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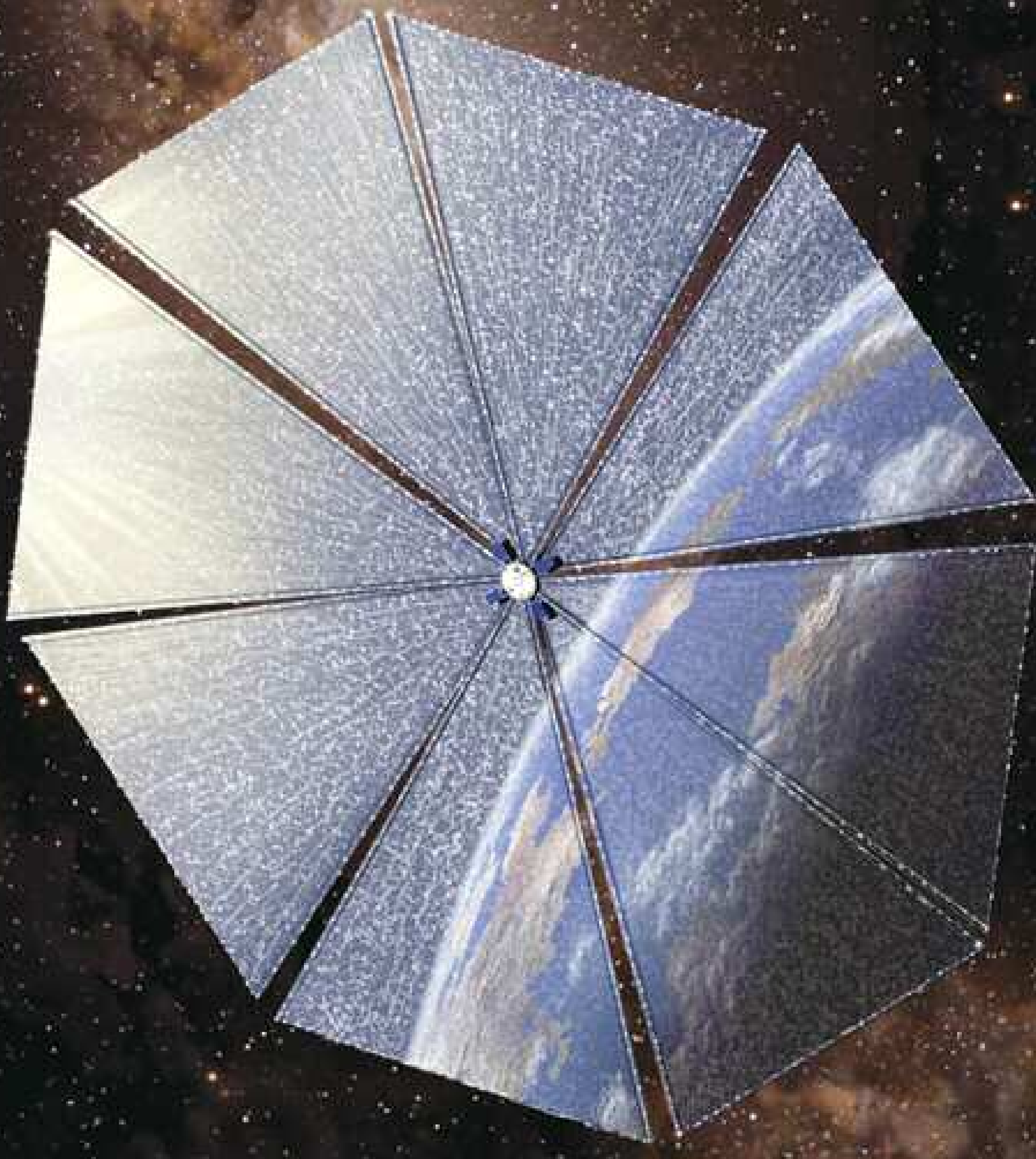

Cosmos 1: Our Solar Sail

A PUBLICATION OF THE PLANETARY SOCIETY

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From The Editor

As I write this, we have literally just announced the launch date for *Cosmos 1*, the first space mission to be conducted by a private membership organization—and the first solar-sail–propelled spacecraft to leave Earth. Launch is set for March 1, 2005, with a window that extends until April 7.

I know Planetary Society members all realize how significant this launch will be. For the first time in history, a group of people have banded together outside government and industry to conduct a mission to space. Twenty-five years ago, when The Planetary Society was formed, few would have thought it possible, but the dedication and support of our members are making it happen.

So get ready for *Cosmos 1*. In this issue, you can brush up on details of the project. Then, we'll soon be inaugurating Solar Sail Watch, which will ask people around the world to watch the skies for *Cosmos 1* and help us track our spacecraft as it begins to orbit Earth and, we hope, gradually move away from its home world to demonstrate that solar sailing works.

In this mission, events will move too fast for us to keep you informed through *The Planetary Report*, so if you can, check our website, *planetary.org*, often. You've made this history-making mission possible. Don't miss a chance to share in your well-deserved pride in *Cosmos 1*.

—*Charlene M. Anderson*

Features

Departments

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On the Cover:

Cosmos 1 has set sail around Earth, its Mylar blades reflecting the planet that launched it. In the background, the Milky Way beckons.

Image: Rick Sternbach, Space Model Systems

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Members' Dialogue

The Debate Continues

Thank you for Andrew P. Ingersoll's thoughtful article, "Robots, Not Humans, on Mars" (see the September/October 2004 issue of *The Planetary Report*). As much as human planetary exploration has always captured the public's, Hollywood's, and yes, my own imagination, now is not the time for an irresponsibly costly, risky, and diversionary human mission to Mars. Such a mission threatens the proven and, frankly, stunning, accomplishments of NASA's more cost-effective, medium-sized projects, not to mention countless other more basic, Earth-bound needs that compete for scarce government funding. In this era of deep deficit spending, NASA should not be reduced to an extravagant form of public entertainment at the cost of continued scientific advancement through more affordable robotic missions.

For entertainment, those stunning close-ups of the magnificent rings and distant moons of Saturn and the outer planets are all that I need.
—MICHAEL DOUGHTON,
Sacramento, California

I believe that robotic probes are an important part of space exploration, but the ultimate goal should be human exploration. Why? Because humans are going to live there. Eventually, there will be colonies living on the Moon, Mars, and beyond.

Most of the public has only a casual interest in the probes sent out to space. Look at how quickly public attention to the Mars rover missions faded. I remember July 20, 1969. The whole world stopped to watch Neil Armstrong step onto the Moon.

The public's preference for human exploration is demonstrated in movies such as *The Right Stuff* and *Apollo13*. Has anyone ever made a movie about the challenges of robotic space probes?

Of course, probes are cheaper and safer, just as it is cheaper and safer to look at pictures of a coral reef on the Internet. But it will never compare to actually going to a coral reef. Let us actually go into space. After all, it is "the final frontier."
—D. POTE,
Dallas, Texas

I have followed the "robotic versus human" exploration debate with interest and, indeed, plausible arguments have been put forward on both sides. However, I believe that much greater emphasis should be placed upon the early need to give our race a foothold elsewhere in the solar system.

Our planet is beset by numerous threats and problems. It is vulnerable to epidemic, the possibility of massive climate change, resource shortage, and even imminent decimation by asteroid impact. Any delay in establishing a permanent human presence elsewhere is not, therefore, a sensible option if we are to improve our chances of survival.

The cost and associated risks of human exploration have been factors throughout history. The former will be accepted because of the tremendous public interest that manned participation arouses, the latter because of the courage and tenacity ingrained in the human spirit.
—BOB MILLEN,
Northfleet, England

I have read the letters coming in to you in *The Planetary Report* concerning whether it would be better to send humans on space missions rather than robots. The obvious answer to this question (in my opinion) is robots—when they can perform the duties the particular mission requires. As Isaac Asimov put forth in his book *I, Robot*, robots are more easily adapted to the harsh reality of space than humans.

We are not in the *Star Trek* world of the 23rd century; we're still blasting humans into space on top of rockets filled mainly with hydrogen and oxygen. Re-entry is just as, if not more, dangerous, as we found out recently with the *Columbia* disaster. We have a long way to go before we should consider sending a manned mission to a hostile planet many millions of miles away.

I think we need to get better, faster propulsion systems and safer spacecraft, and do our homework, before we send humans into space. Missions to the Moon, with the intention of building a Moon base, might be a better goal to strive for at this time.
—CHARLES D. HICKS,
Joppa, Maryland

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We Make It Happen!

by Bruce Betts

We regularly cover our big projects at The Planetary Society in this column, elsewhere in *The Planetary Report*, and on our website. In this issue, I want to give you a couple of examples of "little" projects. The Planetary Society has a long but not well-publicized tradition of seeking comparatively big impacts for small amounts of money. Here, I tell you about two examples that have yielded huge "impacts."

Dinosaur Killers

No, we don't fund dinosaur killers, but we do fund people who learn about the asteroid impact that wiped out the dinosaurs. This impact, which occurred off the Yucatan peninsula in Mexico 65 million years ago, helped our furry ancestors move forward while leading to the extinction of 70 percent of the species on Earth. That period is known as the K/T boundary (Cretaceous-Tertiary geological time scale boundary; geologists use a K because C was used for another period).

Adriana Ocampo, a planetary scientist at the Jet Propulsion Laboratory who also has worked at NASA Headquarters and at the European Space Agency, studies the K/T boundary. She has led a number of Planetary Society member expeditions to Belize to dig in the dirt and hunt for clues.

Adriana had an invitation to a K/T boundary workshop in Argentina in September but did not have travel funds to attend. This is a common story in Planetary Society history, going back to the first SETI funding in the early 1980s. Sometimes scientists are able to find ways to cover their salary but are not able to cover travel, especially to foreign destinations. By funding travel, which we did for Adriana, we foot the comparatively small bill and get big benefits.

In this case, Adriana participated in the workshop and was able to visit K/T boundary geologic exposures and set up collaborations with Argentinian scientists. Typical of The Planetary Society, we got a lot more out of her while she was there, but, to follow that story, let me digress to a different project.

Hunting for Planetary Holes in the Ground

The Planetary Society sometimes awards small grants in one of our subject areas of interest. In the area of NEO study, to complement our observational Gene Shoemaker NEO grant program, we have had the opportunity to fund Maximiliano Rocca in Argentina for the last couple years. Again, a little money went a long way.

Max has been searching satellite and aerial photographs of South America, hunting for possible impact craters. Only about 180 impact craters have been found on Earth so far; most are very eroded and very old. Max has discovered a possible impact crater in Argentina. If it is proved to be an impact crater, it would be only the third one discovered on Earth in basalt, the same material that makes up much of the surfaces of the Moon, Mars, and Mercury.

Site Seeing

While Adriana was in Argentina, she met with Max, and she visited the possible impact site and collected preliminary samples for later analysis to begin the confirmation of impact.

Adriana also explored two other possible K/T exposures in very remote parts of Patagonia. This not only was part of her research but also was an example of scouting for possible Planetary Society member expeditions. The sites are interesting, and if logistics can be worked out for these very remote parts of Argentina, then members will have an opportunity to travel to these sites and participate in a geologic dig, working side by side with scientists like Adriana. We'll keep you updated in *The Planetary Report* about this possible expedition. In the meantime, you can e-mail *lu.coffing@planetary.org* to express interest.

As a side note, our Southern Hemisphere radio SETI program is based in Argentina as well, headed by Guillermo Lemarchand. We have also collaborated frequently with Sergio Stinco in Argentina. Among other things, he discusses planetary topics on an Argentinian radio show and lectures in schools and malls with his wife, Susana Gimenez.

Opportunistic Flexibility

Our big little projects are another reflection of the flexibility you as members give to The Planetary Society. Unlike government agencies, or any bureaucracy-heavy organization, we can respond quickly to timely opportunities around the world. In these sample cases, along with many others I don't have room to discuss, we get a lot of leverage from very small amounts of money. Yay!

Bruce Betts is director of projects at The Planetary Society.

What's **Up?**

In the Sky

Four naked-eye planets are visible now in the predawn sky, and the fifth will appear starting in late December! Venus looks like the brightest star in the sky before dawn in the East. Jupiter, also bright, is to Venus' upper right. In late November, Mars will be just below Venus, looking much dimmer and somewhat reddish. They will grow closer until they are only about 1 degree apart on December 5 and 6. Then, Mars will appear to the upper right of Venus. Mercury and Venus will do a little dance starting in mid-December as they approach each other, low in the predawn sky. They will be less than 2 degrees apart by December 26 and will stay close through mid-January, when they will be low and tough to see. Saturn outshines the nearby Gemini "twin" stars Castor and Pollux. Saturn rises 1 to 3 hours after sunset, and in the predawn sky it is in the West. The five planets will appear nearly in a line because they all orbit in approximately the same plane.

On December 7, the Moon will pass in front of Jupiter as seen from central and eastern North America (don't miss it if you live there).

The Geminid meteor shower, the best average meteor shower most years, peaks on the night of December 13. Look for up to one or two meteors per minute.

Random Space Fact

Neptune's moon Triton is the only large moon in the solar system that orbits its planet retrograde or "backward" compared with how the planet rotates.

Trivia Contest

Our July/August contest winner is Paul Mundy of Belfast, Ireland. Congratulations!

The Question was: What is the farthest object from Earth that was made by humans?

The Answer: *Voyager 1* is more than 93 times the Earth-Sun distance (AU) away from us, making it more than twice as far away as Pluto. *Pioneer 10* is currently in second place at about 87 AU, having been passed a few years ago by *Voyager 1*.

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

What is the gap between Saturn's A and B rings called?

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 February 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*

COSMOS 1: THE JOURNEY BEGINS!

LATE WINTER 2005.

A FEW DOZEN METERS BELOW THE SURFACE OF THE COLD BARENTS SEA, A DELTA III NUCLEAR SUBMARINE OF THE RUSSIAN NAVY LIES SILENT, MOTIONLESS, INVISIBLE. SEEMINGLY WITHOUT WARNING, A SINGLE MISSILE SHOOTS UP FROM THE VESSEL, BREAKING THE SURFACE AND HEADING TOWARD THE SKY, BEARING EAST. A TRAIL OF WHITE SMOKE MARKS ITS WAKE.

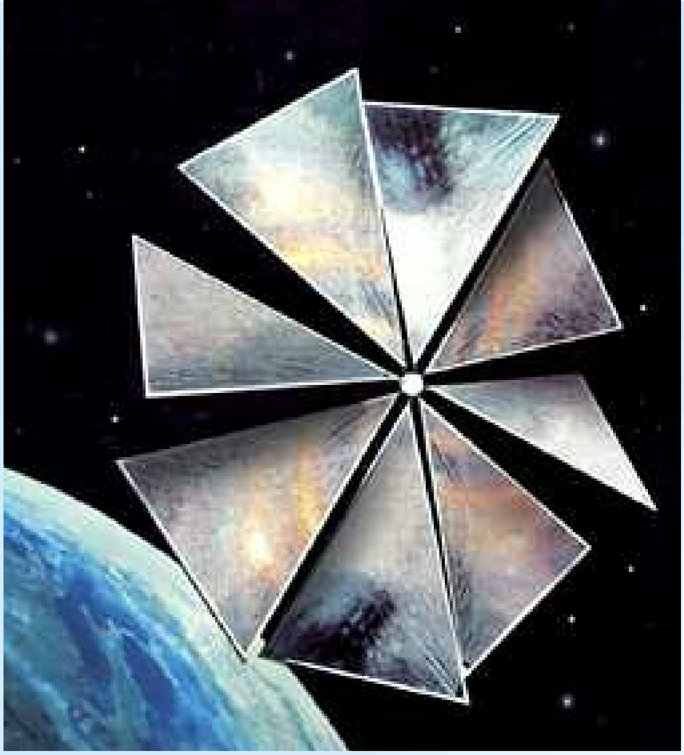
Launch! The Volna Rocket carrying* Cosmos 1 *shoots up from a submerged Delta III submarine and heads for Earth orbit.
Painting: Michael Carroll for The Planetary Society

It is a vision that haunted people the world over during the long decades of the Cold War. Are we now witnessing the beginning of another world war? Not at all: this missile will be carrying not a weapon of mass destruction but a benign and peaceful civilian spacecraft bound for Earth orbit. Folded within the rocket's payload compartment will be The Planetary Society's *Cosmos 1*, the first solar sail spacecraft. It will be the culmination of five years of hard work of former rivals working together to turn the dream of solar sailing into reality. It also will be the beginning of a new age in space exploration.

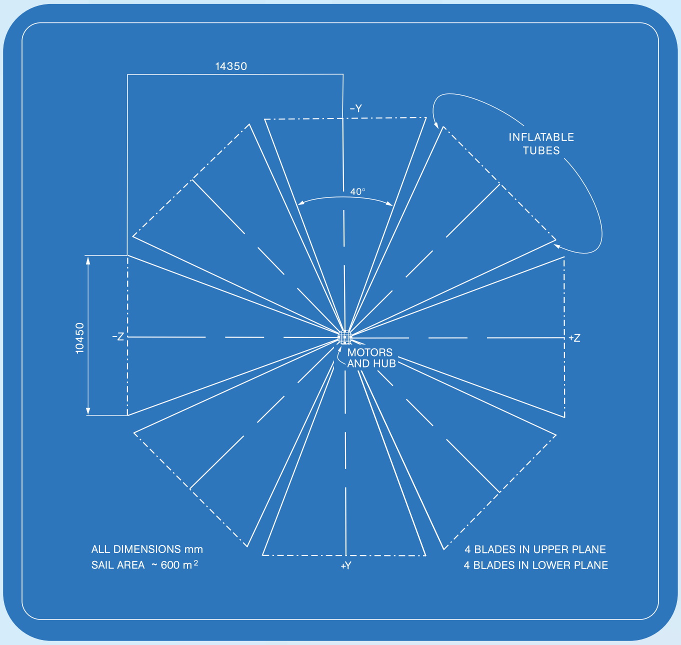
WHAT IS A SOLAR SAIL?

A solar sail is, simply put, a spacecraft propelled by sunlight. Whereas a conventional rocket is propelled by the thrust produced by its internal engine burn, a solar sail is pushed forward by light from the Sun. This is possible because light is made up of packets of energy, known as photons, that act like atomic particles. When a beam of light is pointed at a bright, mirrorlike surface, its photons

BY AMIR ALEXANDER AND
LOUIS D. FRIEDMAN



Above: *In this illustration of* Cosmos 1 *as it will appear in orbit around Earth, note the eight triangular blades, which can be rotated to face the Sun.*
Illustration: Babakin Space Center



The eight blades of Cosmos 1*, each 15 meters (50 feet) in length, are divided into two groups of four—one on the upper plane and one on a lower plane. During the flight, one group of sails will deploy first, to be followed quickly by the second group.* *Illustration: Bee Smith, adapted from a drawing by NPO Lavochkin*

reflect right back, just like balls bouncing off a wall. In the process, the photons transmit their momentum to the surface twice—once by the initial impact and again by reflecting back from it. The bright surface is pushed forward ever so slightly, propelled by a steady stream of reflecting photons.

A solar sail is made up of just such a reflective surface, or several surfaces, depending on the sail's design. When the surfaces face the Sun directly, they are subjected to a steady barrage of photons that reflect off the sails, creating a force perpendicular to the sail's surface By changing the angle of the sail relative to the Sun, it is possible to affect the direction in which the sail is propelled—just as a sailboat changes the angle of its sails to affect its course. It is even possible to direct the spacecraft toward the Sun, rather than away from it, by using the photons' pressure on the sails to reduce the spacecraft's speed and bring its orbit closer to the Sun.

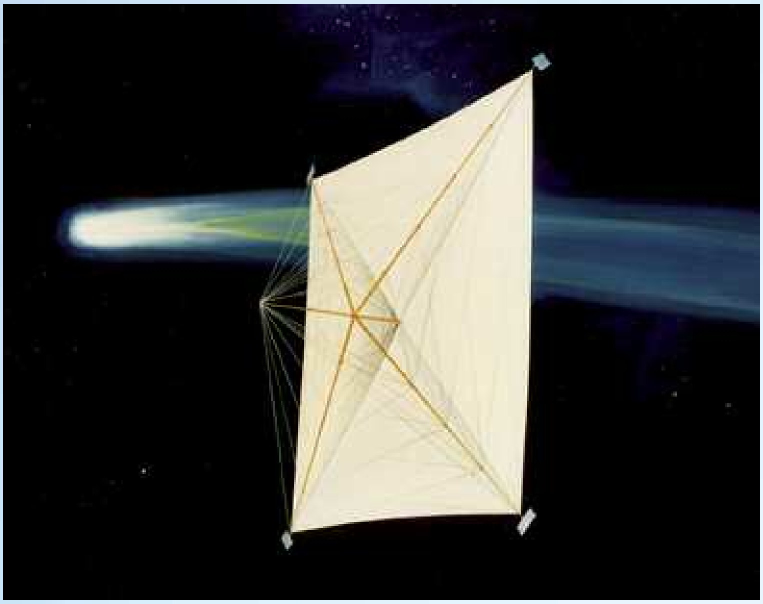
Despite its name, a solar "sail" is not propelled by the solar wind—the stream of ionized gas particles flowing out from the Sun. It is moved, rather, by sunlight itself, which imparts far more energy to the spacecraft than the solar wind ever could.

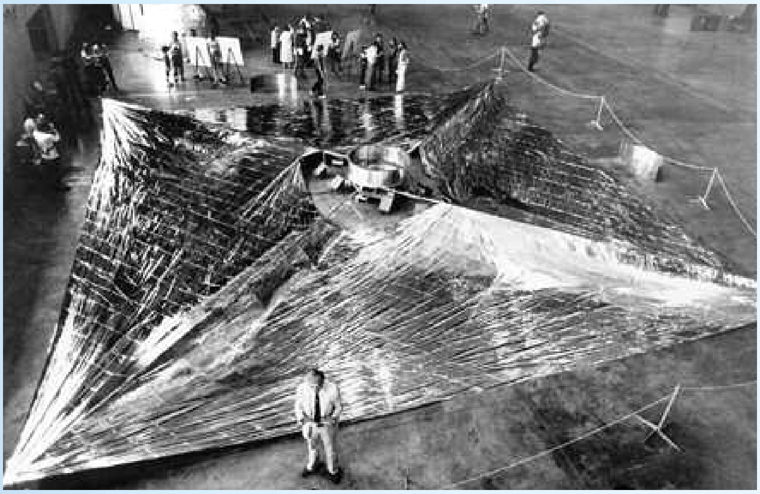
For sunlight to provide sufficient pressure to propel a spacecraft forward, a solar sail must capture as much sunlight as possible. This means that the surface of the sail must be big—very big. *Cosmos 1* is a small solar sail craft intended only for a short mission. Nevertheless, once it spreads its sails, even this small spacecraft will be 10 stories tall, as high as the rocket that will launch it. Each of its eight triangular blades is 15 meters (50 feet) in length and has a total surface area of 600 square meters (6,500 square feet). This is about one and a half times the size of a basketball court.

For a true exploration mission, the requirements are far greater: in the 1970s, when a NASA team headed by Louis Friedman suggested using a solar sail spacecraft for a rendezvous with Halley's comet, the team members proposed a sail with a surface area of 600,000 square meters (6.5 million square feet). This is equivalent to a square of nearly 800 meters (about half a mile) by 800 meters—the size of 10 square blocks in New York City!

Even with such a gigantic surface, the acceleration of a solar sail spacecraft is modest in comparison with that of a conventional rocket. Under optimal conditions, a solar sail on an interplanetary mission would gain only 1 millimeter per second in speed every second it is pushed along by solar radiation. The Mars Exploration Rover spacecraft, by comparison, accelerated by as much as 59 meters (192 feet) per second every second during their launch by conventional Delta II rockets. This acceleration is 59,000 times greater than that of a solar sail!

But the incomparable advantage of a solar sail is that it accelerates *constantly*. A rocket burns for only a few minutes before releasing its payload and letting it cruise at a constant speed the rest of the way. A solar sail, in contrast, keeps on accelerating and can ultimately reach speeds much greater than those of a rocket-launched craft. At an acceleration rate of 1 millimeter per second per second (20 times greater than the expected accelera-





Top: A square solar sail is depicted on its way to Halley's comet. This sail design was developed by Louis Friedman's team at the Jet Propulsion Laboratory in the late 1970s for a rendezvous mission with Halley's comet. NASA turned down the proposal for being overly ambitious.
Illustration: JPL/NASA

Middle: A prototype of the square solar sail developed by the World Space Foundation was displayed at The Planetary Society's Planetfest '81, which celebrated Voyager 2*'s encounter with Saturn.*
Photo: Richard Dowling for the World Space Foundation

Right: This illustration accompanied "The Clipper Ships of Space," the first scientific paper published on solar sailing. Although technical in nature, the paper appeared not in a scientific journal but in the May 1951 issue of Astounding Science Fiction. *Out of concern for his professional reputation, the author, aeronautical engineer Carl Wiley, signed the article with the pseudonym Russell Saunders.*
Illustration: Orban for Astounding Science Fiction

tion for *Cosmos 1*), a solar sail would increase its speed by approximately 310 kilometers per hour (195 mph) in one day, moving 7,500 kilometers (4,700 miles) in the process. After 12 days, it would have increased its speed by 3,700 kilometers per hour (2,300 mph).

While these speeds and distances are already substantial for interplanetary travel, they are insignificant when compared with the requirements of a journey to the stars. Given time, however, with small but constant acceleration, a solar sail spacecraft can reach extremely high speeds. Since the acceleration from solar pressure diminishes with increasing distance from the Sun, scientists have proposed pointing powerful laser beams at the spacecraft to propel it forward. Although such a strategy is not practicable with current technology and resources, solar sailing (or, more generally, light or microwave sailing) is nevertheless the only known technology that could someday be used for interstellar travel.

80 YEARS IN THE MAKING

The idea of solar sailing is not new; it has deep roots in both the American and Russian space programs. As far back as the 1920s, Russian space pioneers Konstantin Tsiolkovsky and Fridrikh Arturovich Tsander were working on it, and in 1924 Tsander wrote an article describing "flight in interstellar space . . . using tremendous mirrors of very thin sheets."

It is an indication of how "far out" the idea was considered that the first serious technical paper about solar sail propulsion was published not in a professional scientific journal but in a popular science fiction magazine. In the May 1951 issue of *Astounding Science Fiction*, aeronautical engineer Carl Wiley published an article titled "The Clipper Ships of Space" describing in detail how solar sails could be assembled in orbit and launched into space. Out of concern for his professional reputation, Wiley chose to sign the article with the pseudonym Russell Saunders.

Where Wiley led, others followed. The year 1958 saw the appearance of the first articles on solar sailing in professional journals, and that same year, *Time* magazine covered the topic in an editorial titled "Trade Winds in Space." Although the *Time* article seemed to reinforce the misconception that solar sails were propelled by the solar wind rather than by light itself, it nevertheless served as excellent publicity for the concept.

NASA picked up the idea of solar sailing in the 1960s, and in the mid-1970s, a group of engineers at the Jet Propulsion Laboratory (JPL), led by Louis Friedman, proposed using a solar sail for a 1986 rendezvous with Halley's comet. The idea for the mission was initially developed by Jerome Wright of the Battelle Memorial Institute, who subsequently joined Friedman's group at JPL.

The concept called for a giant sail, which would be launched from the space shuttle and deployed in space. NASA ultimately rejected the plan as overly ambitious

The Volna rocket bearing the suborbital solar sail spacecraft was lowered into the submarine Borisoglebsk *in July 2001. The suborbital flight was intended to test the deployment of the sails in a space environment. During the flight, a malfunction in the launch vehicle caused the spacecraft to remain attached to the last stage of the rocket, and the sails could not deploy. An identical Volna rocket will launch* Cosmos 1 *on its historic flight this winter.* *Photo: Makeev Rocket Design Bureau*

This photo of the partially assembled Cosmos 1 *spacecraft was taken in late October 2004 at NPO Lavochkin in Moscow. Note the folded solar panels (in red), which will be deployed in the first hour after the launch. In this view, the folded sails themselves have not yet been installed on the spacecraft.*
Photo: NPO Lavochkin

given the time constraints. As a result, for the next 10 years, solar sailing work was relegated to private groups, some of which produced designs to compete in a proposed race to the Moon (an early X Prize type of idea that never got funded). One of these groups was the World Space Foundation, which later became part of The Planetary Society.

The 1990s saw a worldwide revival of interest in solar sailing. Today, NASA, the European Space Agency (ESA), the Japanese space agency (JAXA), and the Russian space agency all have active solar sail research programs. In 2000, Russian scientists from the Babakin Space Center and the Space Research Institute (IKI) approached The Planetary Society with a plan to build a solar sail and fly it in Earth orbit. The Planetary Society took on the challenge and, within six months and with support and funding from Cosmos Studios, *Cosmos 1* was born.

The years since the agreement have not always been easy. Creating a groundbreaking spacecraft using novel technology is a daunting proposition under the best of circumstances. Add to that the fact that this was being done on two continents and in two languages (English and Russian), and one can get a sense of the difficulties involved. The Planetary Society, furthermore, does not have the resources of an agency such as NASA or ESA, and tight funding was an issue throughout. Finally, there was some bad luck: in July of 2001, the Russians provided an opportunity to test the sails' deployment during a suborbital flight conducted for another program. Unfortunately, the Volna launch vehicle malfunctioned, preventing the sails from deploying.

Thanks to the hard work of our team members at IKI, NPO Lavochkin, and The Planetary Society, all this is behind us now. This winter, *Cosmos 1* will spread its bright wings 825 kilometers (513 miles) above Earth and soar higher, borne on nothing more than sunlight.

COSMOS 1—THE MISSION

HERE'S HOW IT WILL ALL HAPPEN.

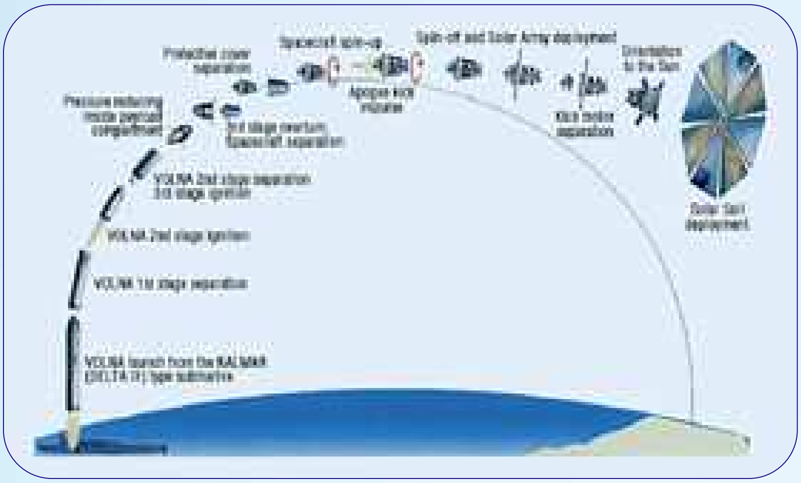
FINAL PREPARATIONS

Three to four weeks before the launch date, *Cosmos 1* will be delivered to the naval base at Severmorsk, near the port city of Murmansk on the Barents Sea. Over the next few weeks, the spacecraft will be checked out, batteries and pyrotechnic devices will be installed and charged, and the electrical units connecting the spacecraft to the rocket will be put in place. Then, the spacecraft will be placed in the payload area at the tip of the Volna rocket. About three days prior to the launch, the rocket will be loaded onto the Delta III submarine. Half a day before launch time, the vessel will leave Severmorsk for the designated launch site.

LAUNCH

At launch, the main engine of the first stage of the Volna will burn, then shut down and disengage from the rest of the rocket. The second stage will then ignite, burn, and disengage from the third stage, which in turn will separate from the payload compartment after completing its burn. A little more than 6 minutes after shooting up from the submarine, the three-stage Volna rocket will have completed its role in the mission.

At this point, the apogee kick motor, which is attached to the payload compartment and unofficially named the



Above: An hour and a half after it launches,* Cosmos 1 *will deliver its first batch of telemetry data to this tracking station at Panska Ves in the Czech Republic. Panska Ves will be the first permanent tracking station to be contacted by* Cosmos 1*, after the portable stations at Petropavlovsk in Kamchatka and Majuro in the central Pacific have tracked the spacecraft in the first few minutes after orbit insertion.
Photo: © CNRS/OHP/S. Ilovaisky

Shown at left are the successive stages of* Cosmos 1*'s launch, including the firing and discarding of the three stages of the Volna rocket, followed by the firing of the TPS apogee kick motor that will bring the spacecraft into Earth orbit. The deployment of the sails, shown at upper right, will follow several days later.
Illustration: Babakin Space Center

"TPS motor," will begin a 70-second orbit insertion burn. When this is completed, the motor and the protective cover encasing the payload compartment will be discarded, leaving the spacecraft alone in orbit, spinning at around 22 revolutions per minute. The entire process, from submarine launch to orbit insertion, will last just under 20 minutes.

INTO EARTH ORBIT

The launch path will take the spacecraft from the Barents Sea, across northern Russia and Siberia, and past the Kamchatka peninsula. When the spacecraft passes east of Kamchatka over the Pacific Ocean, it should enter a near-circular orbit 825 kilometers above the Earth and inclined about 78 degrees. Orbit insertion is a very sensitive phase of any mission, and errors can occur that would result in the spacecraft entering a different orbit. To make sure that *Cosmos 1* is not lost to its mission controllers on Earth, it is critical to establish contact with the spacecraft as soon as possible after orbit insertion.

Because there are no tracking stations within the vast expanse of the Pacific Ocean, the *Cosmos 1* team built two portable ground stations to listen for the spacecraft's signal. One of the stations will be located at Petropavlovsk, at the eastern edge of the Kamchatka peninsula. From there, it will just be able to receive the spacecraft's signal during its orbit insertion burn. The other portable station will be located on the island of Majuro, in the Marshall Islands of the central Pacific. Majuro is the first land point in the spacecraft's orbital path, and *Cosmos 1* will be passing over the island 4 minutes after orbit insertion. The Majuro station should be able to track the spacecraft for around 10 minutes. Once these contacts are established, the role of the portable stations in the mission will be complete.

COSMOS 1 IN FLIGHT

During the first 30–40 minutes of the flight, *Cosmos 1*'s only source of power will be its batteries. The radio will be turned on from the orbit insertion burn through the passage over Majuro, transmitting information about the spacecraft's location to the portable ground stations. It will then be deactivated to conserve power. The Global Positioning Device navigation system will also be operating from 15 to 22 minutes into the flight, to assist in the early tracking.

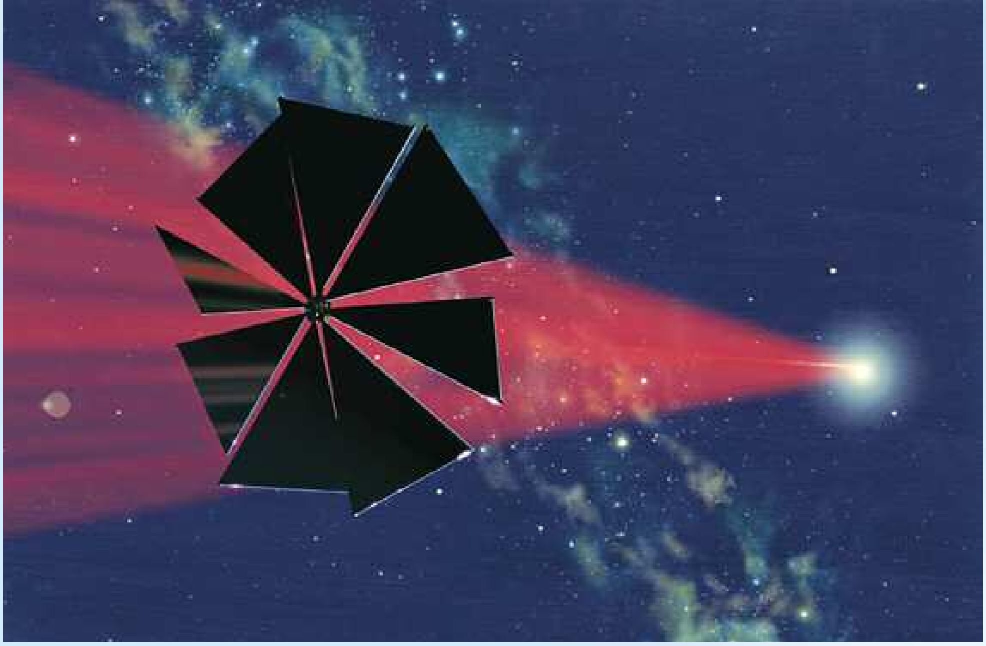
The solar panels will deploy 37 minutes into orbital flight and will orient toward the Sun within 15 minutes after deployment. The solar panels will then provide power to the spacecraft for the rest of the mission.

The next step is for the spacecraft to establish contact with the permanent tracking stations that are spread along its orbital path. There are five of these:

- Medvedzhie Ozera (Bears Lake), near Moscow;
- Tarusa, near Moscow;
- Panska Ves in the Czech Republic;
- Berkeley, California; and
- NOAA station in Fairbanks, Alaska.

The first station to be contacted will be Panska Ves, about 1 hour and 14 minutes after orbit insertion. If all goes well, the station will receive from *Cosmos 1* not only its orbital coordinates but also some engineering data. On subsequent orbits, the spacecraft will frequently contact each of the tracking stations, though not all of them on every orbit.

During the first days in orbit, all the spacecraft's systems will be tested. The two radios on board—one S-band, the other UHF—will be active, and the attitude control jets will be fired to keep the spacecraft stable. In addition, the imaging cameras will be tested, and a plasma ion analyzer will begin collecting data that will be compared



To the stars! A spacecraft similar in design to* Cosmos 1 *makes its way beyond our solar system into interstellar space. Because of its growing distance from the Sun, this spacecraft is propelled by a powerful laser rather than by sunlight. Solar or laser sailing is the only technology known today that may someday take us to the stars.

Painting: Michael Carroll for The Planetary Society

with measurements once the sails are deployed.

Mission control will be based primarily at NPO Lavochkin in Moscow, a center we call Mission Operations Moscow (MOM). The Planetary Society will be the site of another operations center, Project Operations Pasadena (POP), which will maintain full communications capability with MOM and coordinate data handling and the US ground stations telemetry.

SETTING SAIL

Several days into the mission, *Cosmos 1* will deploy its sails. This critical operation will take place while the spacecraft is within range of the two Moscow-area tracking stations, so that data from the procedure can be received in real time. Initially, a set of four triangular blades will unfurl, and if all goes smoothly, they will be followed within minutes by the remaining four blades. It is also possible that mission controllers will wait for the spacecraft to pass over the region again on a later orbit to unfurl the second set of sails. From that point on, *Cosmos 1* truly will be a solar sail.

For a while after deployment, the giant blades will be kept in a fixed position, giving mission controllers a chance to carefully observe the spacecraft's behavior. Only after a few days will the *Cosmos 1* team begin shifting the blades' angles toward the Sun or perpendicular to it, in a controlled program to increase the orbit energy. Gradually, the continuous pressure of reflecting sunlight will raise the spacecraft into a higher orbit above Earth.

The flight of *Cosmos 1* will not last long. Within a month, the Mylar sails will begin to degrade in the harsh sunlight, and the tubes supporting the blades probably will be losing pressure. It is possible that by this time, the spacecraft will have risen to a high enough orbit that it will remain there, forever orbiting the Earth. It is more likely, however, that the orbit will slowly decay and that *Cosmos 1* will end its days as a fireball in Earth's atmosphere.

COSMOS 1 AND BEYOND

Decades from now, when solar sails traverse the vast distances of space hauling massive loads, *Cosmos 1* will seem a very modest mission—a relatively small sail with a short life span that never left the harbor of Earth orbit and that required careful measurements to show that it was indeed sailing on sunlight. But other pioneering missions were modest as well: the Wright brothers' first motorized flight lasted only 12 seconds and 120 feet, and Yuri Gagarin, the first human in space, completed only a single orbit in a mere 108 minutes. Nevertheless, they changed the world.

Cosmos 1 will be another first—the first spacecraft to fly in space powered by sheer sunlight. Compared with today's conventional rockets, it will not soar very high. But it will pave the way for generations of future solar sails that will crisscross the solar system and may one day take us to the stars.

THANK YOU!

This winter, as we prepare to launch *Cosmos 1*, we remember the contributions of those who made it all possible. Twice during the past four years, the *Cosmos 1* mission was nearly canceled due to lack of funds. On both occasions, the project was saved by the generous support of Ann Druyan and her company Cosmos Studios—the Society's partner in this venture and the official sponsor of *Cosmos 1*. We also gratefully acknowledge the support of Peter Lewis, who provided two generous donations at critical moments in the project's development. And last, but certainly not least, this project received enthusiastic support and valuable donations from members of The Planetary Society, who have made *Cosmos 1* a true grassroots effort of space enthusiasts around the world. We thank them all. *—AA and LDF*

Amir Alexander is a web editor for The Planetary Society's website, planetary.org. *Louis D. Friedman is executive director of The Planetary Society and project manager of* Cosmos 1.

OUR FIRST LOOK INSIDE A

DEEP IMPACT

ON JULY 4, 2005 THE *DEEP IMPACT* FLYBY SPACECRAFT WILL RELEASE A 370-KILOGRAM (820-POUND) IMPACTOR THAT WILL SLAM INTO A COMET. IT WILL BE A BLAST, BUT WHY ARE WE DOING IT?

BY LUCY MCFADDEN AND MIKE A'HEARN

Modern ideas about the nature and structure of comets continue to evolve. In 1950–1951, Fred Whipple first proposed the dirty snowball model, suggesting that comets are not just loose aggregations of particles but possess a solid nucleus with some strength and hence internal structure. He theorized that as a comet approaches the Sun, sublimating ices drive off dust, forming the coma that shrouds the nucleus.

In 1986, when Halley's comet returned to the inner solar system, Whipple's ideas were proven to be correct and scientists were able to image it from flyby spacecraft. For the first time, they could peer through the coma at close range and resolve a solid nucleus.

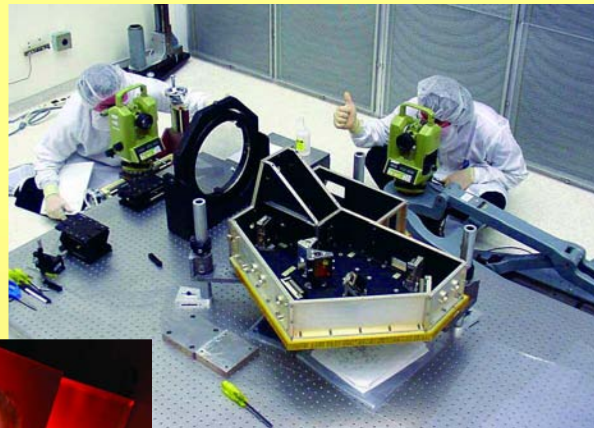
Although the comet possesses a lot of water, the nucleus' measured albedo—the percentage of sunlight reflected from the surface—is a paltry 4 percent (darker than coal). Scientists Mike Belton and Alan Delamere, along with many of their colleagues, were surprised at how little light is actually reflected from the nucleus of comet Halley.

The story goes that after Halley's apparition, Mike and Alan were reviewing proposals for NASA, and they had a conversation that seeded the idea of the *Deep Impact* mission. They pro-

COMET:

Above: The* Deep Impact *spacecraft (a mission first conceived nearly 20 years ago) will begin its journey on December 30, 2004. On July 4, 2005 the two-part spacecraft—a flyby vehicle and a smaller, copper "impactor"— will encounter comet 9P/Tempel 1. There, the impactor will be released to smash into Tempel 1. This experiment, designed to mimic the natural process of impact cratering, will give scientists their first view inside the nucleus of a comet.
Illustration: JPL/NASA

Left: Thanks to flyby spacecraft like Europe's* Giotto*, scientists were able to take close-up images of the nucleus of Halley's comet when it last visited the inner solar system in 1986. Surprised to find how little light is reflected off the comet's nucleus, they hypothesized that a dark crust insulates the nucleus's interior.
Image: Max Planck Institut für Aeronomie



Above: Engineers align mirrors in the Spectral Imaging Module (SIM) of* Deep Impact*'s High Resolution Instrument. This instrument and the camera will watch the crater form and will measure spectral signatures of Tempel 1 before and after impact. These signatures will reveal the composition of the comet's surface and interior.
Photo: Ball Aerospace & Technologies Corporation

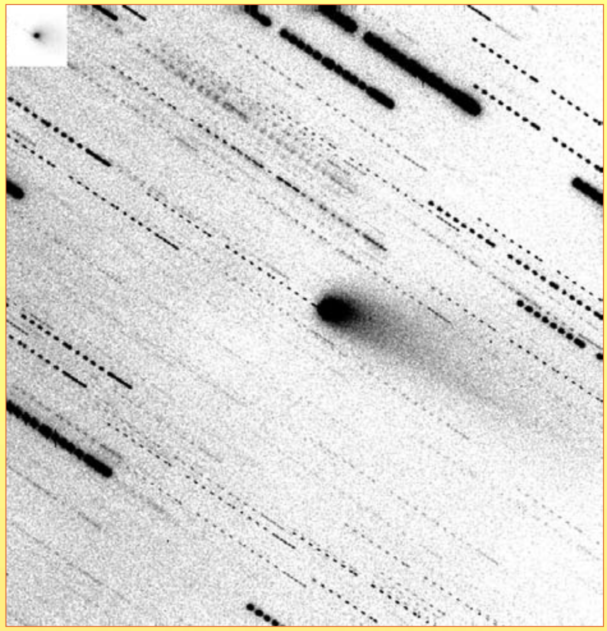
Left: Coauthor Mike A'Hearn poses with the copper impactor that will blast a crater into the surface of comet Tempel 1. He likes to say that "the concept is simple, but the execution is complex."
Photo: Ball Aerospace & Technologies Corporation

posed to each other that in the creation of a dark nucleus, some process results in an accumulated layer or crust. They suspected that the vaporizing ice leaves behind a dark crust that insulates the interior, trapping ices inside the comet.

They conceived a mission to hit a comet with a projectile moving at many kilometers per second that would vaporize upon impact and excavate a crater. A flyby spacecraft would observe the impact and any spreading curtain of ejecta. After the gas and dust settled, cameras and a spectrometer would peer into the freshly exposed cometary interior to see what lies beneath. The *Deep Impact* mission was born.

They assembled the mission team—a partnership of scientists led by Mike A'Hearn at the University of Maryland; engineers at Ball Aerospace & Technologies Corporation in Boulder, Colorado; and managers and engineers at the Jet Propulsion Laboratory in Pasadena, California.

The mission proposal was submitted to NASA's Discovery Program in 1996 and was rejected because the review teams didn't believe the selected target, 3200 Phaeton, was really a comet. They also ques-

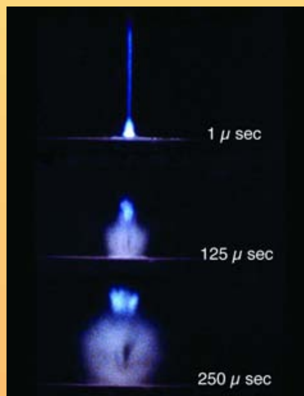


Right: Discovered in 1867 by Wilhelm Tempel, comet 9P/Tempel 1 was chosen as Deep Impact*'s target because it is a good match for the mission's science objectives as well as its mass and fuel constraints.*

This image of Tempel 1 was taken on August 21, 2000 with the University of Hawaii's 2.2-meter telescope on Mauna Kea. The picture is a composite of several short-exposure images, and because the comet moves across the sky with respect to the background stars, those stars appear as dotted lines. *Image: Karen J. Meech, University of Hawaii*

An engineer holds the filter wheel from inside the SIM. The different filter colors allow only particular wavelengths of light to pass into the detector.

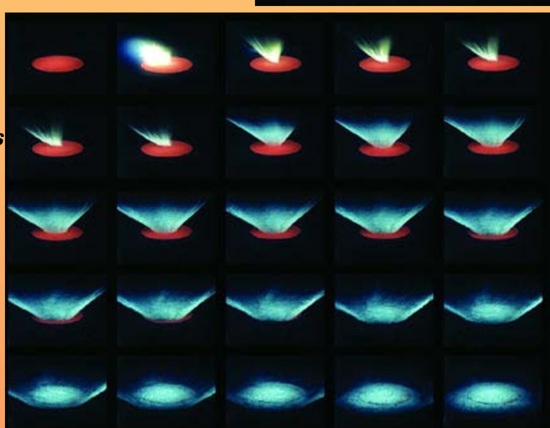
Parts of the flyby and of the impactor spacecraft are seen here undergoing electromagnetic and interference testing inside a clean tent. *Photos: Ball Aerospace & Technologies Corporation*



Cratering experts on the Deep Impact *team have performed various experiments attempting to predict the outcome of the impactor's collision with comet 9P/Tempel 1. Peter Schultz of Brown University used NASA's Ames Vertical Gun Facility in Moffett Field, California to simulate hypervelocity impacts into cometlike substrates.*

The image at right shows three frames of a side view of an impact into dry ice at 1, 125, and 250 microseconds after impact. (A microsecond is one millionth of a second.)

The view below shows an experiment that allows scientists to watch the inside of the crater as it grows. In these tests, a small Pyrex sphere was shot into a powdered silicate target. A thin layer of dry red paint powder differentiates the surface from underlying materials. In the laboratory, the crater finished forming in about 120 milliseconds (a millisecond is one thousandth of a second). Under the low gravity of Tempel 1, the crater could take as long as 400 seconds to form.
Images: Peter Schultz, Brown University



tioned whether, without guidance and control mechanisms, the impactor would successfully hit the target.

In 1998, following continued engineering development and selection of a new target—Comet 9P/Tempel 1—the proposal was resubmitted and selected as the eighth Discovery Mission. Design and mission planning picked up in January 2000, the preliminary design was reviewed at the end of February 2001, and the critical design review followed in January 2002. The science team defined a scientific experiment that re-creates a common solar system process, impact cratering.

Engineers at Ball Aerospace & Technologies Corporation designed, built, and tested the spacecraft and its three imagers and infrared spectrometer. Mission planners at JPL have developed the spacecraft trajectory and the mission plan that will get the spacecraft to the comet, calibrate the instruments, separate the impactor from the flyby spacecraft, and target it toward an encounter at 06:00 UT on July 4, 2005. The concept is simple, but its execution is complex.

The two-part spacecraft, to be launched from a Delta II rocket, consists of a larger flyby spacecraft carrying a smaller impactor spacecraft. The 370-kilogram (820-pound) impactor is a battery-powered spacecraft designed to operate independently for only one day. After its release, it will take over its own navigation and maneuver into the path of the comet. A camera on the impactor will capture and relay images of the comet nucleus just seconds before the impactor collides with the comet, as the *Ranger* spacecraft did before purposely crashing into the Moon in the mid-1960s. After separation, the flyby spacecraft will observe and record the impact, any ejected material blasted from the crater, and the structure and composition of the crater's interior.

A massive preparatory observing campaign is under way, coordinated by team member Karen Meech of the University of Hawaii. Astronomers have observed the comet with ground-based and space-based telescopes to deduce its size, shape, and production rates of gas and dust. Engineers have used this information to build protective shields on critical parts of the flyby spacecraft and to plan for successful data acquisition with working instruments.

Team associate Casey Lisse worked with other team members developing a model of the dust distribution around Tempel 1. This model, based on both observations and probabilities, indicates that as the flyby passes through the orbital plane of Tempel 1, the spacecraft will be hit by about 20 particles the size of a grain of sand and maybe one the size of a sugar cube, which may harm the spacecraft.

IN MEMORIAM—
Fred Whipple

Comet West Image: Observatoire de Haute, Provence, France

Fred Lawrence Whipple, a leader and a legend in 20th-century planetary science, died August 30 at a Cambridge, Massachusetts hospital following a prolonged illness. He was 97.

A discoverer of six comets, Whipple forever will be remembered for revolutionizing the study of these celestial bodies. In 1950–1951, he hypothesized that comets were not "sandbags" held together by gravity, as was widely believed, but "icy conglomerates" made of rock, dust, and ice, what newsmen then dubbed "dirty snowballs." He was right.

Born in Red Oak, Iowa on November 5, 1906, Whipple led a remarkable life. When polio dashed his bid to become a tennis champion, he turned to astronomy. After earning his doctorate from the University of California at Berkeley, he accepted a position at the Harvard College Observatory, then went on to direct the Smithsonian Astrophysical Observatory (SAO) from 1955 to 1973 before it became the Harvard-Smithsonian Center for Astrophysics.

"He was one of the fixed stars in the firmament of planetary science," says Planetary Society cofounder Bruce Murray. "He was there before there was a field. For those of us who came in at the beginning of the Space Age, he was a giant and had a big influence on how things got started."

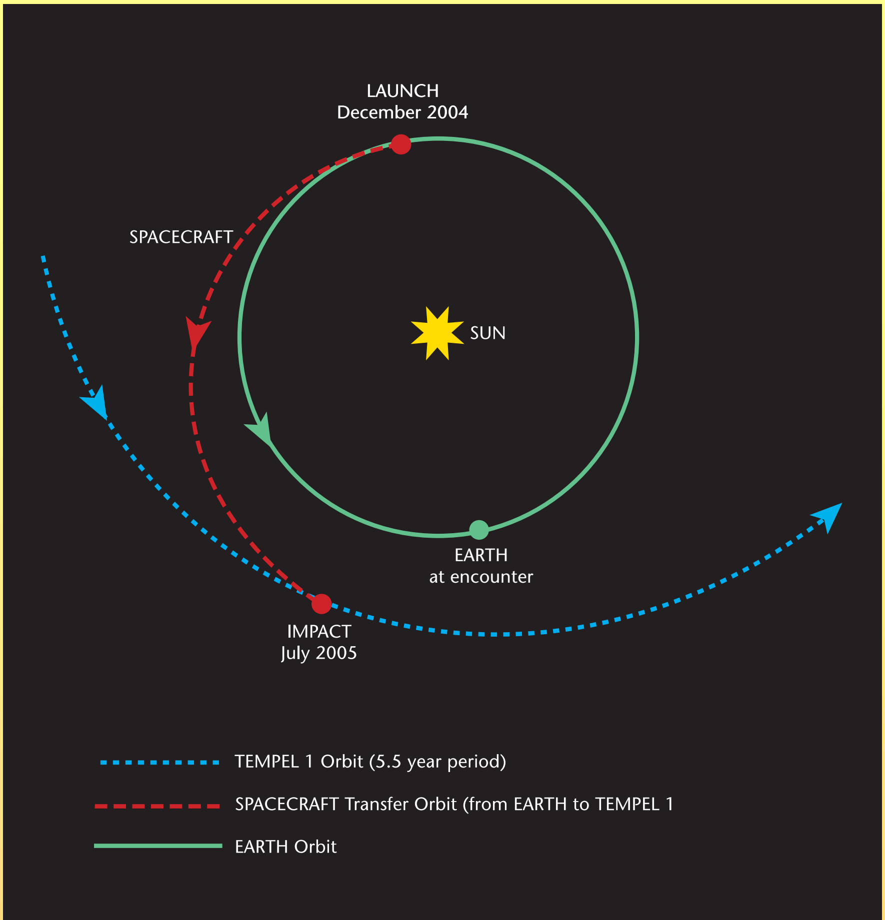
Indeed, Whipple predicted the coming of artificial satellites and space exploration, and when *Sputnik* was launched in 1957, his network of amateur astronomers was the only group prepared to track the Russian orb. Although he received many awards in his illustrious career, he considered as his "most exciting moment" the time President John F. Kennedy honored him in 1963 with the Distinguished Federal Civilian Service Award for his satellite-tracking network.

Whipple continued to work almost to the end of his life, and for many years he could be identified easily on the streets of Cambridge as he cruised around in his car, which sported a license plate that read "COMETS."

"Fred Whipple was the dean of cometary scientists," says Wes Huntress, president of The Planetary Society and director of the Geophysical Laboratory at the Carnegie Institute of Washington. "All understanding of these cosmic apparitions begins with Fred. The rest of us have just been refining and confirming what he already knew."

"Fred made significant contributions to fields as diverse as meteor astronomy, stellar evolution, and radio astronomy, among others," reflects Don Yeomans of JPL, manager of NASA's Near-Earth Object Program office. "Yet through it all, he remained just Fred to all who knew him."

"One of the most striking things about Fred was that he had very, very high principles," reminisces Joe Veverka, Whipple's last graduate student, now astronomy chair at Cornell. "And he also had a subtle sense of humor. One winter day in the late 1960s, he was getting ready to go to the Virgin Islands, where he had a home. It was an annual ritual. On his desk, he had half a dozen tiny potted cactuses. 'What are you doing with those, Fred?' I asked. He got this devilish grin on his face and said: 'I take some every time I go and plant them somewhere. Just think, 50 years from now graduate students will be trying to figure out—how the hell did these things get here?!' Fred was very special, a gentleman in every sense of the word, and he will be deeply missed." *—A.J.S. Rayl*



Originally a backup plan, the December 30, 2004 launch date allowed scientists and engineers more time to test the spacecraft systems while still keeping the July 2005 encounter date. *Illustration: JPL/NASA*

THE NUCLEUS OF COMET 9P/TEMPEL 1

PROPERTY	VALUE
Size (km)	~14 x 5 x 5 km
Shape	Elongated, irregular
Mean density (kg/m^3)	500 ± 400
Mean mass (kg)	~1 x 10^{14}
Mean radius (km)	3.4 ± 0.2
Geometric albedo (R-band)	0.047 ± 0.01
Rotation period (length of day)	41.85 ± 0.1 hr
Orbit	Jupiter-family comet with a 5.5-year orbit; orbit regularly varying between perihelia near 1.5 and 2.0 AU

In preparation for data analysis in July 2005, science team members and their associates have also worked hard at calibrating the spacecraft's instruments with pre-flight test data. Understanding the performance of the instruments is critical for accurate analysis of the returned data.

We believe the comet's interior is cold ices from the early solar nebula and formed at the outer edges of the solar system 4.5 billion years ago. We expect to place constraints on the density and structure of the comet's nucleus by examining the size and depth of the crater and the nature of any ejected material.

We want to measure brightening from the impact and follow the evolution of any material ejected from the crater. After the dust has cleared, we will peer inside the crater with a camera and spectrometer and see what we can learn about its structure and composition. All the measurements require an understanding of the performance of the instruments.

Pete Schultz at Brown University has conducted laboratory experiments simulating hypervelocity impacts into possible comet-like substances using the Ames Vertical Gun Facility at Moffett Field, California. Jay Melosh of the University of Arizona and his graduate student Jim Richardson have developed computer simulations that explore the possible outcomes of the experiment.

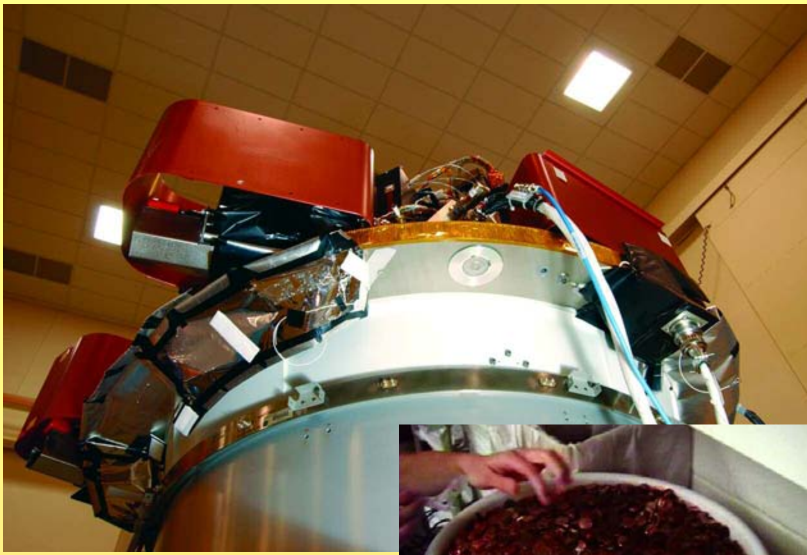
Based on the theory and analysis of our cratering experts, the science team is now considering which outcome they expect. Will the crater be large, with a diameter-to-depth ratio of 4:1 as expected? Does the comet have strength, in which case the diameter-to-depth ratio would be 3:1? If there is a hard crustal layer with porous material beneath, will that affect the size and shape of the crater or its ejecta? Does anyone want to place a bet?

COMET 9P/TEMPEL 1

Comet 9P/Tempel 1 was discovered

in 1867 by Ernst Wilhelm Tempel. It has a 5.5-year orbital period and spends most of its orbit between the orbits of Mars and Jupiter. It was selected as the mission's target for its good match with science objectives and because it is easily accessible by a spacecraft from Earth. Near perihelion, it can both be reached in a flyby mission and be readily observed from Earth (at a distance of 0.9 astronomical units).

The orbital geometry also allows a flyby speed giving enough energy to vaporize most of the impactor and excavate a crater so the flyby spacecraft can look inside the comet. In addition, this comet has a relatively large phase angle (the Sun-comet-spacecraft angle) of 63 degrees during encounter, providing a large sunlit surface for targeting. Tempel 1 is also a relatively low activity comet so that dust will not obscure the spacecraft's view.



Above: A CD-ROM holding the names of more than 500,000 participants in the Send Your Name to a Comet campaign will travel to Tempel 1 on board the impactor.

Dee McLellan, a teacher at Meadow Creek School in Andover, Minnesota, had a great idea for making a "deep impact." She had her 7th grade class collect the weight of* Deep Impact*'s copper projectile in pennies. Once classmates gathered enough pennies to "make weight," they counted them and sent the same amount of money to their sister school in the Ukraine. *Photos: JPL/NASA*

THE SCIENTIFIC INSTRUMENTS

The primary instruments on the flyby spacecraft are the High Resolution Instrument (HRI) and the Medium Resolution Instrument (MRI). The HRI is a narrow-field-of-view imager with a filtered CCD (charge-coupled device) camera and infrared spectrometer. It provides the highest-resolution images of 1.4 meters per pixel at 700 kilometers. The HRI is optimally suited to observe the comet's nucleus.

The MRI backs up the HRI, and, with a wider field of view, a filter wheel, and a CCD camera, it is slightly better at navigation for the last 10 days of travel before impact. This imager also provides context for the HRI. The Impactor Targeting Sensor (ITS) on the impactor is identical to the MRI except that it does not have a filter wheel.

THE MISSION SCENARIO

Deep Impact is scheduled to launch on December 30, 2004 at 2:39 p.m. EST, with a second opportunity at 3:18 p.m. The launch window spans 30 days. Just after launch, in the commissioning phase, the spacecraft functions will be checked and verified. The science team has asked that soon after launch, the spacecraft take a look at the Moon, a well-studied standard for imaging and spectroscopy.

During cruise, there will be in-flight calibrations of the flight system and the payload as well as trajectory correction maneuvers (TCM). The approach phase begins in early May, when we acquire the comet and perform the third TCM.

The impactor separates from the flyby on July 3, and 24 hours later, it will hit the comet. Meanwhile, the flyby will slow down to watch the crater grow (and, we hope, observe some ejecta). Eight hundred seconds after impact, the flyby enters shield mode while it passes through the innermost coma and then the comet's orbital plane, where dust and debris are densest. Shortly afterward, it will turn and look back, taking pictures and spectra as it recedes from the comet. The end of mission is scheduled for August 3, 2005.

REACHING OUT TO THE PUBLIC

As part of the Education and Public Outreach program of the mission, we've developed materials and activities for educators and the interested public. Team members and their education partners at Mid-Continent Research Education Lab have materials for school-aged kids and adults alike on the education section of the website at *deepimpact.umd.edu/educ.html*. We asked the Fiske Planetarium at the University of Colorado to produce a planetarium show based on the mission, which was distributed to members of the International Planetarium Society in August, so it may be available at your local planetarium on request. Also, a CD-ROM with the names of more than 500,000 people (including all Planetary Society Members as of October 1, 2003) will travel to the comet on the impactor. We are all making a "deep impact" in our own way.

We hope you will join us on July 4, 2005 for what we hope will be a spectacular event.

It will be a blast!

Lucy McFadden is a research professor at the University of Maryland and Deep Impact *co-investigator and is looking forward to determining the nature of any minerals seen in spectroscopy. She has responsibility for education and public outreach for the mission. Mike A'Hearn, a distinguished university professor at the University of Maryland and* Deep Impact *principal investigator, is interested in all aspects of the experiment.*

World  Watch

by Louis D. Friedman

Mojave, CA—Commanding the world's attention in September and October were the successful flights of *SpaceShipOne*. A team led by Burt Rutan of Scaled Composites, Inc., won the $10 million Ansari X Prize for completing two successful flights to space within two weeks in a completely privately funded venture.

The two flights were accomplished within just one week, with the first on September 29 and the second on October 4, the 47th anniversary of the dawn of the space age.

The flights were backed by Microsoft cofounder Paul Allen. The cost of the Scaled Composites venture has been estimated in excess of $25 million.

The backers of the Ansari X Prize and many in the space community heralded the flights as opening a new era for private, commercial space travel. The US Air Force X-15 achieved the technical accomplishment of the flights 40 years earlier, but this was the first time it was done in a private venture. A height of 100 kilometers (62 miles) is commonly defined as the boundary between the Earth's atmosphere and outer space. The two pilots, Mike Melvill and Brian Binnie, who crossed the 100-kilometer mark were both awarded astronaut status.

This was a laudable technical accomplishment, and The Planetary Society congratulates all involved. I, personally, did not think it would be done, and for their support and vision, I salute the X Prize backers as well as the technical and financial team that made *SpaceShipOne* possible.

I remain skeptical about the possibilities for commercial development or the future of private flights to orbit. As Buzz Aldrin put it (despite his strong backing for private space ventures), it is one giant leap from the suborbital flights of today to private orbital flights. *SpaceShipOne* accelerated to 3.5 times the speed of sound to reach the edge of space, but a spacecraft has to reach 25 times the speed of sound to go into orbit. Nonetheless, the new era of barnstorming to space is upon us, and raising public interest and excitement is an excellent goal.

There is a role for private initiative in space, and it lies in seeding new ideas, working on topics that bureaucracies find too speculative, sparking creativity and "out-of-the-box" thinking, and building partnerships from various public and private sectors. We have examples of this type of activity in our own projects. Our Mars microphone was the first privately funded instrument, and Red Rover was the first privately funded student experiment to go to another world. Soon, the *Cosmos 1* solar sail will be the first privately funded space mission by a space interest group. Innovation and creativity are hallmarks of space ventures—we congratulate again the X Prize and the *SpaceShipOne* team on theirs.

Washington, DC—Despite numerous rumors about the NASA budget, the US Congress adjourned without acting on it. Neither an appropriations nor an authorization bill was passed before October 11, when Congress adjourned. A continuing resolution passed by Congress provided funds for NASA (and most of the rest of the federal government) at the previous year's level.

Congress is scheduled to return shortly after the November election to finish up the 9 (of 13) spending measures that were not completed on time, including the appropriations for NASA. This session is called a "lame duck" session, referring to a changeover in Congress that will have been voted by the people but won't take effect until January. It is possible, therefore, that defeated or retiring legislators will have a key role in setting NASA's budget for the fiscal year that began on October 1.

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

We Make an Impact

To support the proposed exploration space policy, The Planetary Society assembled an outstanding team of aerospace experts to conduct a study on the transportation steps necessary to extend human presence into the solar system. Skylab Astronaut Owen Garriott and Johns Hopkins University Applied Physics Laboratory Director of Space Michael Griffin led the team. The report is available on our website at *aimformars.org*

We presented the report to key staff in the White House, who were so positive about it that they asked us to come back and present it to a larger group. Then we met with Admiral Craig Steidle, head of NASA's Exploration Systems office, and his staff. Finally, we went to Congress and presented it to staffpersons in the House and Senate concerned about the NASA budget.

Senator Sam Brownback commented favorably on the report in his remarks to NASA Administrator Sean O'Keefe at a hearing examining issues for the shuttle's return to flight. The study was also favorably cited in opinion pieces in two leading aerospace industry trade publications: *Space News* and *Aviation Week & Space Technology*.

We cannot ensure that we will be listened to. But The Planetary Society will keep trying, and if the past is any indication, we will make a difference.

Questions and Answers

Won't it be too dark for the* Huygens *probe to take pictures of Titan's surface, considering how cloudy and far from the Sun this Saturnian moon is?
—Ed Stewart
Warminster, Pennsylvania

Because Titan is 10 times farther from the Sun than Earth is, the solar illumination is 1 percent as bright at the top of Titan's atmosphere as it is at the top of Earth's atmosphere. Our best models indicate that some 10 percent of this illumination reaches Titan's surface. That is, the illumination at the surface of Titan is about one thousandth that on Earth at midday. For comparison, the full Moon's illumination on Earth is about one millionth of that at noon. Thus, the illumination at the surface of Titan is about 1,000 times as high as on Earth's surface with full Moon illumination and one thousandth what it is with full Sun illumination. This is plenty of light for imaging with sensitive CCD (charge-coupled device) detectors, as exposure times need to be only a few hundredths of a second.

The more interesting question is why we have so much difficulty seeing features on the surface of Titan from high altitudes and from outside the atmosphere. The answer is that much of the illumination that reaches the surface of Titan is due not to photons streaming directly down to the surface but instead to diffuse illumination by photons that have scattered several times on their way to the surface. The same thing happens to photons that are reflected by the surface and then travel upward and out of the atmosphere. Perhaps only 10 to 20 percent of the photons that leave the surface escape from the top of the atmosphere without being scattered by a haze particle and then changing direction. What we see from outside the atmosphere is a small fraction of the photons that come directly from the surface (and contain information on the brightness of specific features on the surface), mixed with a diffuse general brightness. This background brightness from the scattered photons acts to decrease the contrast of the surface to only a few percent.

To get the best images of the surface, we must subtract this general background and boost the remaining brightness to see surface features. However, this boosting also increases the noise in the images, and if the fraction of the photons that come directly from the surface is too small, we do not see surface features very well in the resulting picture.

The great advantage of the Descent Imager/Spectral Radiometer (DISR) camera on the *Huygens* probe is that as it descends deeper and deeper into the hazy atmosphere of Titan, we will get closer to the surface, and photons coming up from the surface will experience less and less scattering. In fact, our models indicate that the bottom of Titan's haze is approximately 70 kilometers (44 miles) from the surface. If so, images taken below that level should show the surface with no dilution resulting from photon scattering between the altitude of the camera and the surface.

Because Titan's haze particles rapidly appear darker when observed at successively shorter (bluer) wavelengths, the satellite Titan appears orange from outside the atmosphere. The dark particles in the blue wavelength prevent blue light from reaching the surface, so Titan's sky should appear orange from the ground as well.
—MARTIN TOMASKO,
University of Arizona

Looking at all the rocks on Mars—small, medium, and large—leaves me wondering how they came to be. I know that on Earth, small rocks came from larger ones, and those from still larger ones. These rocks were broken up by floods and earthquakes. But did things work the same way on Mars?
—Mack Dougherty
San Diego, California

Rocks on Mars certainly were formed by processes similar to those on Earth, such as floods and earthquakes. On Mars, however, an additional process is responsible for most of the initial formation of rocks: impact cratering. This process is so dynamic and powerful that it can instantly produce a host of smaller rocks from solid bedrock, and it can distribute them widely across the planet. Impacts happen randomly again and again at particularly high rates in a planet's early history.

Impact cratering is a mechanical process of weathering that is thought to produce a rock and soil debris layer many kilometers thick; it is known as a mega-regolith (or large and thick soil layer). Geologic processes such as flooding and wind can then break up this material further.
—JAMES W. HEAD III,
Brown University

Factinos

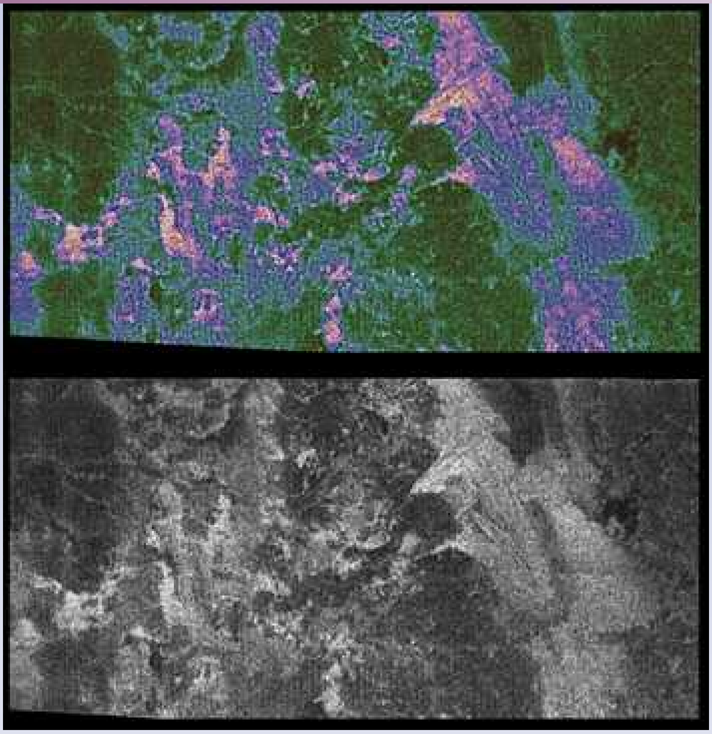
New radar images of Titan show a complex geologic surface that may be relatively young. *Cassini* flew past Saturn's cloud-enshrouded moon and took a series of radar observations on October 26, 2004.

Approximately 1 percent of Titan's surface was mapped during the October 26 flyby. Radar images from Titan's northern hemisphere, a region that has not yet been imaged optically, show great detail and features down to 300 meters (984 feet) across.

The radar images at right show a world brimming with features that are dark and white, indicating sharp contrast. One area, called "Si-Si" or the "Halloween cat" because it is shaped like a cat's head, is very dark and relatively smooth. Scientists speculate that it might be a lake of some sort, but they caution that it is too soon to know for sure.

The optical imaging cameras on *Cassini* show streaks on the surface that may be caused by flowing hydrocarbon liquids, movement of a material over the surface by wind, or a moving ice sheet like a glacier. Imaging scientists also see multiple haze layers in Titan's atmosphere that extend about 500 kilometers (310 miles) above the surface.

"In the two days since this flyby, our understanding of Titan has grown tremendously," said Jonathan Lunine of the University of Arizona. "Titan is a dynamic place with complex geologic processes that may be shaping its surface. Its surface may well be covered with organic materials, but we still don't know how much of the surface is liquid or solid. The fact that we have seen few craters tells us that Titan's surface is young."
—from the Jet Propulsion Laboratory



The black-and-white radar image of Saturn's moon Titan, at bottom, was acquired on October 26, 2004 when Cassini *flew about 1,200 kilometers (745 miles) above the Saturnian moon's surface and gathered radar data for the first time. The image reveals a complex surface geology that scientists believe to be composed of icy materials and hydrocarbons.*

To provide a better perspective of the surface features, a color version of the same image appears at top. In the color view, brighter areas may correspond to rougher terrains, radar-facing slopes, or different materials. Pink enhances smaller details, while green represents smoother areas. The winding linear features that cut across dark areas may be ridges or channels.

Images: JPL/NASA

On September 25, 2004, the Mars Exploration Rover *Spirit* snapped its 50,000th image of Mars—then kept on snapping. The images above are of the Panoramic Camera's calibration target, also called the MarsDial. The 50,000th image (black and white) was taken as part of a sequence of images in a panoramic view of the Columbia Hills on Spirit's 260th Martian day.

To read more on this story, go to *http://planetary.org/news/2004/spirit_image-milestone_1105.html*
—from the Jet Propulsion Laboratory

Spirit*'s 50,000th image of Mars (black and white) was captured on September 25, 2004, or Martian day (Sol) 260 of the mission. To the right of that is a true Mars-colored compilation of frames 50,000, 50,001, and 50,002. For an idea of how much dustier the MarsDial has become, compare the middle image with the color view at right, taken on Sol 77, or 183 Mars days, earlier.*

Images: JPL/NASA/Cornell University

Society News

Newest Members of Advisory Council

The Planetary Society welcomes two distinguished scientists as the newest members of its Advisory Council: Laurie A. Leshin of Arizona State University and Bruce M. Jakosky of the University of Colorado, Boulder.

Leshin's research program seeks to understand the formation and evolution of our solar system as a basis for better understanding Earth and its biosphere and for investigating the possibility of life elsewhere. Her research is conducted both through the study of meteorites and with exploration missions.

Jakosky's interests focus on the surfaces and atmospheres of planets and include research into the possibility of life on other worlds. His current emphasis is on Mars, and he is an interdisciplinary scientist for surface-atmosphere interactions on the Mars Global Surveyor mission.

—Susan Lendroth, Manager of Events and Communications

Planetary Radio Expands

As we go to press, we're able to announce that listeners in four communities can tune in to public radio's only half-hour program about space exploration. Here's a rundown:

- Allentown, Pennsylvania: Hear us on WMUH, 91.7 FM, Mondays at 9:30 a.m.
- Irvine, California: Tune in to KUCI, 88.9 FM, Mondays at 5:30 p.m.
- Ocean City, Maryland: Planetary Radio airs on WSDL 90.7 FM, Fridays at 7:30 p.m.
- Radio Free Lytle Creek, in California's San Bernardino Mountains: 91.5 FM and 9150 AM, Mondays at 10:00 p.m.

There's much more to come! Visit *planetary.org/radio* for the latest additions or to hear every episode of Planetary Radio online as either a Windows Media or an MP3 file.

Haven't caught us at all yet? Then you've already missed *SpaceShipOne* winning the X Prize, a conversation with JPL Director Charles Elachi, solar sail coverage, *Apollo* astronauts, and much more in just the last few weeks. Then there's the weekly Space Trivia contest presented by Bruce Betts as part of "What's Up?" Listen, enter, and win your very own Planetary Radio T-shirt. We'll see you on the radio.

—Mat Kaplan, Planetary Radio Producer

Help Us Launch Our 25th Anniversary

Thank you, members, for helping to shape the future of space exploration. Our success depends on your support—in our advocacy campaigns, at events in your communities, and for special projects and daily operations. As this year draws to a close, we hope you will consider making a financial gift to the Society to help launch us into our 25th anniversary year.

In addition to outright gifts to support the Society or a specific project, you may wish to consider making a gift of appreciated stock. It's a fast and easy way for you to generously support The Planetary Society and to derive considerable tax benefits.

A gift of stock owned for more than one year entitles you to a charitable deduction for the full market value at the time the gift is made. With appreciated stock, you also avoid a capital gains tax on the appreciation in value.

Because electronic transfers of stock are made without identifying the donor, we ask that you let us know in advance about the stock and number of shares you would like to donate to the Society.

To let us know, or if you have questions about making a gift of appreciated stock, please call or e-mail Andrea Carroll at 626-793-5100, extension 214, or *andrea.carroll@planetary.org*

Thank you, and best wishes from all of us for the coming year.

—Andrea Carroll, Director of Development

Special Members-Only Discount!

Autographed Copies of Astronaut Sally Ride's book, *The Third Planet: Exploring Earth from Space*

Through a special arrangement with Sally Ride Science, Planetary Society members can purchase an autographed copy of *The Third Planet* for $17.00, a savings of more than 30%.

The award-winning science writing team of Sally Ride and Tam O'Shaughnessy takes on the Earth in this beautiful book. Packed with full-color photographs of Earth from space, this new edition explores everything that makes our home planet such a special member of the solar system.

This winner of the American Institute of Physics Children's Science Writing Award was written especially for readers ages 10–14, but it is a fascinating guide to our planet for readers of all ages.

To redeem your special Planetary Society discount, follow the steps below:

1. Visit the special page at the Sally Ride Science Store: *www.sallyridestore.com/store/third_planet_tps.do*. This will take you to a page with *The Third Planet* already in the shopping cart. You may add copies (at the same discount) and either check out or continue shopping.

2. At checkout, enter the following Planetary Society code: **tps01**
The discount will be applied to all autographed copies of *The Third Planet*.

If you prefer to order by phone, call 1-800-561-5161 and give your Planetary Society code.

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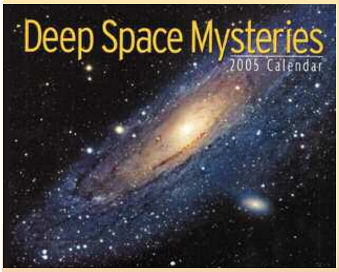

Deep Space Mysteries: 2005 Wall Calendar
Each month, enjoy awe-inspiring full-color images from deep space. This 2005 wall calendar is produced by the creators of *Astronomy* magazine.
2 lb. **#520 $12.00**

The Year in Space: 2005 Desk Calendar
A dazzling photograph awaits you each week as you plan your daily appointments. This planner includes 52 weekly calendars, 12 monthly calendars, a full-year planning calendar, and a four-year, long-range calendar.
1 lb. **#523 $12.00**

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**

Nebula Poster
This spectacular 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. **#315 $13.50**

"Is Anybody Out There?" Poster
This astounding image, obtained by the Two Micron All Sky Survey, reveals some of the 400 billion stars in our own Milky Way galaxy. 39" x 16" 1 lb. **#320 $13.50**

***Spirit*'s View at Bonneville Crater Poster**
Sixty-seven days after landing, *Spirit* 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
This 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**

An Explorer's Guide to Mars Poster
Images from *Mars Global Surveyor*, speculative paintings of the Red Planet's past and future, informative captions and charts, and images of Mars' surface from the *Pathfinder* and *Viking* spacecraft enhance a detailed US Geological Survey map. 24" x 37" 1 lb. **#505 $15.25**

Explore the Planets Poster
This poster is full of fascinating facts about our planetary neighbors. 34" x 22" 1 lb. **#310 $11.50**

***Pathfinder* Images of Mars**
20 slides. 1 lb. **#215 $7.50**

Future Martian T-Shirt
Child sizes: S, M, L 1 lb. **#565 $13.50**

***Cosmos 1* T-Shirt**
Adult sizes: S, M, L, XL, XXL 1 lb. **#570 $25.00**

***Cosmos 1* Team Jacket**
Adult sizes: M, L, XL 1 lb. **#573 $60.00**

"Is Anyone Out There?" T-Shirt
Adult sizes: S, M, L, XL, XXL 1 lb. **#586 $19.95**

SETI@home Mug
Our new 11-ounce mug features a wraparound image of the SETI@home screen saver. 2 lb. **#550 $10.00**

"Top Three Reasons I Want to Move to Mars" Mug
This humorous mug featuring an image of *Spirit*'s landing site suggests three added benefits of life on the Red Planet. 2 lb 1 lb. **#610 $16.00**

***Cosmos 1* Thermal Mug**
Stainless steel 16-ounce thermal mug.
2 lb. **#575 $18.00**

Spacecraft Science Kits
Build your own spacecraft and learn how it works. Each sold separately. 1 lb. **$15.75**

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#530 *Lunar Prospector*
#531 *Mars Global Surveyor*
#538 *Magellan*
#560 *Voyager*

***Winds of Mars* and the Music of Johann Sebastian Bach**
This audio CD features digitally simulated sounds of the winds of Mars heard between 17 of Bach's finest compositions, played on piano. Liner notes explain the production of the Martian sounds and offer a general history of Mars exploration. 1 lb. **#785 $15.00**

Mini Mars Polar Lander Science Kit
1 lb. **#778 $3.00**

We're Saving Space for You! Bumper Sticker
1 lb. **#695 $3.00**

***Craters!* A Multi-Science Approach to Cratering and Impacts**
By William K. Hartmann with Joe Cain. For grades 9–12. 224 pages (softcover). 2 lb. **#109 $24.95**

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The royal blue cap features our logo on the front and *planetary.org* on the back. 1 lb. **#673 $13.50**

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In *Resplendent*, three alien planets drift in space, illuminated by ethereal starlight. As our telescopic "vision" grows more acute and our spacecraft explorations become more ambitious, perhaps life will one day imitate art.

Greg Martin is a senior at The University of Washington, working toward a bachelor of fine arts degree in visual communication design. He produces digital illustration as a hobby that runs parallel to his job as a graphic designer.

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