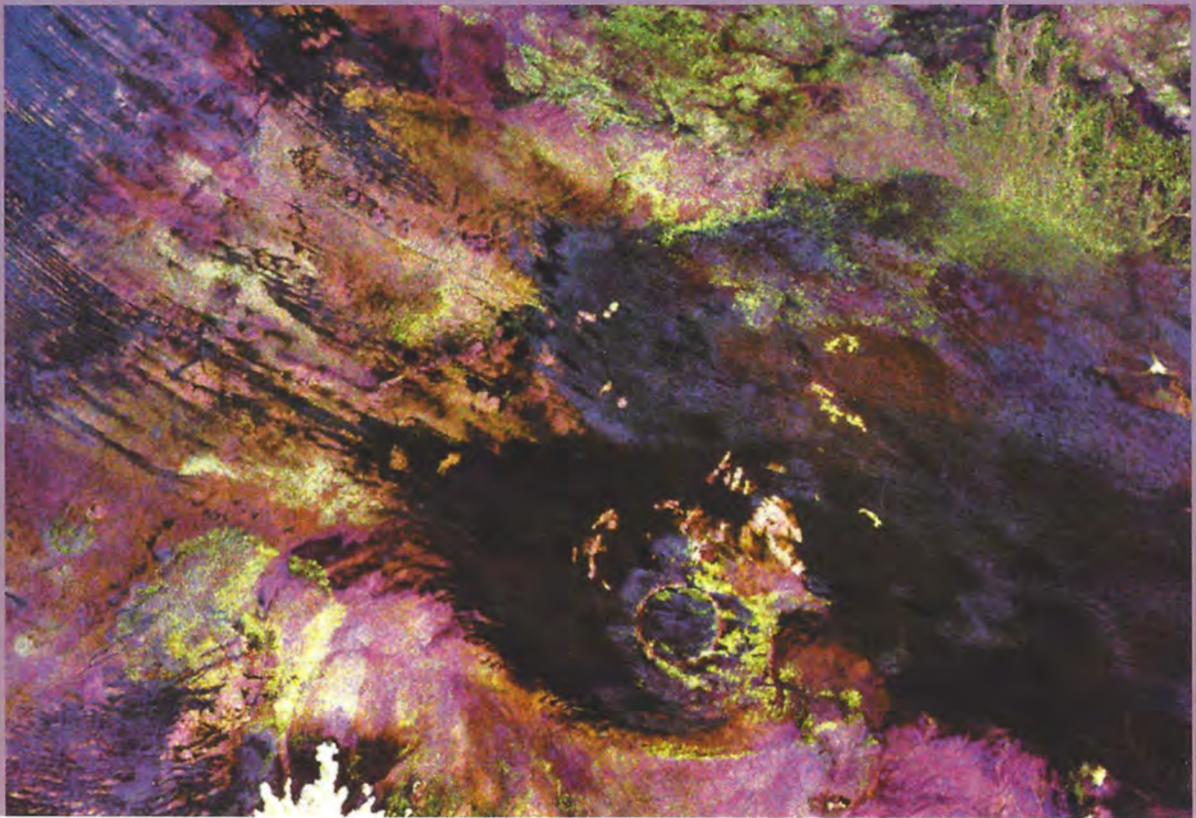
*Brian G. Marsden is Director of the Minor Planet Center of the International Astronomical Union.*



***This space radar image shows the Roter Kamm impact crater in southwest Namibia. The radar-bright circle in the center is the crater's rim. Geologists believe the crater was formed by a meteorite that hit Earth about 5 million years ago. Roter Kamm is a moderate-sized impact crater, 2.5 kilometers (1.5 miles) in diameter and 130 meters deep. In a conventional aerial photograph, the brightly colored surfaces immediately surrounding the crater cannot be seen because they are covered with sand.***

***This data set was captured on April 14, 1994 by the Spaceborne Imaging Radar-C/X Band Synthetic Aperture Radar (SIR-C/X-SAR) instrument onboard the space shuttle. The colors in this image are not natural but represent various radar reflectivities.***

*Image: JPL/NASA*

# Human Exploration of Near-Earth Asteroids

by Daniel D. Durda

The NEAR spacecraft's rendezvous with Eros is providing our first close-up look at one of thousands of near-Earth asteroids (NEAs) that orbit the Sun among the inner planets of our solar system. NEAR's fascinating images of Eros reveal a wildly undulating surface covered by impact craters of various sizes and strewn with myriad blocks of rock ejected from the craters. Adventurous explorers will naturally ask what it might be like to travel to and explore an asteroid like Eros in person. Let's take an imaginary trip to a small NEA and preview the exciting journey that future human explorers have in store . . .

## Making the Trip

The imaginary target asteroid of our exploratory mission is a 1-kilometer (0.6 mile) -diameter NEA traveling on an orbit closely resembling Earth's. With a moderate orbital eccentricity and low inclination, our target asteroid is relatively easy to travel to, rendezvous with, and return home from. Like many other NEAs, our target is easier to get to than our own Moon! Because of the similarity of its orbit to Earth's, though, the asteroid's synodic period (the time between close approaches to Earth) is quite long, and opportunities to visit this particular NEA come only every several years.

Our NEA mission has been approved not only because of its intrinsic scientific value but also because it is serving as a "dress rehearsal" for the first human mission to Mars. In much the same way that *Apollo 8* provided an important engineering test and an inspiring preview of the first lunar landing, our mission is paving the way for the first human journey to the Red Planet.

The transit time from low-Earth orbit to our asteroid has been eight months, fairly typical for the various targets we considered. Interestingly, our crew has not had to venture very far from home during the flight. The transfer orbit from Earth to the asteroid has taken us no farther from Earth at any time during the mission than about 0.15 astronomical units. That's only 22.4 million kilometers (13.9 million miles), or about 58 times as far from Earth as the Moon! Even at our farthest point during the flight, Earth has appeared in the spacecraft windows no smaller than about 2 arc minutes across, just resolvable to the naked eye as a brilliant blue-white disk. It has been a reassuring sight along the way!

## Meet "The Rock"

Upon arrival at the asteroid, our spacecraft enters a fairly high orbit to conduct a preliminary survey of the asteroid's shape and gravitational field, much as the NEAR spacecraft did when it arrived at Eros. As we lower the vehicle's orbit closer to the asteroid and refine our knowledge of its gravitational field, the crew is busy studying the rocky surface, mapping the distribution of minerals, and scouting out safe but scientifically interesting sites to visit. Our spacecraft, "parked" in a stable orbit, serves as a base of operations for several excursions to the asteroid's surface during our two-week exploration.

Our small asteroid presents us with a geologic environment quite different from that on the Moon or Mars. There are myriad craters of various sizes and a dusty, rock-strewn regolith to be sure, but there ends any great similarity to the lunar surface experienced by the *Apollo* astronauts. The topography in some places here is quite extreme. Ridges and facets defining the overall shape of the asteroid, saddles between overlapping large craters, and large ejecta blocks make for a wildly varying terrain with steep slopes. On a world the size of a small town, the horizon is never far away—the vista over the other side of the next hill might well fall away beneath you to encompass a whole other side of the asteroid.

Our crew has to deal with rapidly changing lighting conditions. The rotation periods of many small NEAs are much shorter than the several-hour surface stays that astronauts' space suits allow. Our crew sees several sunrises

***Many near-Earth asteroids would be easier for astronauts to get to than our Moon, and a human mission to one of these small bodies would be a good practice session before we send people to Mars. These two paintings show how future exploration might look.***

***Left: Two astronauts venture out of their lander to explore an asteroid's cratered surface. Below: Like bumblebees hovering over a flower, two astronauts in special "sample collection" spacesuits gather specimens from the surface of one body as another asteroid looms in the sky overhead.***

*Paintings: Pat Rawlings*

and sunsets during their excursions to the surface.

The very low surface gravities and rapid rotation of our NEA make moving around quite interesting. The surface gravity here is only 1/28,000th that of Earth. Even fully decked out in our space suits, we weigh barely as much as a handful of paperclips. When you hold a rock out in front of you and drop it, it takes some 75 seconds to settle to the dusty surface. We long ago gave up any notion of walking or driving rovers across the undulating landscape!

## Moving in Milli-Gravity

In some ways, the near-weightless environment has made it easier on our crew. We've been able to reach just about any point on the asteroid from our orbiting mothership, and we've been able to move around on and near the surface by simply drifting over rough terrain and high obstacles.

The surface environment poses some interesting challenges, however. We have to use highly capable transportation and navigation systems for moving about the asteroid's surface. Our personal transportation and maneuvering units are similar to the Manned Maneuvering Units once used by space shuttle astronauts. However, transiting back and forth between the orbiting spacecraft and the asteroid's surface uses up plenty of propellant and precious time in the suits.

We have to be particularly careful while flying the maneuvering units near the asteroid's surface. The exhaust from the gas thrusters easily stirs up slowly settling dust that can obscure visibility and make a mess of our equipment and scientific samples.

Once on the surface, our exploration team sets about surveying and photographing the local environment and collecting geologic samples. Instead of bounding about the asteroidal landscape, as the *Apollo* astronauts did on the Moon, here in the milli-gravity environment of a small NEA we work floating over its surface, tethered to the asteroid and work platforms like astronauts repairing a satellite in Earth orbit. Working in this way, we find we have more in common with cave divers than Moon walkers. We enjoy all the benefits of three-dimensional motion, but we have to move with care and finesse, perhaps at times using only a fingertip to move or steady ourselves with our attached tools, instruments, and samples.

With fieldwork completed at one scientific site, we don our maneuvering units again, pull up stakes, and move to another site on the asteroid. After the last ejecta blanket soil sample has been scooped up, when no more hand-picked meteorites will fit in the sample bags, it's time to wrap up the surface-exploration phase of the mission. We depart the asteroid and return to Earth on a four-month trip using the same trajectories and recovery techniques designed for Mars missions.

Sometime in the next one or two decades, such a mission may well be attempted. Before the first footsteps are trod on the red sands of Mars, the black dust of small near-Earth asteroids may be sifted and collected by astronauts learning to explore beyond the Earth-Moon system.

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*Daniel D. Durda is a planetary scientist at the Southwest Research Institute in Boulder, Colorado, where he studies the collisional evolution of asteroids. A pilot, cave diver, and space artist, Dr. Durda is also the Coordinator for The Planetary Society's Shoemaker NEO Grant program.*

# NEAR Shoemaker Goe

*by Charlene M. Anderson*

***NEAR is there. The Near Earth Asteroid Rendezvous spacecraft is now orbiting its ultimate destination, 433 Eros. It has been a long trip: launch in 1996, flyby of the asteroid 253 Mathilde in 1997, misfire of a trajectory correction in 1998, and, finally, rendezvous with Eros on February 14—last Valentine's Day.***

***It has been worth the wait. The pictures and other data are fantastic. We can look forward to a full year of discoveries streaming in from NEAR.***

***Meanwhile, NEAR has acquired a surname:*** **Shoemaker.** ***Gene Shoemaker was a pioneer in the largest sense of the word, extending the science of geology to worlds beyond Earth. Gene played a crucial role in demonstrating that collisions with near-Earth objects have had and may yet have profound effects on our planet and the life that covers it.***

***In 1997, Gene died in a road accident while on a field trip in Australia. Soon after, The Planetary Society established its NEO grant program in his honor. The new name for NEAR*** **Shoemaker** ***is another honor fully deserved.***

***And how Gene would have reveled in the discoveries from his namesake spacecraft! Here are a few of the highlights so far.***

**Two Very Different Asteroi**

*NEAR* Shoemaker *has scored two important firsts in the explorati*
*and, with its June 1997 flyby of Mathilde, it was the first to encou*
*Asteroids are classified into groups based on their colors, as o*
*colors are consistent with "stony" or rocky compositions, typica*
*the asteroid belt. Eros and the two asteroids Galileo encountered,*
*have a dark gray color consistent with a "carbonaceous" compos*
*materials. C-type asteroids, like Mathilde, prevail in the outer par*
*In the montage above, Mathilde (left) and Eros (right) are show*
Shoemaker *from about 1,800 kilometers (1,100 miles). Mathilde's*
*—it is actually six times darker than Eros, with about the same r*

## Chip Off an Old Block?

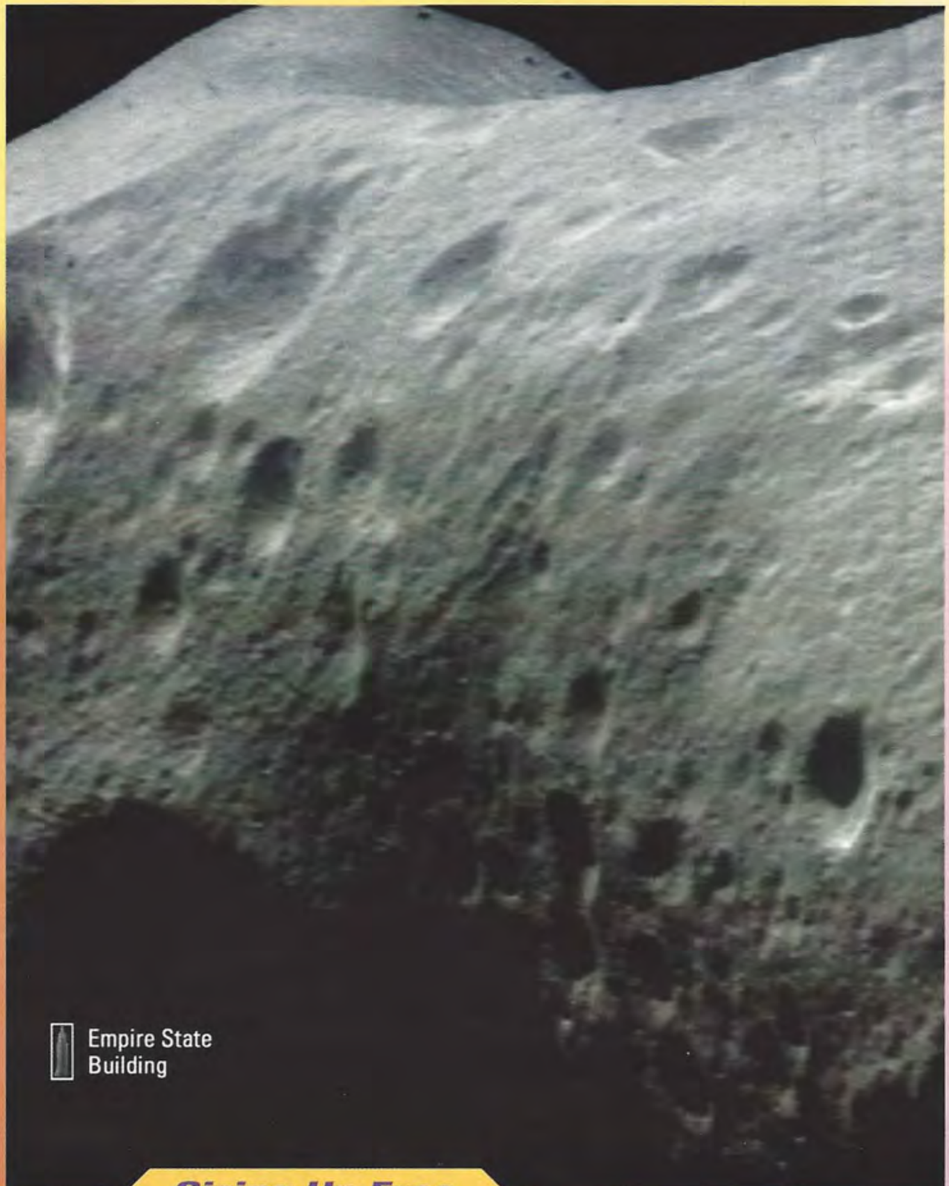
It looks like Eros may be a fragment from a larger asteroid, blasted apart by a collision. In analyzing the images, scientists see traces of layers within the rock. This stratigraphy suggests that some geologic process laid down layer after layer of material. Then another asteroid struck Eros' parent, fracturing it and sending the pieces flying.

In this scenario, volcanism is the likely suspect for creating the layers. Eros today is not large enough to generate volcanic activity, so the layers must have come from an earlier existence. The original asteroid was perhaps the size of Vesta, 500 kilometers (about 300 miles) across or larger.

# s to Work

s

of asteroids—it's the first to orbit an asteroid,
er a C-type asteroid.
erved through telescopes. S-types, whose
orbit closer to the Sun than the midpoint of
aspra and Ida, are all S-types. C-type asteroids
on, rich in carbon compounds and other dark
f the asteroid belt.
at the same scale, both imaged by NEAR
rightness is exaggerated for viewing purposes
ectivity as soot.




**Sizing Up Eros**

*On March 10, 2000, NEAR* Shoemaker *looked down the length of Eros and caught this image revealing a variety of landforms now deemed to be characteristic of this tiny world. The area shown is 10 kilometers (6 miles) from top to bottom. The inset of the Empire State Building puts the asteroid's size into perspective.*

*This image shows craters of varied sizes. The largest craters, such as the two at upper left, have conspicuous brightness (high albedo) on their interior walls. Also at the upper left is a portion of a prominent ridge that nearly wraps around Eros' waist. Near the center of the image, from upper right to lower left, are several broad troughs about 200 meters wide. On the horizon, there are three boulders that are roughly 80 meters across—each nearly the size of a football field.*

*Images: Johns Hopkins University Applied Physics Laboratory/NASA*

Then again, maybe the "layers" we see aren't of volcanic origin. Another possibility is that a giant impact cracked Eros, creating roughly parallel fissures in the rock. Such features might now appear like stratigraphic layers. As a possible comparison, Mars' moon Phobos, which may be a captured asteroid, displays strange parallel grooves. The grooves radiate from the large crater Stickney, formed by a collision that punched in one end of the moon. The leading hypothesis for these grooves is that they are cracks created by the force of the impact.

Life among the asteroids has been more than a little violent.

## *Fluorescing Elements*

Solar flares disrupt communications on Earth, threaten to irradiate astronauts in orbit, and excite certain elements on asteroids to fluoresce. On March 2, in a happy happenstance, an unusually large solar flare reached Eros when the spacecraft had its X-ray spectrometer turned toward the asteroid. The instrument detected emissions from magnesium, iron, and silicon and possibly from aluminum and calcium.

The X-ray instrument is designed to operate when NEAR *Shoemaker* is in a low orbit, 50 kilometers (about 30 miles) above Eros' surface. The spacecraft was fully

**Boulders, Boulders, Boulders**

*One of the most striking features in NEAR* Shoemaker *images of Eros' surface is the abundance of large boulders. This image of the southwestern part of the saddle region, taken March 6, 2000 from a range of 201 kilometers (125 miles), shows a particularly boulder-rich part of the surface. Many of the huge rocks are 50 meters or more in diameter. They are believed to be fragments of Eros' native rock, shattered over eons by the formation of impact craters.*

**Oblique View**

*This oblique view of Eros' large central crater was taken at a resolution of about 20 meters per pixel. Albedo (brightness) patterns on the walls of this crater reveal brighter materials near the tops of walls and darker materials farther down. We can see boulders inside this crater and in the smaller nearby craters. The higher density of craters to the left of the large crater suggests that this region is older than the smoother area associated with the saddle region on the opposite side of the asteroid.*

*Images: Johns Hopkins University Applied Physics Laboratory/NASA*

212 kilometers (132 miles) from Eros when the flare hit, but the opportunity was not to be missed. The unusual intensity of the flare triggered such a strong reaction at the asteroid surface that the spectrometer could read the fluorescence from the greater distance.

The instrument team now is confident that they will be able to develop detailed maps of the elements making up Eros, which will deepen our understanding of small solar-system objects.

## *Bouncing Laser Beams*

By the time you read this, NEAR *Shoemaker* will have entered its 50-kilometer polar orbit, where it will spend 100 days. The spacecraft's laser rangefinder will begin its important work, having already demonstrated that it can gather data from much higher orbits. This bodes well for coming observations.

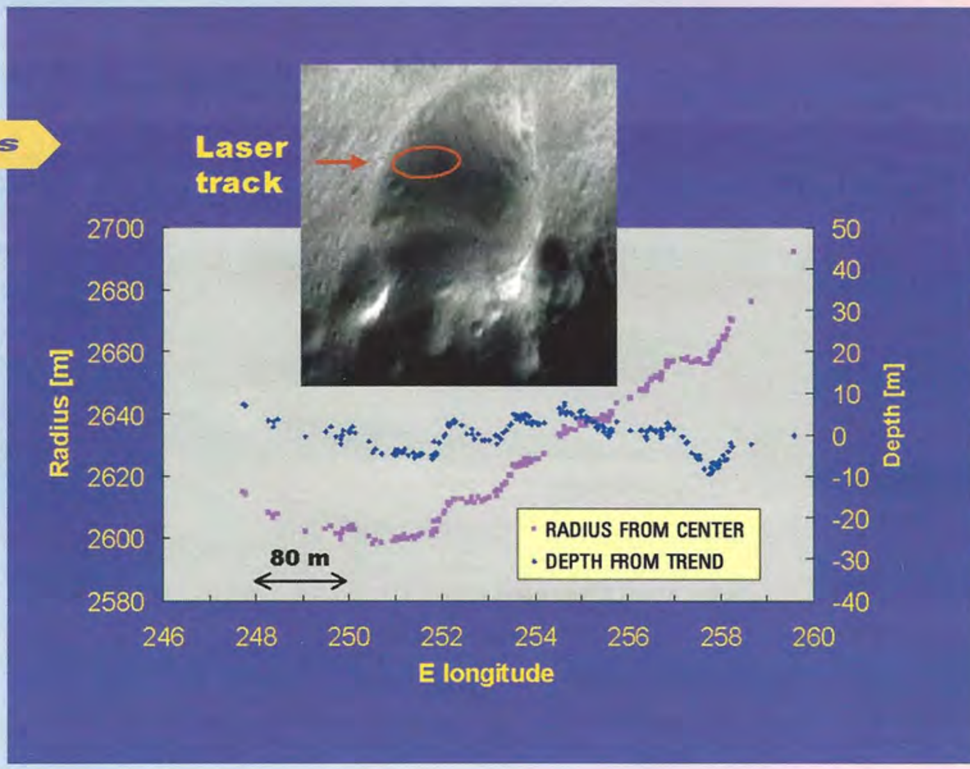
Eros' surface features, as seen through the camera, appear as patterns of dark and light. Powerful as these images are, they cannot present a full picture of the asteroid's topography, for the cameras cannot penetrate shadowed areas, and it is sometimes difficult to distinguish differences in height from differences in surface markings.

## The Sign of the Times

*NEAR* Shoemaker*'s investigation of Eros from low-altitude orbit continues to bring the asteroid's history into sharper focus. This pair of images, taken April 18, 2000 from an orbital height of 99 kilometers (61 miles), shows the dissimilarity of two regions of the asteroid—the image on the left is of highly cratered terrain, typical of Eros, whereas the image on the right, showing the inside of the saddle region, has far fewer noticeable craters.*

*Craters are formed by the explosive impacts of asteroid fragments that have rained onto the surface over the eons. A freshly exposed surface will have fewer craters than a surface exposed to space for a longer time. The lesser number of craters in the saddle shows that it has been wiped clean, or "resurfaced," by geologic processes relatively late in Eros' history.*

## Topographic Profiles




*The NEAR* Shoemaker *laser rangefinder obtained this "staircase" altimetric profile from within the walls of the 6 kilometer (3.7-mile) diameter crater shown in the image inset. The profile represents 10 minutes of data obtained from a range of 217 kilometers (135 miles) on March 2, 2000. The purple points plot a radius from the center of Eros (left axis), and the blue points show the same measurements but with the overall trend removed (right axis).The laser track runs from left to right in a line along the major axis of the red ellipse.*

*The laser profile reveals a series of shallow depressions, about 50 to 80 meters wide and 5 to 10 meters deep, that may be a chain of pits or craters. The staircase profile may be the signature of a series of small ridges. We'll learn more about the spatial structure and origin of the features producing the staircase as the laser rangefinder accumulates more elevation measurements during the one-year mapping mission.*

*Images: Johns Hopkins University Applied Physics Laboratory/NASA*

Eros' laser rangefinder will provide a way to remedy those problems. It will fire a laser at the surface and catch the light that bounces back. This procedure will give researchers measurements of the heights and depths of the ridges, grooves, and craters that mark Eros.

### *Beaming Back to Earth*

Radio is a very useful invention. We can use it to send and receive data from robot explorers far out in space, and we can use it to determine the density of the objects they fly by.

On NEAR *Shoemaker*'s first pass by Eros in December 1998, the radio-science team derived a density for the asteroid of 2.7 grams per cubic centimeter, which is close to the average density of rocks in Earth's crust. Now that the spacecraft is orbiting Eros, they have been able to refine that number to 2.6 grams per cubic centimeter. It looks like Eros is a pretty solid rock.

When a spacecraft flies by or orbits an object, scientists can use the radio signal to measure the distance between Earth and the spacecraft. An Earth station beams the signal up, the spacecraft sends it down, and

**Eros' North Pole**

*As Eros' seasons progress, NEAR* Shoemaker *has been focusing on Eros' high northern latitudes, watching the subsolar point (the point at which the Sun is directly overhead) move from Eros' northern regions to the equator. As this happens, the northern hemisphere is illuminated less and less, and previously dark southern regions come into view. In this image, taken on March 19, 2000, Eros' north pole is in the upper right of the frame. The image was taken from a range of 205 kilometers (127 miles), and the whole scene is 7.4 kilometers (4.6 miles) across.*

**Structural Features**

*This image of the interior of Eros' saddle area, taken at a range of 204 kilometers (127 miles), shows a variety of interesting structural features. On the left wall is a series of closely spaced grooves that follow the terrain downslope. Toward the back of the saddle, on the upper right wall, there is a prominent ridge. Boulders and craters are visible throughout this image, although there are far fewer craters on the left wall than on the right.*

*Images: Johns Hopkins University Applied Physics Laboratory/NASA*

the time it takes for this exchange can be converted to the craft's velocity. Meanwhile, the spacecraft is taking pictures, from which scientists can determine its distance from the object. With velocity and distance, they can determine the density of the object.

During NEAR *Shoemaker*'s quick pass by the main-belt asteroid Mathilde, the radio-science team determined that it is very different from Eros. Mathilde's density is 1.3 grams per cubic centimeter—if it were a bit lighter, it could float in water, which has a density of 1 g/cc. Mathilde is likely a porous object, perhaps a clump of debris remaining from a large impact.

## *Mining for Minerals*

The big difference in density between the two asteroids visited by NEAR *Shoemaker* probably should not come as a surprise. Eros is an S-type (silicaceous) asteroid, while Mathilde is a C-type (carbonaceous). S-types are made mostly of metallic iron mixed with iron and magnesium silicates. Carbon compounds, perhaps similar to coal, are predominant in C-types.

NEAR *Shoemaker*'s near-infrared spectrometer is taking a close look at the minerals that make up this Sun-orbiting rock. The instrument has found evidence of pyroxene and olivine, two common minerals on

## Eros' Shadows

*From the northeast, the Sun illuminates a shadowed feature consisting of three large craters in close proximity. The two largest are each about 4 to 5 kilometers (2 to 3 miles) across. Because the Sun is very low, even small topographic features cast long shadows, making them easy to see. As a result, we can distinguish several boulders, ranging from about 50 to 100 meters in diameter, on the crater walls.*

*Features as small as 20 meters are visible in this image mosaic taken on March 3, 2000. At right, we see the characteristic saddle region. Unusual brightness patterns are also visible in the crater at the top left of the image. The walls of the crater appear to be more reflective and its floor less reflective than nearby parts of the asteroid.*

*Image: Johns Hopkins University Applied Physics Laboratory/NASA*

## Eros' X-Ray Glow

*Two powerful solar flares blasted the surface of Eros with X-rays on March 2, 2000. Each 300-second blast caused elements at Eros' surface to glow in unique X-ray "colors." The X-ray/gamma-ray spectrometer on NEAR* Shoemaker *analyzed this X-ray glow and detected magnesium, silicon, iron, and possibly aluminum and calcium. Scientists used the new data to construct this digital model of the asteroid. The red areas highlight the regions on Eros that glowed in response to the flares.*

*This marks the first time the composition of an asteroid has been identified by an X-ray signature. Researchers expect that the interpretation of future X-ray data will help determine the origin of Eros and could potentially become a Rosetta Stone to help translate the geochemical story of our solar system's origin.*

*Image: Goddard Space Flight Center/NASA*

Earth, the Moon, and Mars and in meteorites.

The spectrometer's data will be combined with images from the camera to develop a mineral map of Eros. Perhaps someday a prospecting astronaut, with map in hand, will visit Eros seeking solar-system riches.

NEAR *Shoemaker*'s mission will go on for a year, and the spacecraft will continue to return priceless data to scientists on Earth. This story is just beginning.

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*Charlene M. Anderson is Associate Director of The Planetary Society.*

# World Watch

**by Louis D. Friedman**

**Washington, DC**—NASA released four major reports in March: one each on the failure of *Mars Climate Orbiter* and *Mars Polar Lander*, one analyzing the "faster, better, cheaper" approach to space missions, and one by the Mars Program Independent Assessment Team (MPIAT) putting it all together. MPIAT, known as the Blue Ribbon team, was chaired by A. Thomas Young, retired executive vice president of Lockheed Martin. Planetary Society President Bruce Murray was a special consultant to MPIAT.

The reports endorsed faster, better, cheaper, both as a viable technical approach and as a political necessity. They also supported the goal of doing smaller, more frequent missions. But glaring problems were found in the implementation of such missions in the Mars program—huge system and management errors that not only contributed to the failures but also called into question the planning for future missions.

Following recommendations from the teams, NASA canceled the *Mars Surveyor 2001* lander and is reexamining plans for the 2003 lander and Mars sample return. It appears there will be delays in the larger rover mission that was planned for 2003 and in the sample return, part of an international development with a 2005 launch.

The next issue of *The Planetary Report* will give an in-depth look at the reports of the NASA teams about the loss of the Mars missions.

## Small Errors, Huge Losses

While the system and management errors identified by MPIAT can be described as "huge" because of the effects they caused, the root mistakes could just as reasonably be called small. On the *Mars Climate Orbiter*, it was inappropriate use of English, rather than metric, units. On the *Mars Polar Lander*, it may have been omitting a simple reset in the software subroutine dealing with the lander-legs contact sensor.

The cause of failure on *Mars Polar Lander* is not definitively known, but an improper signal from the lander-legs sensor indicating contact with the ground when the spacecraft was still well above the surface may have caused the descent engines to prematurely shut off. This improper signal is now a known fault in the design. If the spacecraft reached this point in its descent, the MPIAT team concludes, the premature shutdown would certainly have occurred.

Most errors are small errors—and the annals of space exploration are replete with them: a minus sign instead of a plus sign, a backwards wiring of battery leads, and so on. The problem is not small errors—people make them every day. The problem is our not catching them. That is where systems analysis and testing comes in, and it is on systems analysis and testing that much of the criticism for the lost Mars missions falls. *—LDF*

**Pasadena, California**—As Planetary Society members know, there are two great missions to the outer planets of vital interest to us: a Pluto fast flyby and a Europa orbiter. The Europa orbiter is of highest science priority—the hints of an ocean beneath the global ice have raised questions about the possibility of life on this distant world. Thus, the Europa mission was scheduled first, for a 2003 launch, with the Pluto mission scheduled for 2004. But now the Europa mission will be delayed—to a 2006 launch. Three big problems loom: launch vehicle, power supply, and radiation shielding.

Both missions require a larger launch vehicle than is now available in the US stable. Atlas 5 and Delta 4 are being considered, but neither is expected to fly until next year, and cost estimates for using them have risen considerably. Both missions require a nuclear source for onboard electrical power, called a radioisotope thermoelectric generator (RTG). The Europa mission includes planning for a new advanced-technology RTG, but development of this component has slowed, and it can't be ready for 2003. In addition, the Europa orbiter needs the capability to survive the high-radiation environment of Jupiter. These factors persuaded Jet Propulsion Laboratory engineers not to plan for the earlier launch.

The Pluto fast flyby is now receiving prime attention. Pluto is the only planet in the solar system (yes, we still call it a planet) not yet visited by spacecraft. Science proposals for both the Europa orbiter and the Pluto fast flyby are being reviewed now.

**Tokyo**—"No matter how bad things are, they can get worse," commented Bruce Murray after the losses of the three Mars missions last year. He was referring to news about the failure of the Japanese M-V launch vehicle, which experienced a first-stage failure in February while launching the *Astro-E* space-science mission. The mission was designed to do X-ray observations from Earth orbit.

M-V is the launch vehicle planned for the twice-delayed *Lunar-A* mission, now scheduled for launch in 2002. This orbiter mission will carry two penetrators, which will insert to a depth of 1 to 2 meters in the lunar surface. As the first Japanese mission to the lunar subsurface, the penetrators will conduct seismological and heat-flow experiments to help us learn more about the lunar interior. The Japanese are developing another lunar mission, *Selene*, an orbiter scheduled for launch in 2003.

Japan's *Nozomi* mission continues on its way to Mars with no significant problems. The spacecraft is scheduled to go into Mars orbit in January 2004.

**Washington, DC**—The Planetary Society has weighed in heavily as Congress considers the NASA authorization bill. Different versions of the bill have been passed by the House Science Committee and the Senate Commerce, Science, and Transportation Committee. The House version eliminates support for the Trans-Hab module, an inflatable habitation module being planned for the space station. We have supported the Trans-Hab, since it is generally seen as an important development for future human flight to Mars. We urged Congress to adopt the Senate version of the NASA bill, which leaves funding for the Trans-Hab intact.

We also protested a House provision that would add bureaucratic restrictions to NASA efforts in international cooperation. Specifically, the proposed restrictions ask the NASA Administrator to go through extra procedures if NASA wants to fly missions on a foreign launch vehicle or on a foreign spacecraft. These added procedures would threaten proposed international cooperation on the Mars sample return and would prevent consideration of other cooperative projects.

The NASA budget is now being considered by the House and Senate appropriations and authorization committees. Please see our website for the latest details. Of most concern is the fate of requested increases for space-science funding, including additional support for Mars exploration. Some in Congress have made highly critical statements about NASA and the Mars program—statements designed more for political posturing than for helping the program.

The Society is urging that the increased funding for space science be directed to Mars exploration, as proposed by the Administration; fixing program problems; and providing additional resources to enable missions to continue. Reports on our efforts can be found on The Planetary Society website, along with links for letting your congressional representatives know your opinions.

*This is how Mars' south polar cap appeared to* MGS *on April 17, 2000. At the time of this writing it is summer there, and the polar cap has shrunk to its minimum size. In June this pole will be in autumn, and the area covered by frost will start to expand.*

*The Planetary Society will conduct training sessions for Student Navigators using* MGS *imagery. Michael Malin will provide these students with a chance to use the Mars Orbital Camera to choose a sample-return site on the Red Planet.* Image: MSSS/NASA

## Can Red Rover Still Get to Mars?

The loss of the 2001 lander mission particularly affects us at The Planetary Society. Red Rover Goes to Mars, our telerobotic project with LEGO to let Student Astronauts and Student Scientists be part of real space missions, had been selected by NASA as an exploration education experiment on the *Mars Surveyor 2001* mission.

We even had a Red Rover Goes to Mars payload—a LEGO mini-figure experiment mounted on the face of a CD, and two nanoexperiments designed by students for studying conditions at the Martian surface.

We expect that Red Rover Goes to Mars will be part of the next Mars lander mission, although we cannot confirm that until NASA determines the mission payload. In the meantime, we will conduct a training mission for Student Navigators (in place of the Student Astronauts), using *Mars Global Surveyor* (*MGS*) imagery. Michael Malin, principal scientist of the *MGS* Mars Orbital Camera, is allowing us to provide students with an opportunity not only to use the pictures but to "take" them. Students will control the camera sequencing in a special *MGS* activity in which students will choose a sample-return site on Mars.

For more information about Red Rover Goes to Mars, visit our website, or contact Linda Hyder in our office. *—LDF*

**Laurel, Maryland**—The Near Earth Asteroid Rendezvous (NEAR) spacecraft is now renamed NEAR *Shoemaker*, in honor of the pioneering planetary scientist Eugene Shoemaker. Shoemaker was one of the first scientists to recognize the importance of near-Earth asteroids and their influence on planetary evolution.

NEAR *Shoemaker* has lowered its orbit to about 100 kilometers (about 60 miles) around Eros, moving at an orbital speed of only 5 kilometers per hour (3 miles per hour). This combination of distance and speed allows instruments to obtain information about the asteroid's elemental composition (mostly metallic). Visit our website and link to the NEOs section for the latest news.

*Louis D. Friedman is Executive Director of The Planetary Society.*

# Questions and Answers

***Is there any gravity on the surface of Eros?***
**—Carlos Acuna, Cordoba, Argentina**

The gravity of Eros is very small indeed—but not negligible. Depending on where one is standing on Eros, the local gravitational acceleration varies from 2.4 to 5.6 $mm/s^2$, roughly a factor of 3,000 less than the gravitational acceleration at Earth's surface. For example, it would take just over half a second for a basketball, dropped from 6 feet, to reach Earth's surface, but on Eros a ball dropped from the same height would take about 30 seconds to hit the ground. If a 200 pound Michael Jordan can leap 3 feet on Earth, on Eros the now one-ounce superstar could jump well over a mile and he'd run the risk of jumping off the asteroid entirely.

Because its gravity is so low and because it is rotating once every 5.27 hours, Eros' escape velocity varies from 3.4 to 17.6 meters per second (7.6 to 39.3 miles per hour). While it would be easier to escape Eros by leaping from atop the highest mountain or from the ends of the long axis of the asteroid (where the rotation velocity is largest), there is no point on the surface of Eros where the rotational velocity is high enough—and the gravity low enough—to allow loose surface particles to launch themselves onto escape trajectories. Hence we expect any boulders would remain there on the surface (at least between major impact events, which could eject nearby material to escape velocity rather easily).
—DONALD K. YEOMANS,
*Jet Propulsion Laboratory*

***Why don't at least some planetary satellites have satellites of their own?***
**—William M. Friedman,**
**St. Louis, Missouri**

Satellites may have had satellites in the very early solar system; at least we know of no reason why sub-satellites could not have formed. However, if any once existed, they would have been removed by tidal effects. A planet raises tides on a satellite, which slows its rotation. All of the large satellites (and most small ones) in the solar system have been de-spun by tides so that they keep one face toward their planet, as does our own Moon. This state is called synchronous rotation.

A satellite's orbit also evolves in response to the tides that it raises on its planet. The direction of this evolution

## Factinos

A microbial world hidden deep below Antarctica's ice may tell scientists about how life can survive under extreme conditions on other planets or moons. Hardy microbes were discovered in the ice above Lake Vostok, a huge freshwater lake buried beneath the East Antarctic ice sheet (see image at right).

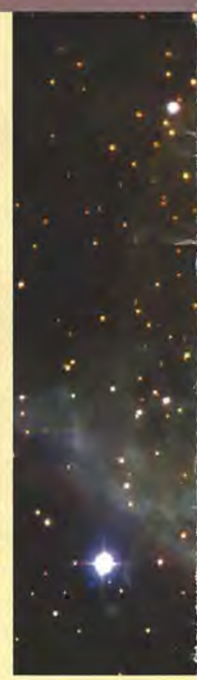
The research team, which includes Chris McKay of NASA Ames Research Center (also a member of The Planetary Society Board of Directors), tested samples taken in January 1998 from the ice 3,590 meters below Vostok Station and found diverse colonies of microbes. Scientists say this is significant because the lake has been isolated from the usual sources of atmosphere-derived energy, like photosynthesis, for millions of years.

"How the bacteria get energy to survive is an important question," McKay said. "The lake could be an analog to sub-ice Europa or subsurface Mars, where conditions are similar."

Scientists believe that ice is a good environment for primitive bacteria. A bacterium needs less food when it's cold because its metabolism slows down, somewhat like a hibernating bear's. —from NASA Ames Research Center

*More than two miles beneath the frozen surface of Antarctica lies Lake Vostok, a massive freshwater lake. A multi-disciplinary science team has found diverse colonies of bacteria in this ice—a discovery that could shed light on viability in similar harsh environments beyond Earth, such as Jupiter's moon Europa. This image was captured by the NASA-launched Canadian satellite RADARSAT.*

*Image: Canadian Space Agency*



depends on the planet's spin rate as well as the satellite's distance. If the satellite is outside the *synchronous distance*, the planet's tidal bulge leads the satellite, and its gravitational pull transfers angular momentum from the planet's spin to the satellite's orbital motion. This causes its orbit to expand, as is the case for Earth's Moon. If the satellite is inside the synchronous distance, the tidal bulge lags, and its pull causes the orbit to shrink. Phobos, the inner satellite of Mars, has an orbital period shorter than a Martian day, and its orbit is decaying.

The same type of interaction would occur with a sub-satellite in orbit about a satellite. Once the satellite had been de-spun by the planet, its spin period would equal its orbital period, so any sub-satellite close enough to have a stable orbit would be inside the satellite's synchronous distance. Tides raised on the satellite by the sub-satellite would cause its orbit to decay until it collided with its "parent."

The timescales for de-spinning and orbital decay are much shorter than the age of the solar system, so any evidence of such a collision could have been erased by later cratering and/or geologic activity on the satellite. Only the small outer satellites of the giant planets are far enough from their planets to be unaffected by tides. Some of them might have satellites, as do some asteroids, but there is no observational evidence.

Incidentally, Mercury and Venus, which rotate slowly due to de-spinning by solar tides, may have lost primordial satellites in the same manner.
—STUART WEIDENSCHILLING,
*Planetary Science Institute*

***In the March/April issue, Factinos showed an image of Eros taken by NEAR* Shoemaker. *The asteroid has been described as potato-shaped and about the size of Manhattan. Today's news reported that the spacecraft was in a 100-kilometer (60-mile) orbit of Eros and will descend eventually to 48 kilometers (30 miles).***

***How do you control the orbit of the spacecraft at that close distance without the different gravitational pulls of an irregular shaped body acting on it and spinning the spacecraft out of control?***
**—Stephen Jonasch,**
**Keene, New Hampshire**

It is true that the irregular shape of Eros produces a non-uniform gravitational attraction on the spacecraft, perturbing its orbit path. In fact, it is from these perturbations that we are able to determine the gravity field for both navigation and science purposes. The spacecraft does not go spinning out of control because we plan in advance the size and shape of the orbit, based upon a prediction of the non-uniform gravity field, so that the orbit is stable. This is why we started the spacecraft orbiting Eros at a higher altitude, where gravity perturbations were smaller. We improved our estimates of the gravity field before incrementally lowering the orbit altitude and re-determining the gravity field with better and better resolution. This "boot-strapping" technique has been working successfully and will be used to improve the gravity model for the final phases of the mission in early 2001.

In these final phases, we intend to bring the spacecraft closer than 1 kilometer (0.6 miles) above selected regions of the surface of Eros, and, pending NASA approval, we may even attempt to land on the surface.
—BOBBY WILLIAMS,
*Jet Propulsion Laboratory*

***This image of the Trapezium Cluster in the Orion Nebula shows the star-forming region where British scientists recently found 13 very young planets drifting through space with no star to call home. The planets, along with over 100 brown dwarfs, were discovered with the new camera on the United Kingdom Infrared Telescope in Hawaii.***

***Image: Royal Astronomical Society***

British scientists have discovered "free floating planets" in a star-forming region of the Orion Nebula (see image at left). Philip Lucas of the University of Hertfordshire and Patrick Roche of the University of Oxford used a new camera on the United Kingdom Infrared Telescope in Hawaii to perform the most sensitive survey ever taken of this stellar nursery.

The new infrared survey of the Trapezium Cluster in Orion turned up 13 objects with masses less than 13 Jupiters as well as more than 100 very young brown dwarfs. The runaway planets do not orbit any star but drift through space by themselves.

Because brown dwarfs and loose planets cool down quickly, they are easiest to find when they're young and still retain some heat from their birth. These objects in the Trapezium Cluster are mostly about a million years old—very young compared to our Sun's age of 5 billion years. The discovery of 13 wandering planets in one cluster suggests that such bodies might be very common.
—from the Royal Astronomical Society

Planet-hunting scientists have crossed an important threshold with the recent discovery of two planets that may be less massive than Saturn. So far, all of the 30 planets detected around Sun-like stars have been at least the size of Jupiter. The existence of these Saturn-sized worlds suggests that many stars harbor smaller planets, in addition to Jovian-style giants.

The discovery was made by Geoff Marcy of the University of California at Berkeley, Paul Butler of the Carnegie Institution, and Steven Vogt of the University of California at Santa Cruz using the mighty Keck telescope on Mauna Kea, Hawaii. They found one planet orbiting the star HD46375, which is 109 light-years away in the constellation Monoceros, and another planet around 79 Ceti, a star located 117 light-years away in the constellation Cetus.

"It's like looking at a beach from a distance," explained Marcy. "Previously we saw only the large boulders, which were Jupiter-sized planets or larger. Now we are seeing the 'rocks,' Saturn-sized planets or smaller. We still don't have the capability of detecting Earth-like planets, which would be equivalent to seeing pebbles on the beach."
—from the University of California, Berkeley

# Society News

## Astronomical Society of the Pacific Hosts Universe 2000 Expo

Universe 2000 Expo is a weekend of astronomy activities for the general public. Part of a week-long annual meeting of the Astronomical Society of the Pacific (ASP), the Expo includes panel discussions, talks by leading astronomers, hands-on activities for children, book signings, a raffle for a telescope, a silent auction, and an exhibit hall.

This year's lecturers include Alex Filippenko of the University of California, Berkeley discussing "Einstein's Greatest Blunder"; Seth Shostak of the SETI Institute focusing on "The Search for Extraterrestrial Intelligence"; Ellis Miner of NASA's Jet Propulsion Laboratory outlining "NASA Missions to the Solar System"; and Debra Fischer of San Francisco State University talking about "Searching for Extrasolar Planets."

The Expo takes place Saturday and Sunday, July 15 and 16, from 8:30 a.m. to 5:30 p.m. at the Pasadena Convention Center, Pasadena, California. Admission is $25 for a weekend pass, $15 for one day only. For complete details, visit ASP's website at **www.aspsky.org/meetings.html**.
*—Susan Lendroth, Manager of Events and Communications*

## Expanding Our Board of Directors

We are pleased to announce that Wes Huntress, a member of The Planetary Society Board of Advisors, has now joined our Board of Directors. After a 20-year career as a scientist at the Jet Propulsion Laboratory, Huntress served as Associate Administrator for Space Science at NASA Headquarters, where he was a key architect of the "smaller, faster, cheaper" space-science mission model and of NASA's new Origins program. Currently, Huntress is director of the Geophysical Laboratory of the Carnegie Institute of Washington and is president of the American Astronautical Society.

Last year, we welcomed two other notable members to our Board, Bill Nye and Christopher McKay. Nye, who was once a student of Society co-founder Carl Sagan, is best known for his Emmy Award-winning weekly television series, *Disney Presents Bill Nye the Science Guy*. Nye is carrying on Sagan's legacy of inspiring a new generation with the excitement and wonder of the universe.

McKay has been a research scientist with the NASA Ames Research Center since 1982. His current research focuses on the evolution of the solar system and the origin of life. He is also actively involved in planning for future Mars missions, including potential human settlements.
*—Jennifer Vaughn, Managing Editor*

## We're Back Online!

We are back up on the Web. After a terrible month in which our site was broken into and vandalized, we have restored ourselves—both in content and style—with new security procedures. At the same time, we have initiated developments to make **planetary.org** bigger, faster, and better.

Our website had a great year last year, with SETI@home, Planetfest online, 7,000 new members joining on the Web, several webcasts, and new members-only features. Please bear with us while we get the remaining problems fixed up; then help us come roaring back by visiting and promoting our site and by joining our e-mail list—now the second-largest space-interest list in the world (The Planetary Society membership list is the largest).
*—Louis D. Friedman, Executive Director*

## Nominations for 2000 Thomas O. Paine Award

The Planetary Society invites nominations for the Thomas O. Paine Award for the Advancement of Human Exploration of Mars. This award is given to the person or group who, in the opinion of an independent selection committee, has made an outstanding and significant contribution to advance human exploration of Mars.

Past recipients include Christopher McKay, NASA Administrator Dan Goldin, the *Apollo-Soyuz* crew, and the *Mars Pathfinder* and *Mars Global Surveyor* teams. Last year a posthumous award to Carl Sagan was presented at Planetfest '99.

The award consists of a recognition plaque and a cash award of up to $5,000 (government employees are not eligible for the cash prize).

To nominate someone, send us a short biography of the person being nominated, an explanation of why he or she should receive the award, and any references or supporting material you consider appropriate. Please send your nominations to the Society, ATTN: Thomas O Paine Award Nominations, by mail, fax, or e-mail. *—LDF*

## Student Journalists Question Scientists

On April 4, 2000, 40 middle school and high school journalism students from numerous campuses in northern California gathered at the NASA Ames Research Center Visitor Center for The Planetary Society's third Student Press Conference. The topic, "Life in the Universe," elicited a slew of lively questions for the press conference panel: planetary scientist Chris McKay; Peter Ward, coauthor of *Rare Earth*; Dan Wertheimer, a developer of SETI@home; and Society Executive Director Louis Friedman as moderator.

The Society has hosted two previous Student Press Conferences. The first helped kick off Planetfest '99 in Pasadena, California; the second, cohosted by the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland, coincided with NEAR *Shoemaker*'s encounter with Eros. Check **planetary.org** for information on upcoming student press conferences. *—SL*

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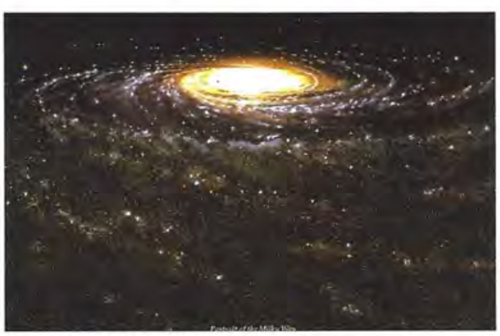
**Explore the Planets Poster**
This eye-catching poster is chock-full of fascinating facts about our planetary neighbors.
34" x 22" 1 lb. **#310 $10.00**


***Winds of Mars*** **and the Music of Johann Sebastian Bach**
Audio CD includes extensive liner notes explaining the simulation of the Martian sounds and giving a general history of Mars exploration. 1 lb. **#785 $14.99**



**Portrait of the Milky Way Poster**
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It is hard not to think about asteroids, meteorites, and other assorted cosmic rocks when looking at one of René Magritte's "stone" paintings. In *La Flèche de Zenon* (Zeno's Arrow), a huge boulder sits motionless in the air above the sea. It's unlikely that Magritte knew his work would remind future generations of the threat to Earth posed by these denizens of space.

René François-Ghislain Magritte (1898–1967) was born in Lessines, Belgium, where he first painted and took art lessons at the age of 13. In 1916, he left high school to attend the Académie des Beaux-Arts in Brussels. He moved to Paris in 1927, when many avant-garde artists were gathering there, and he came to know André Breton, Max Ernst, Joan Miró, and Hans Arp. Magritte's work, beloved for its irony and unsettling psychological edge, is most often associated with the Surrealist movement. He believed that a viewer could be released from the banality of perceived reality by viewing that reality in a disrupted context, revealing its underlying fantastic component.



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PRINTED ON RECYCLED PAPER
Printed in USA