The PLANETARY REPORT

Volume XXIII Number 2 March/April 2003

View From *Columbia*

A PUBLICATION OF THE PLANETARY SOCIETY

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Number 2
March/April 2003

Features

A Special Note: You'll find something new in this issue of *The Planetary Report*: advertising. To keep our organization healthy, we are adapting to the new economic climate and expanding our sources of revenue. To keep our members happy, we will limit the amount of ad space and only accept ads related to our mission. This will be a small change, but we hope it will make us more effective in maintaining our active and influential organization and in advancing our shared goals.

Departments

From The Editor

I feel as if I've written this column before: in 1986, in the aftermath of the *Challenger* tragedy. Then, as now, we faced a critical examination of why human beings should explore space at all, and why human life should be risked in any endeavor with so intangible a return.

The official examination first will focus on *Columbia* itself, next on the space shuttle program, and then expand, as if through concentric rings, to encompass NASA itself. Beyond that, in the public arena, the space programs of all nations will be debated and reviewed. Things will change.

How they change could largely be up to those of us who care deeply about this great endeavor of humanity. The name of our organization says what we are about. The planets are our destination, and we have always looked beyond low-Earth orbit—that narrow circle to which the space shuttle is confined.

As a first step, as you'll read in Lou Friedman's article on page 4, the Society is organizing a top-level meeting of leaders in the space community. We then will take the debate to the wider public. We will be calling on our members to join together and provide evidence that people want to explore space, to move beyond Earth orbit, and to reach that destination we long to attain.

—*Charlene M. Anderson*

On the Cover:
In this cross section of the sky, a partial Moon hangs in the dark space above Earth's horizon and airglow. A digital still camera on board the space shuttle *Columbia* captured this oblique view on January 26, 2003. The image, as well as other pictures from *Columbia* in this issue, was transmitted to Earth during the mission. Image: NASA

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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 $30 (US dollars); in Canada, $40 (Canadian dollars). Dues in other countries are $45 (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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Members' Dialogue

On *Columbia*'s Loss

One hundred years from now, humans will view space disasters and loss of life as historic incidents that paved the way for explorations of that era.

One thousand years from now, human expeditions to Mars will be fairly routine and serve as stepping stones to exploring interstellar planets.

Hundreds of centuries from now, human space colonies will proliferate throughout our galaxy and beyond.

While we all mourn the loss of human life in our quest for space colonization, it is logical to accept the fact that future tragedies are inevitable.

Out of 113 shuttle flights, only 2 have been catastrophic. This represents a success rate of 98 percent. In my view, given the incredible complexities of human spacecraft, this is a reasonably acceptable risk factor.

—BARRY ROWE,
Melbourne, Florida

I am deeply shocked and saddened by the loss of *Columbia*. The initiative taken in sponsoring the GOBBSS (for Growth of Bacterial Biofilms on Inorganic Surfaces During Spaceflight) experiment (see page 8) was a small but important action for peace. When I first read on your website about the experiment, I was very proud of you all and moved by the gesture. The Society's involvement with GOBBSS shows the immense utility of the space program to inspire, encourage, and motivate.

The crew of *Columbia* knew the risks, and they also were aware of their roles as educators, mentors, and sources of inspiration as people of great courage and commitment. It is in this latter role that we shall most remember them.

—ALAN PRITCHARD,
Stockholm, Sweden

As we mourn the *Columbia* accident, we must resolve not to lose sight of the future. While the past glories of NASA—the landing of humans on the Moon, and a blank check to do the job—are a thing of the past, the current nickel-and-dime approach to NASA's budget and space exploration must be considered.

"To boldly go where no one has gone before" never has come cheap, and we are once again reminded of the human capital expended in this endeavor. While anemic funding may not be a direct cause of this event, it cannot be completely excused from responsibility.

We have come to the point not only of shortchanging future generations but also of failing to honor generations of the past. If we wish to memorialize and pay tribute to those who have given their lives on *Columbia* in pursuit of the future, let that monument be a living one, one embodied in a strong, vibrant, properly funded NASA program.

If we then wish to build a physical remembrance to those that have paid the ultimate price, we can place it on the Moon, Mars, or some yet undiscovered shore on the great ocean that is space.

—DALE R. WINKE,
Port Clinton, Ohio

NASA's outdated, obsolete fleet is getting costly to maintain and control. It's time for us to push seriously for more modernized spacecraft for both human and nonhuman spaceflight needs, instead of relying on outdated stuff from the '70s.

—BRIAN HART,
Irvine, California

The loss of the *Columbia* is a terrible tragedy, and the space community should spare no effort to investigate its causes and make sure that nothing similar happens again. Nevertheless, spaceflight is an inherently risky business, and all involved are well aware of the dangers to crew and equipment.

In the same way as planes are not grounded, or cars left in parking lots after air or road disasters, the space program should not be put on hold indefinitely because of this tragedy. Instead, we should renew our efforts to produce better and safer vehicles, along with more space exploration, manned or unmanned.

That would be the best tribute to *Columbia*'s crew, as well as to the crew of the *Challenger*. Spaceflight is one of the greatest adventures of humankind.

Please, make space, not war.

—GRACIELA A. JAHN,
Mendoza, Argentina

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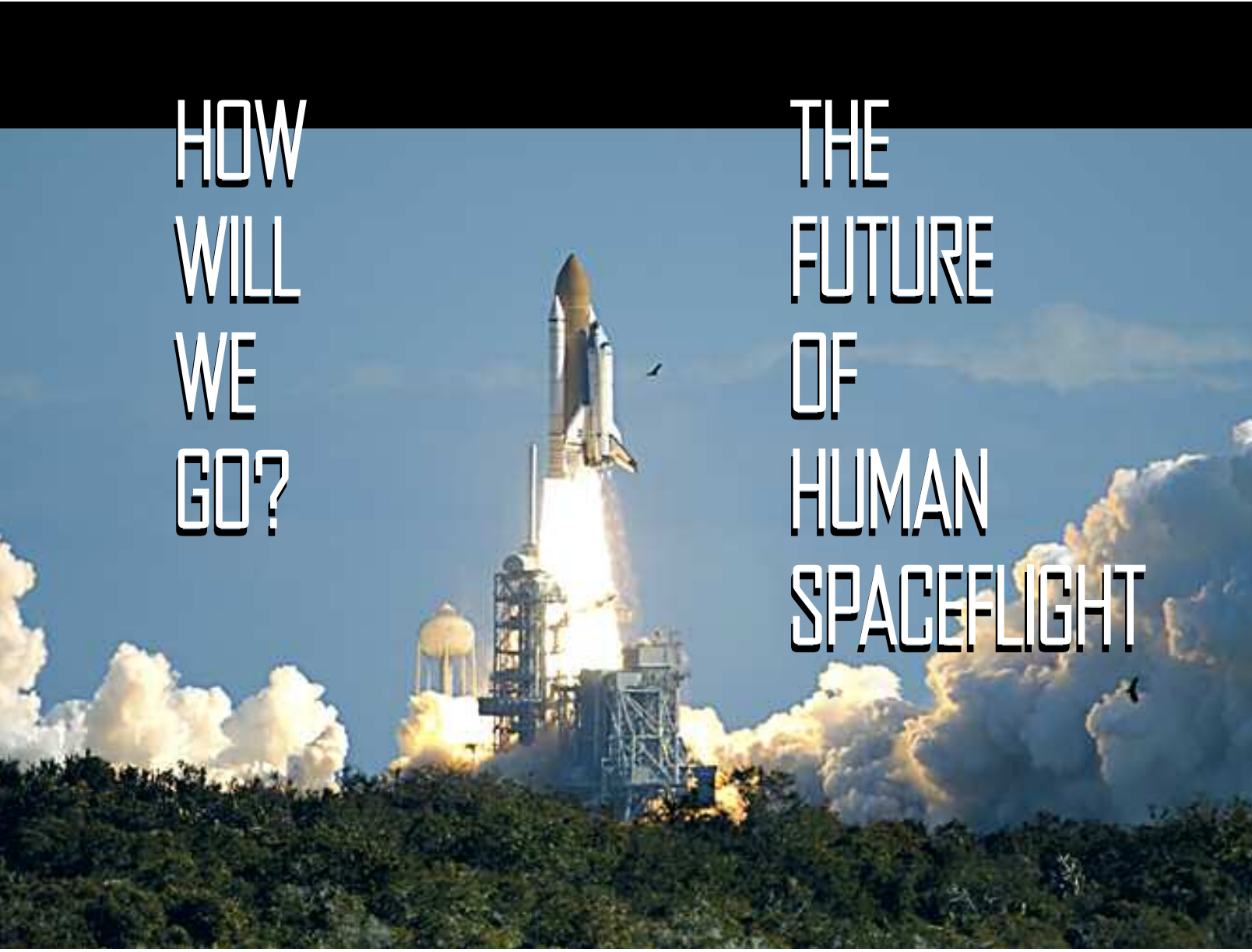
HOW WILL WE GO? THE FUTURE OF HUMAN SPACEFLIGHT



BY LOUIS D. FRIEDMAN

The tragic loss of *Columbia* and its crew of seven will profoundly change the future of spaceflight and will shape the role humans play in our exploration of the solar system. As we struggle to deal with the tragedy, attention will first be focused on the cause of the accident, the underlying reasons for it, the possible fixes to the shuttle, and the emotions that accompany the loss of life. Then, we will grapple with what to do next, and hanging in the balance will be the space shuttle itself, the International Space Station, future US launch vehicles, and the human spaceflight program.

The Planetary Society represents and, to some extent, speaks for members of the public interested in space. Sometimes we are perceived by those unfamiliar with our positions as being focused solely on science and robotic missions. This is ironic, since we have consistently, from our founding by Carl Sagan and Bruce Murray, argued that space exploration is too great an endeavor to be justified by science alone. Any vital space program must include exploratory goals, including sending humans to other worlds.

Those who know us understand this position. The Society has long enjoyed close relations with astronauts; several have sat on our Advisory Council, and Michael Collins and Kathy Sullivan served on our Board of Directors. We have worked many times with the Association of Space Explorers (ASE), the worldwide organization whose membership is limited to those who have flown in space. In this time of crisis, we have again joined with the ASE, and with the American Astronautical Society, as we start to grapple with the many questions that must be answered as the world plans a future for human spaceflight.

A GLOBAL ENTERPRISE

Astronauts are the representatives of humankind in the exploration of space. Each time they fly, they carry with them the dreams and aspirations of all of us moved to explore the frontier of space. And, as in any effort to push into the unknown, there are great and deadly risks that must be accepted. The loss of the space shuttle *Columbia* reminded us of that bargain with devastating effect.

But the astronauts are only the most visible members

Left:* Columbia, *the first shuttle mission of 2003, lifted off from Kennedy Space Center into a clear, blue sky on January 16. After a smooth and uneventful countdown, the launch took place, as planned, at 10:39 a.m. Eastern Standard Time.
Image: NASA

Right: Like many great explorers, astronauts risk their lives to venture into the unknown —not just for their own space agencies or countries, but on behalf of all people of Earth.
Painting: Robert McCall

of the great team necessary to achieve something as profoundly difficult as spaceflight. Every flight, every venture represents a huge enterprise involving many people and many machines. NASA refers to itself as a family, but even the roster of a government agency understates the number of people involved. There is a much larger family of participants including scientists, technicians, engineers, writers, students, educators, and many others intimately connected with each mission.

But beyond the thousands directly involved with a mission, and even the tens of thousands engaged in other aspects of space exploration, is the public's recognition that such exploration is an enterprise of our entire planet. Not even this flight belonged solely to NASA or the United States. People everywhere felt connected to it. The public outpouring of grief and interest in the future of human spaceflight proved that.

AN INSPIRATION

This mission of *Columbia* was of minor importance to NASA and, indeed, had been delayed for more than a year as missions of higher priority flew to the space station. *Columbia* carried lots of science experiments, but most of them, too, were not of high priority. Many could have been done about as well in an earthbound laboratory or in a less expensive robotic space laboratory.

But as a symbol, the *Columbia* mission was significant, and if it did not in and of itself justify the shuttle program, it was a worthy addition to the program as constructed. I regard the shuttle as a great technological achievement that has been used incorrectly by the United States as its sole operational human space transportation system.

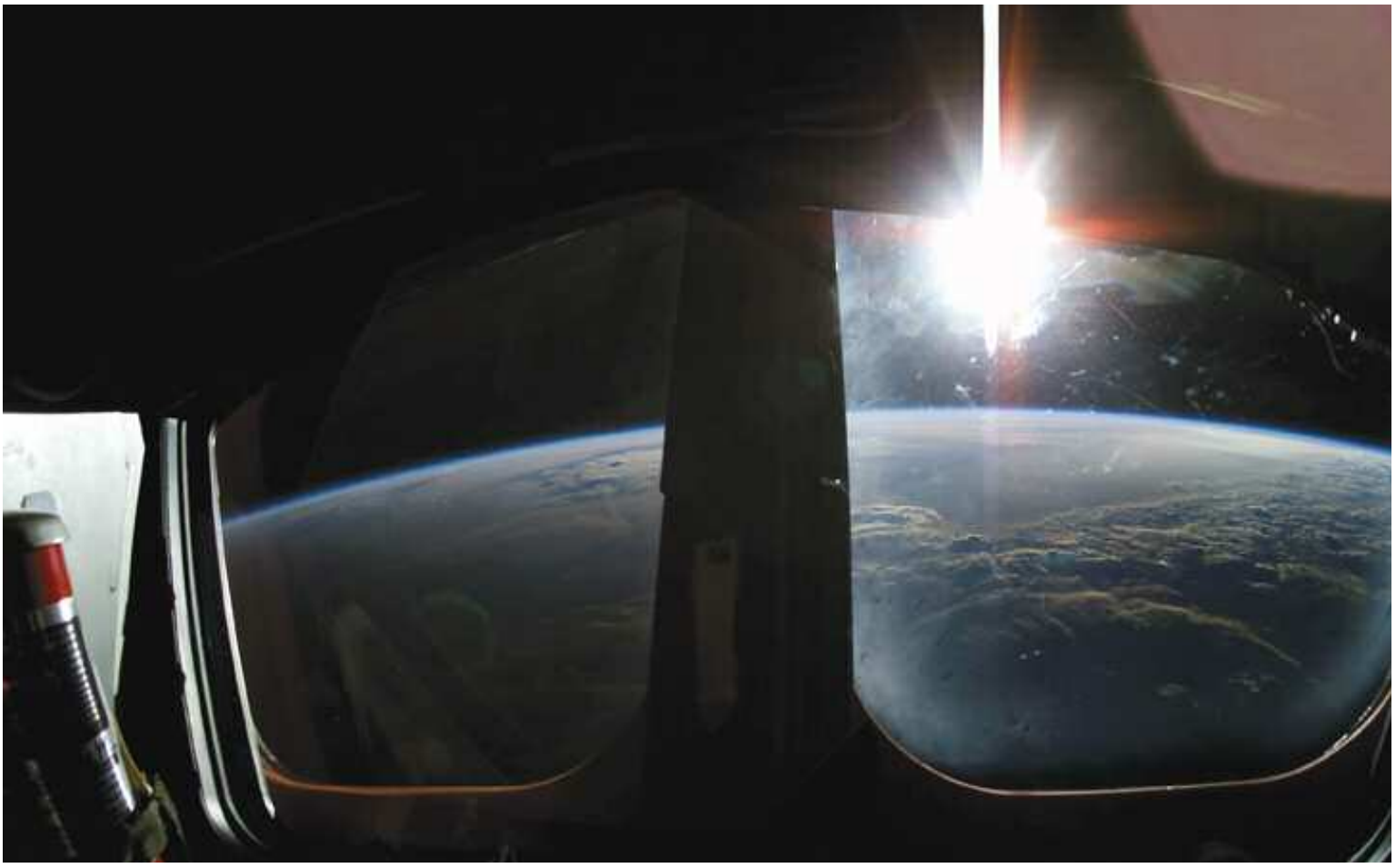
I have no doubt that the human spaceflight program will continue. Indeed, it may well be renewed with a new sense of purpose: the exploration of our solar system beyond Earth. The risk to human life that we are willing to accept should be commensurate with the potential gain. Exploring the unknown to extend humankind's reach to other worlds is perhaps the only mission that can justify the risk. As Pulitzer Prize–winning columnist Charles Krauthammer put it, "Fantastic risks are justified only by fantastic journeys."

Left: The solid rocket boosters separate from the orbiter and external tank as* Columbia *heads for low-Earth orbit. This painting was produced 22 years ago as a celebration of* Columbia*'s maiden flight, which took place on April 12, 1981.

Painting: Robert McCall for the NASA Art Program

Below: On day seven of the mission, an astronaut on board* Columbia*'s final flight used a digital still camera to capture a sunrise from the crew cabin.

Image: NASA



In my role as executive director of the largest space interest group in the world, I speak to many people in all walks of life about space exploration. I am continually impressed by the strong support it has, the inspiration it offers, and the optimism about the future demonstrated by achievements in space. I also find that people inherently know what is important about the space program: that we explore space to seek new knowledge and to learn about ourselves and our role in the universe. The mundane reasons or quick commercial gains that are sometimes promised are rarely realized and even more rarely inspiring. I hope and

expect that our recovery from this tragedy will reaffirm a national and international commitment to exploration and bold ventures—but ones worth the cost.

THE FUTURE OF HUMANS IN SPACE

The Planetary Society will participate in considering the human role in space exploration and in defining what steps should be taken now to return astronauts to space. That is why we have joined with the ASE and the American Astronautical Society to organize a workshop that will examine transportation technologies enabling humans to explore new worlds. It is not our role to investigate the causes of the accident or how to fix the shuttle. NASA will do that and will do it well.

But we do need to think beyond returning the shuttle fleet to active duty. What about the International Space Station? It is now under construction but far from complete. Three remaining shuttles are the sole US means to transport people and cargo to the station. But Russia, with years of outstanding experience in human spaceflight, is still flying regularly to the station. Russia's contribution will become extremely important in our recovery and in future planning. America cannot and should not go it alone, and international cooperation in space is needed more than ever. The space station has many of the same faults the shuttle program has—one of the most glaring being that as soon as it becomes ready for full operation, its technology will be almost obsolete. The space station, designed in the 1980s, will be more than 20 years old the day it becomes operational.

The plan for how astronauts and cosmonauts will use the space station should be reevaluated. It should focus on human exploration beyond low-Earth orbit. We are heartened by the start of the Human Research Initiative in the fiscal year 2004 budget proposal for NASA (see World Watch, page 10). Its goal is to prepare astronauts for long-duration space flights to the planets.

The space station might also serve as a transportation node for missions beyond low-Earth orbit. That option should now be examined. The way to begin is to consider the requirements for reaching more distant destinations, such as libration points (equilibrium points in the combined gravity field of the Sun, Earth, and Moon), asteroids, the Moon, and Mars. The next step is to match these requirements with concepts for lifting cargoes and crews to low-Earth orbit. I am betting this will result in a lower-risk, higher-gain plan for human spaceflight to succeed the shuttle program.

Space exploration is a rewarding—but risky—adventure. The astronauts accepted the risks. The ever-present and recognized danger of catastrophe makes space exploration a very human enterprise, whether conducted by astronauts or by robotic spacecraft. Today, we express sorrow and concern over the loss of *Columbia* and her crew. In the coming weeks and months, we will join in the effort to learn and recover from this tragedy. I believe, with my colleagues and members of The Planetary Society worldwide, that a positive future awaits us in space and that the nations of the world will move toward it for the benefit of all humankind.

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

Israeli astronaut Ilan Ramon takes in Earth's horizon from a window on* Columbia*. This portrait was captured on January 26, 2003.

Image: NASA

A Shuttle Mission Like No Other

by Amir Alexander

We of The Planetary Society were stunned on the morning of February 1 when we learned of the loss of the space shuttle *Columbia* and the seven astronauts on board. Like all those in the space exploration community, we take this loss very personally. We are, after all, an inseparable part of the family that is the space program.

And yet, there is something more. For us, space shuttle mission STS-107 was unlike any other shuttle flight, because in our own small way we were part of it. For the first time ever, among the dozens of scientific experiments flying on board the shuttle was one sponsored by The Planetary Society.

The goals of our project were not only scientific. The experiment brought together students from one of the Earth's most troubled spots: the Middle East. Tariq Adwan, a Palestinian biology student from Bethlehem, and Yuval Landau, an Israeli medical student from Petah-Tiqwa, joined with American, Israeli, and Palestinian mentors in designing and building the experiment. They showed how the common spirit of discovery and exploration can overcome even the most persistent human divides.

Days before *Columbia*'s scheduled launch on January 16, Yuval and Tariq flew to Cape Canaveral, Florida. At the Cape, they were met by Eran Schenker of the Israeli Aerospace Medicine Institute and David Warmflash of the Johnson Space Center, the lead investigators on the experiment. Also there to greet them were the vice president of The Planetary Society, Neil DeGrasse Tyson, and Linda Kelly, our education programs manager.

During the few days before the launch, the six of them spent many hours together, working and touring the grounds. They became a tight-knit group. Yuval and Tariq in particular forged a close bond, well beyond the needs of their immediate working relationship. They watched together as *Columbia* roared into space on a clear morning, right on schedule. Once in space, our experiment, known as GOBBSS (for Growth of Bacterial Biofilms on Inorganic Surfaces During Spaceflight), was in the hands of the shuttle's astronauts. Mission Specialist Kalpana Chawla turned the experiment on shortly after the launch, and Specialist Laurel Clark turned it off two weeks later in preparation for the shuttle's return to Earth.

As we now know, *Columbia* never did return. The shuttle's remains were scattered along hundreds of miles of the southern United States. Somewhere in this debris

field may be found all that remains of our own experiment.

All shuttle flights are remarkable, requiring the best efforts of thousands of engineers, scientists, and technical personnel, as well as of the astronauts themselves. As part of the space community, we know that, and we take pride whenever a shuttle soars into space.

And yet, mission STS-107 was special for us. We watched it a little more closely, and took a little extra pride in what seemed like a remarkably successful mission. Its loss struck us very close to home.

Amir Alexander is a web editor for the Society's website, planetary.org.

Background: On January 22, 2003, one of the astronauts on board* Columbia *took this photograph of Earth's horizon beyond South Yemen and the Gulf of Aden. Also visible are the Hadramawt Plateau (the light area at right) and the Ramlat As-Sab'atayn sands (the long triangular feature at lower middle). The approximate coordinates of this region are 16 degrees north latitude and 48.5 degrees east longitude. *Image: NASA*

Above: The Planetary Society sponsored an experiment—officially for science and symbolically for peace—that rode on board the ill-fated space shuttle* Columbia. *Here, Yuval Landau (left) and Tariq Adwan—the Israeli medical student and the Palestinian biology student who worked together with American, Israeli, and Palestinian mentors in designing the Growth of Bacterial Biofilms on Inorganic Surfaces During Spaceflight (GOBBSS) experiment—hang out at Kennedy Space Center before the launch. *Photo: Linda Kelly, The Planetary Society*

You can learn more about the GOBBSS experiment and The Planetary Society's part in *Columbia*'s last mission on our website, *planetary.org*.

World Watch

by Louis D. Friedman

Washington DC—Two days after the *Columbia* accident, the Bush administration released its proposed fiscal year 2004 budget for NASA. The timing was coincidental, and the budget, prepared weeks earlier, contained no reference to *Columbia* or to the changes that will be necessary to the human spaceflight program. Here are some of the highlights:

• A 3 percent increase in NASA's budget, including a 13 percent increase in space science. This was good news, considering present economic pressures and the policy issues currently being debated in the United States.

• A major initiative to develop nuclear propulsion to shorten trip times and increase payload capacity to the outer planets and also new nuclear power sources to operate spacecraft. This follows a similar proposal in the fiscal year 2003 budget, which had yet to be passed by Congress when the fiscal year 2004 budget was submitted. (The Planetary Society statement cautiously supporting the nuclear space initiative is on our website, as is a statement concerning the fiscal year 2004 budget proposal for NASA.)

• A proposal to develop a mission to Jupiter to test a nuclear-electric propulsion system. The *Jupiter Icy Moons Orbiter* (*JIMO*) would successively orbit the outer three Galilean satellites—Callisto, Ganymede, and Europa—over a 10-year mission.

• Optical communications for planetary spacecraft as an alternative to radio. The first application of this technology, which will be included on the Mars 2009 mission, could potentially provide streaming video from Mars.

• Funding for the Pluto–Kuiper belt mission as the first in the line of New Frontiers missions. This was a great victory for The Planetary Society. We successfully campaigned last year for the addition of this mission to NASA's fiscal year 2003 budget.

• Full support for Mars exploration, providing for the *Mars Reconnaissance Orbiter* in 2005, a *Mars Scout* mission in 2007, and the *Mars Science Lander* in 2009, as well as the introduction of a Mars telecommunications satellite for 2009.

• A proposal for a Human Research Initiative. This would prepare astronauts for flights exceeding 100 days. Since the only purpose for such extended flights is exploration beyond Earth orbit, we regard this as a welcome commitment to the future of planetary exploration.

In a statement released to the press, The Planetary Society applauded NASA Administrator Sean O'Keefe for his boldness and commitment to the exploration of space beyond Earth orbit. Three of the budget proposals in particular—nuclear propulsion on the *JIMO* mission, optical communications for the Mars orbiter, and the Human Research Initiative—bode well for the future of solar system exploration if they are passed by the US Congress.

The president's budget is only a proposal to Congress. The months ahead will see hearings and debates about NASA's budget, in the context both of the *Columbia* disaster and of the broader demands of the United States' foreign and domestic policies. We will keep you informed of the progress of these initiatives that could be crucial to humankind's future in space.

Paris, France—It has been a tough period for comets—at least for those who wait to be visited by spacecraft. First *CONTOUR*, the NASA mission to comets Encke and Schwassmann-Wachmann 3, was lost when it attempted to leave Earth orbit. The spacecraft fell silent after firing its onboard STAR 30 solid-propellant rocket motor on August 15, 2002 during a maneuver to boost the spacecraft out of its parking orbit.

Almost immediately, telescopes on Earth were pointed at the coordinates where the spacecraft should have been, and they saw three separate pieces traveling on nearly parallel paths through space. The spacecraft had broken apart. As we go to press, we await the report from the accident investigation team, which should contain the reasons for the loss of the mission.

Soon after that blow, NASA came close to canceling the *Deep Impact* mission because of development problems with the spacecraft and danger of running over budget. However, the mission survived the review and is still scheduled to launch January 4, 2004. On July 4, 2005, *Deep Impact* will fire a solid ball of copper into comet Tempel 2. Scientists hope the resulting debris cloud will reveal what lies beneath the comet's crust.

And now, the European *Rosetta* mission, which was to fly toward a 2012 rendezvous with the comet Wirtanen, has been postponed. It had been scheduled to launch in January on an Ariane 5 rocket. But a few weeks earlier, another Ariane 5 exploded at launch, and a failure review board concluded that there were too many problems and uncertainties with the rocket to risk another launch.

Rosetta team members are now studying new mission designs, anticipating that Ariane's problems will be solved later this year.

Mission options include targeting the same comet, but on different and less favorable trajectories, or changing the target to a different comet.

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

STAND BY! WE'RE LANDING ON TITAN

BY CHRISTOPHER P. McKAY

Traveling through the outer solar system, locked in orbit about the majestic planet Saturn, is a small world that might be able to tell us much about the history of our own. But it's 10 times as far from the Sun as Earth is, and it's enshrouded in a thick haze, wrapped in mystery as only an unexplored world can be. What little we know prods us to learn more.

Titan is one of the most tantalizing worlds yet discovered. Of all the bodies in the solar system, it has an atmosphere most like Earth's—made mostly of nitrogen. A smoggy haze forms in Titan's atmosphere, shielding its surface from our view. Oceans—or at least seas and lakes—may cover much of its rocky face.

From Earth, we can track seasonal changes on Titan but can't determine exactly what drives them. We know a greenhouse effect warms the atmosphere, as on our planet, but an anti-greenhouse effect also makes itself felt. And clouds may or may not be important on Titan.

For planetary scientists, all these questions are irresistible. We want to learn enough about Titan to answer them. And we will soon have the means to ferret out the data we need.

On January 14, 2005, the *Huygens* probe, deployed from the *Cassini* orbiter, will enter the atmosphere of Titan, jettison its heat shield, deploy its parachute, and then slowly drift down to the surface. As it descends, it

will investigate this fascinating world and, after hitting the surface, might even survive for a few moments.

Previously, the best close-up exploration of Titan was accomplished in November 1980 by the *Voyager 1* spacecraft when it flew 3,900 kilometers (about 2,425 miles) above the moon's surface and gave us our first glimpse of this world.

AN ATMOSPHERE LIKE OURS AND MAYBE AN OCEAN TOO

Titan, the largest satellite of Saturn, is the only moon in the solar system with a significant atmosphere. Indeed, the atmosphere of this small world—Titan is about the size of the Moon—is most similar in composition and pressure to the atmosphere of Earth.

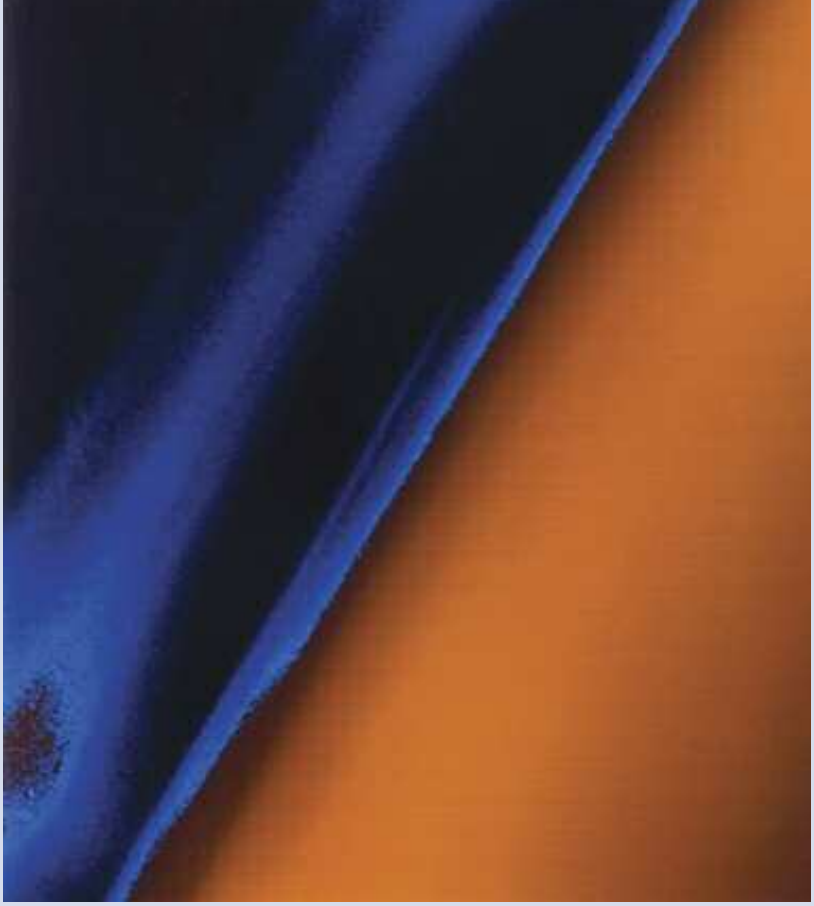
The main gas in Titan's atmosphere is nitrogen—just as on Earth. Although we don't know the exact composition of the air on Titan, we can determine that its atmosphere is approximately 95 percent nitrogen, 5 percent methane, and 0.1 percent hydrogen. The pressure on the surface of Titan is just 50 percent higher than sea level pressure on Earth. By contrast, Venus and Mars—which are closer and might seem more similar to Earth—have surface pressures that are about 100 times higher and 100 times lower, respectively, than Earth's, and both have atmospheres composed mainly of carbon dioxide (CO_2).

After nitrogen, the second most abundant gas in Titan's atmosphere is methane (CH_4), with a concentration between 5 and 10 percent in the lower atmosphere. The surface temperature on Titan is 95 kelvins (– 180 degrees Celsius, – 290 degrees Fahrenheit). At these low temperatures, methane can condense to form clouds and possibly lakes and seas. High in the atmosphere, the methane is split apart by ultraviolet sunlight. At even higher altitudes, molecular nitrogen is split by energetic electrons and extreme ultraviolet sunlight. The fragments of these molecules react to produce a complex organic brew that forms a haze covering the entire planet as smog does parts of Earth.

When methane is broken apart by sunlight, one of the intermediate products is ethane (C_2H_6). On cold Titan, ethane will condense on the surface and, presumably, accumulate there. As this ethane, and the organic haze, is produced, the available methane

In January 2005, the European Space Agency's* Huygens *probe will drift down through Titan's thick, hazy atmosphere to reveal the mysteries of this hidden world's landscape.

Painting: Michael Carroll



Since 1980, this has been one of our best close-up views of Titan. **Voyager 1** ***took the image at a range of 22,000 kilometers (13,700 miles) on November 12, one day before the spacecraft's closest approach. The colors, which are false, are used to show details in the haze that enshrouds Titan. The orange area represents the upper level of the thick aerosol above the moon's limb.***

Image: JPL/NASA

is used up. At the current rate of destruction, the supply of methane in the atmosphere would last less than 100 million years. Since Titan is more than 4.5 billion years old, this poses a puzzle: why didn't it run out of methane long ago?

One possible answer was suggested by University of Arizona's Jonathan Lunine and colleagues just after the *Voyager* missions: maybe Titan has a deep ocean of methane that continually resupplies the atmosphere, while the ethane produced collects in the ocean. This is an intriguing possibility. However, radar observations and infrared images of Titan's surface show that it is not covered by a global ocean. Seas of methane and ethane may exist, but they are not global bodies, and there may be reservoirs of liquid beneath the surface.

Just how methane is maintained on Titan, and what happens to the ethane produced in its atmosphere, remains a mystery—one that we hope the *Huygens* probe will help us solve.

THE HAZE AND ITS SEASONS OF CHANGE

The opaque organic haze in Titan's upper atmosphere is the main reason we know so little about its surface and lower atmosphere. The brownish color of the haze was the first clue that it was organic—that is, composed primarily of carbon and hydrogen compounds.

Carl Sagan and colleagues at Cornell University showed that if nitrogen and methane, as in Titan's atmosphere, were placed in a flask and exposed to ultraviolet light or electrical shock, a brownish haze with the same optical properties as the Titan haze would be produced. A later discovery of organic molecules more complex than methane in Titan's atmosphere confirmed the organic nature of its chemical makeup.

When *Voyager* flew by Titan, its cameras showed that the haze was distinctly asymmetrical. The southern hemisphere was brighter than the northern hemisphere. For decades, researchers using ground-based telescopes had tracked a seasonal change in the brightness of Titan. Further observations with high-resolution telescopes showed that the hemispherical asymmetry reversed with the seasons on Titan. Half a Titan year (15 Earth years) after *Voyager*, the northern hemisphere was brighter.

But we didn't understand why the hemispheres changed in brightness according to the season. Early explanations suggested that the production rate of the haze depended on sunlight: as sunlight changed with the seasons, so did the atmospheric brightness. However, Bill Hutzell, then a student at Georgia Tech working toward his Ph.D. at NASA Ames Research Center, showed this explanation to be invalid. The haze settled so slowly that a change in production rate alone would average out—therefore, we'd see no noticeable difference between the seasons.

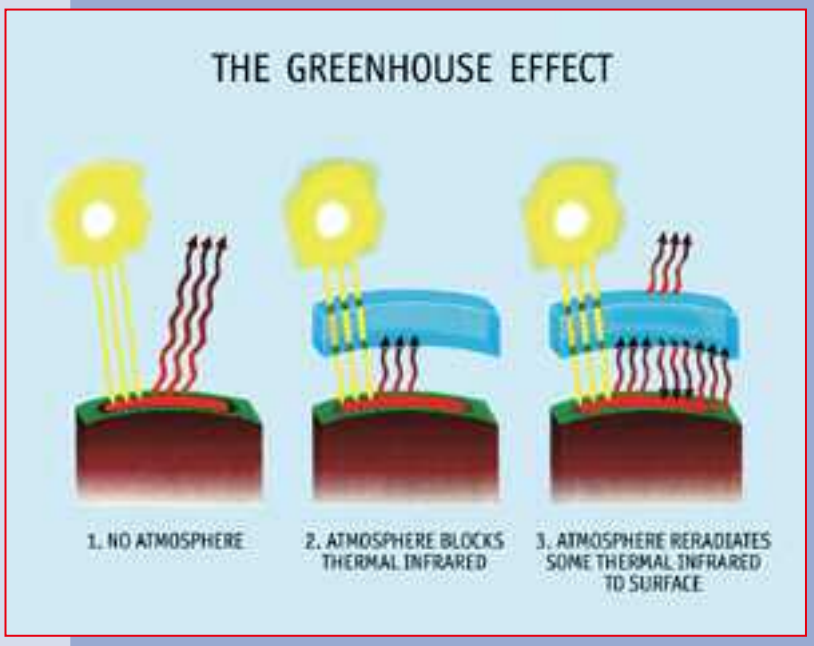
What could be producing the seasonal change? If it were not sunlight, then most researchers considered changing winds to be the cause. If the winds were strong enough, they could literally blow the haze from one hemisphere to the other.

Computer simulations showed this explanation to be plausible. In the last few months, Pascal Rannou at the University of Paris and colleagues have confirmed the hypothesis that winds produce Titan's hemispherical asymmetry by driving small particles from one hemisphere to the other and then, half a Titan year later, driving them back again.

A GREENHOUSE EFFECT LIKE NO OTHER

One of our goals in planetary science is to contribute to the understanding of Earth. The greenhouse effect is one phenomenon that's particularly useful when comparing Earth and other planets.

Venus has the strongest greenhouse effect in the solar system. The greenhouse effect of its heavily carbon dioxide atmosphere contributes 99.9 percent of the energy that strikes the planet's surface. With its weaker greenhouse effect, primarily caused by atmospheric carbon dioxide and water, Earth's greenhouse provides 67 percent of the energy that reaches its surface. Titan beats Earth in the greenhouse competition, with 92 percent of the energy reaching its surface due to the greenhouse effect. But

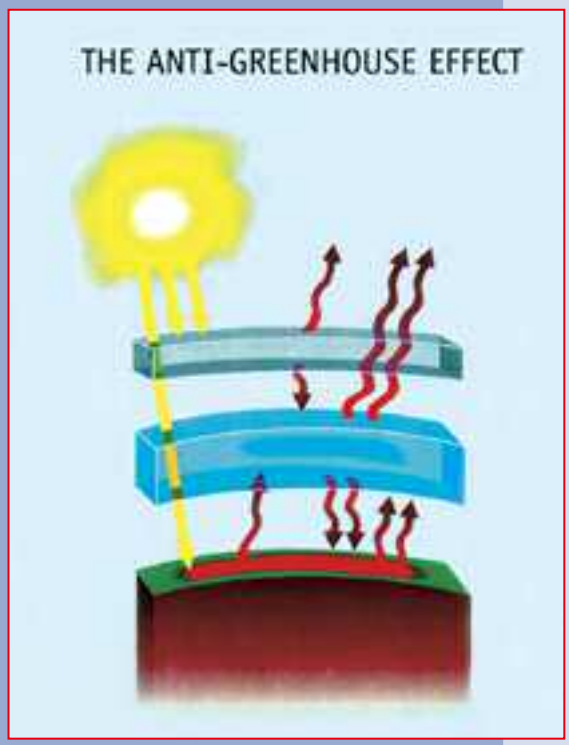


1. When a planet has no atmosphere, its surface radiates only the energy it receives directly from the Sun, illustrated here as three rays of sunlight striking the surface, which then results in three rays of radiation returning to space.

2. A severe greenhouse atmosphere, such as that on Venus, allows sunlight to pass through but blocks any outgoing thermal radiation. The atmosphere then reradiates some of that energy back to the surface.

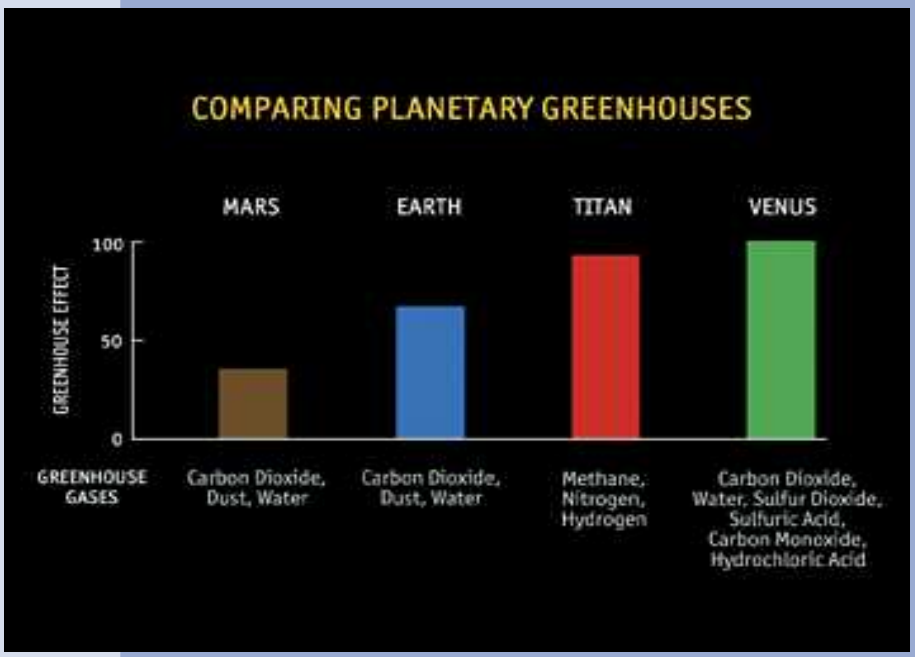
3. In equilibrium, such as that found on Earth, the surface now radiates energy to balance the energy it receives from the Sun, plus the radiation from both the Sun and the atmosphere. That balance is shown here as three rays of sunlight plus three greenhouse rays of thermal energy reradiated from the atmosphere—ultimately becoming six rays of thermal energy issuing from the surface.

Illustration: NASA



A layer in the upper atmosphere (such as the organic haze in Titan's stratosphere) that blocks some sunlight, but is transparent to thermal radiation, has the opposite properties of the greenhouse layer.

Illustration: NASA



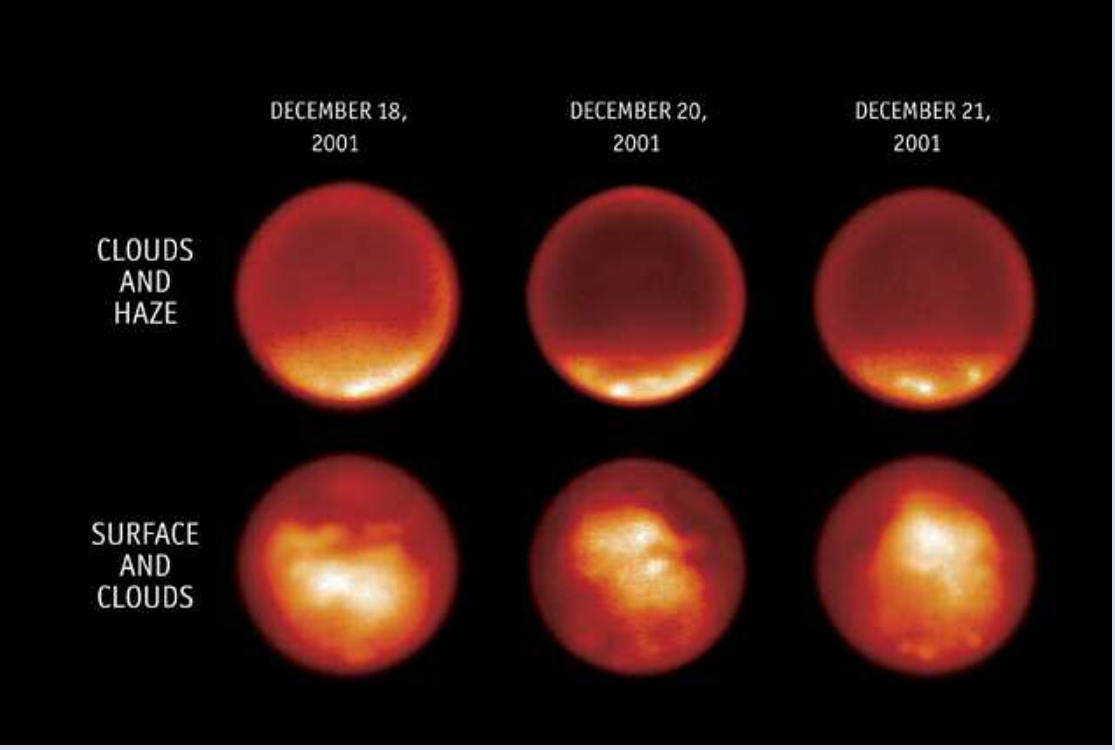
This comparison of atmospheres shows the percentage of energy reaching the surface of a planet due to the greenhouse effect. The gases responsible are listed at bottom.

Chart: Barbara S. Smith

Titan's greenhouse effect operates slightly differently, since its drivers are nitrogen and methane.

Titan is also different in that it displays an anti-greenhouse effect. The greenhouse effect arises because some gases let sunlight in but block infrared radiation going out, trapping the energy and warming the atmosphere. Imagine a material with the exact opposite properties: blocking solar radiation but letting infrared radiation escape. Such material could suitably be called anti-greenhouse.

The organic haze in Titan's stratosphere is composed of small, dark, organic molecules about the same size as



These images of Titan were taken with Hawaii's Keck II telescope during three nights in December 2001. The top three images show just Titan's troposphere (lower atmosphere), which contains, along with the newly discovered methane clouds at the south pole, a "haze" covering the south polar cap. The satellite's bright limb is also produced by a tenuous global atmospheric haze layer. The bottom three images show Titan's surface rotating, as well as the same methane cloud features at the south pole. *Images: H.G. Roe, I. de Pater, B.A. Macintosh, C.P. McKay and W.M. Keck Observatory*

the wavelength of visible light; this makes them efficient absorbers of sunlight. However, the wavelength of infrared radiation from Titan is about 100 times larger than those small organic particles, so they can't stop its escape. Thus, Titan's haze blocks 30 percent of the incoming sunlight but allows any infrared radiation from the surface to pass right on through.

Titan's anti-greenhouse effect is almost as strong as its greenhouse effect. Computer calculations show that Titan's greenhouse effect could warm the surface by 20 degrees Celsius (36 degrees Fahrenheit), but the anti-greenhouse effect takes away 9 degrees Celsius (16 degrees Fahrenheit), leaving a warming of only 11 degrees Celsius (20 degrees Fahrenheit). Titan is the only body in the solar system with an appreciable anti-greenhouse effect.

Nevertheless, some researchers have suggested that the asteroid impact on Earth that caused the demise of the dinosaurs kicked up a stratospheric dust and soot layer, which produced a strong anti-greenhouse effect. The plunging temperatures that resulted may have helped kill off the giant creatures. Another example of the anti-greenhouse effect could be the "nuclear winter" that might occur after a full-scale nuclear war. By studying the anti-greenhouse effect on Titan, we could better learn what might be possible here on Earth.

CLOUDS OF MYSTERY

Below the obscuring haze, Titan's lower atmosphere could be the scene of active storms, clouds, and heavy rain. Or it could be as placid and uneventful as a clear winter's day. The data available could be interpreted to support either alternative. Unfortunately, we can't see the lower atmosphere well enough to know if there are Titanian clouds or not. Several lines of reasoning argue against their existence.

We know that there is methane in the lower atmosphere and that it should be present in high enough concentrations to condense and form clouds. However, if clouds formed regularly as they do on Earth, particularly in upwelling air, then the atmospheric temperature on Titan should decrease with altitude at a rate of 0.5 degree Celsius per kilometer (1.4 degrees Fahrenheit per mile). But we don't see that in the data. Rather, it decreases at a rate of 1.2 degrees Celsius per kilometer (3.5 degrees Fahrenheit per mile), consistent with the absence of methane condensation.

Furthermore, the methane in Titan's atmosphere is more than 40 percent supersaturated. This means that it exceeds the concentration at which clouds would form by 40 percent—a result possible only if clouds were not present. Without this supersaturation, our models would not match the infrared spectrum of Titan measured by *Voyager*, and the computer simulations of the surface temperature wouldn't produce the observed value.

Finally, the Hubble Space Telescope and other high-resolution instruments can see through the haze in the near infrared and photograph the surface. These images do not show clouds. So, if present, clouds must be rare, transient, or thin.

On the other hand, some detailed observations by Caitlin Griffith of the University of Arizona argue for clouds. Her data show bright but transient features covering a small fraction of Titan. In 1995, these features lasted a few days, covered 6 percent of the planet, and appeared at an altitude of 16 kilometers (about 10 miles). In similar observations in 1999, the brightening features lasted a few hours, covered 0.5 percent of the planet, and appeared at an altitude of 27 kilometers (about 17 miles).

Recently, California Insti-

tute of Technology's Henry Roe and colleagues, using adaptive optics on the giant 10-meter Keck telescope, captured images of small clouds in the south polar region during the southern spring.

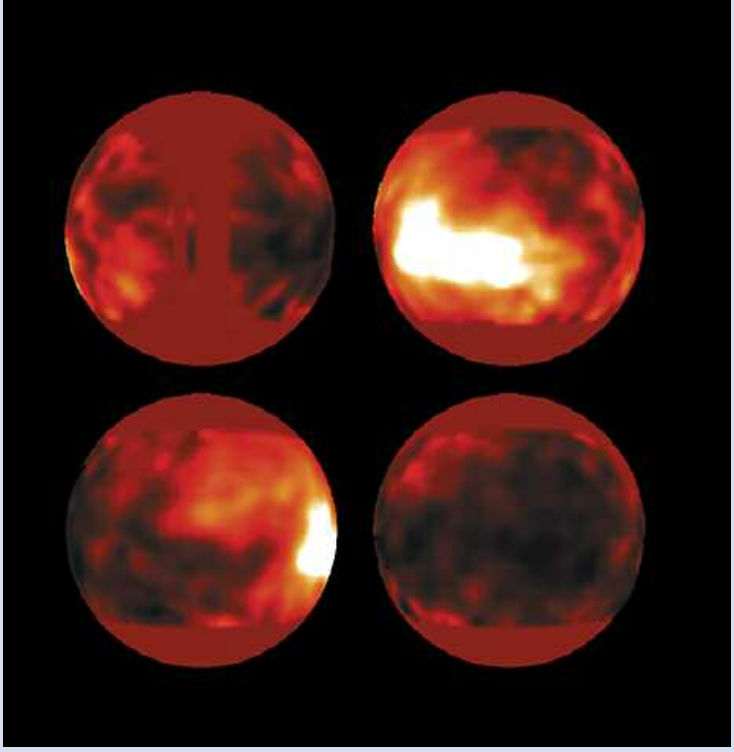
So, clouds may play a role on Titan. We just don't know exactly what that role is or how important it may be.

LAND HO!

While Titan's haze is opaque in the visible spectrum, it is much more transparent in the infrared—transparent enough that some telescopes can see down to the surface. Peter Smith and colleagues, using the Hubble Space Telescope, demonstrated this dramatically.

Their images showed a surface that was clearly not as uniform as a global ocean would be. There were bright regions (continents?) and dark regions (seas?). The surface is clearly more complicated than we expected. The variation is probably due to topography—the higher regions might be brighter if any settling organic haze were washed from the surface, revealing brighter, icy material below.

However, the haze appears white in the infrared and, in fact, looks like snow. So, perhaps the bright regions are places where the haze collects, analogous to snow-capped mountains on Earth. We haven't been able to figure out the nature of the surface from the infrared data alone. We are looking forward to the *Huygens* probe, which will land on the edge of the bright region. We might then be able to solve this mystery.



Captured in 1994 with the Hubble Space Telescope, these are the first images ever taken of Titan's surface. Peter Smith of the University of Arizona and colleagues mapped infrared light and dark features on the satellite's surface over a nearly complete (16-day) rotation. These global projections are separated by about 90 degrees. One prominent bright area Smith and his colleagues discovered is a surface feature 4,023 kilometers (2,500 miles) across—about the size of Australia.

Images: University of Arizona Lunar and Planetary Laboratory and Space Telescope Science Institute

THE *HUYGENS* INSTRUMENTS

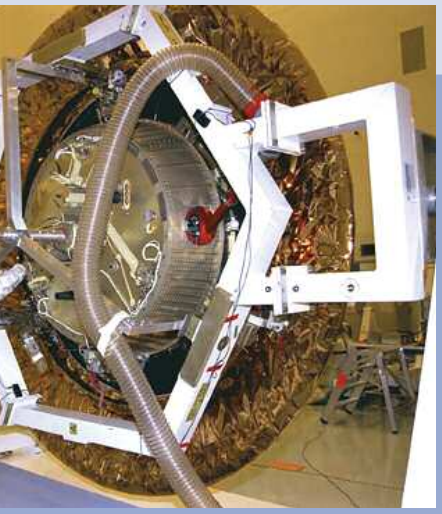
The *Huygens* probe will carry six instruments on its voyage of discovery. As the probe first enters the atmosphere, the only instrument working will be the accelerometer, which will inform us of the vehicle's changing speed. From the rate the probe decelerates, we will be able to reconstruct the density profile of the atmosphere.

As the probe slows down, the heat shield will be jettisoned and a parachute will open. *Huygens* will then begin to measure air temperature and pressure and take samples for analysis by a combination gas chromatograph and mass spectrometer on board. As the gas samples are gathered, they will pass through a filter that collects solid haze particles, which can then be analyzed separately.

A combination camera and spectrometer, also on board, will take images of Titan's sky, its clouds (if there are any), and its surface. The probe even carries a small headlamp to illuminate the surface as it nears touchdown. In addition, it has electrodes to detect lightning.

Once the probe reaches the surface, it will use another instrument, called the surface science package, to determine the composition of any liquid it might land in—in case Titan has seas or lakes. This same instrument can determine the atmospheric composition during the final stages of descent.

All in all, *Huygens* will provide a bonanza of information that will keep scientists busy for decades. We hope it will supply the data we need to clear up the many mysteries of Titan. So, stand by as the *Huygens* probe—an extension of human curiosity—lands on a strange new world: a moon with an atmosphere.



A worker inspects* Huygens' *heat shield after installation at Kennedy Space Center's Payload Hazardous Servicing Facility in July 1997.

Image: NASA

Christopher P. McKay of NASA Ames Research Center studies planetary atmospheres and astrobiology. He is a team member on the Huygens' *Atmospheric Structure Instrument. He also serves on the Board of Directors of The Planetary Society and as chairman of its Advisory Board.*

We Make It Happen!

by Bruce Betts

Welcome to We Make It Happen!—a new feature to appear regularly in The Planetary Report*. Through it, we will endeavor to keep you, our members, updated on our projects—what we are doing together to make space exploration happen.*

The Planetary Society, with its members—and because of its members—does a lot of amazing things. These include our many SETI ventures, mars exploration projects like Red Rover Goes to Mars and the Mars Microphone, extra-solar planet activities, near earth object programs, and, of course, our groundbreaking solar sail mission.

I came to the Society a little less than two years ago as the director of projects, although I have been a member almost since the beginning and have served in other capacities for more than 15 years. My role as director of projects has given me a greater appreciation for the incredible reach we have with space agencies around the world and how unique we are. I hope to share this excitement, as well as a sense of wonder for space exploration, with you in this column. No other membership group provides opportunities for member and public involvement with space exploration as does The Planetary Society.

A Quick Trip Through Projectland

Let's take a whirlwind tour of our current projects. In future issues, I'll focus on one or two projects at a time to give you more in-depth updates and insights.

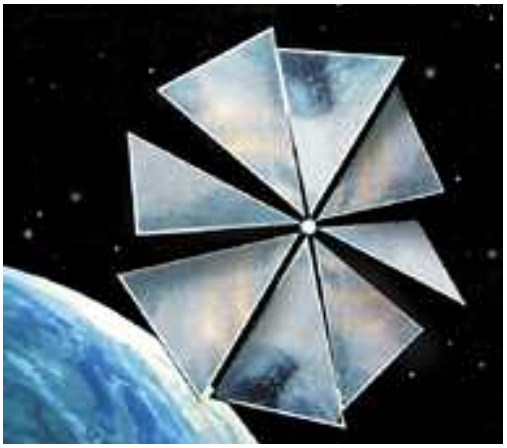


Illustration: Barbara S. Smith

***Cosmos 1* Solar Sail Mission:** The Society is attempting to fly the first-ever solar sail mission: *Cosmos 1*, scheduled to launch later this year. Solar sails, which use light pressure—in this case from the Sun—to push them, represent an exciting new opportunity for the future of space propulsion. But someone has been needed to kick-start the process with a demonstration mission. We are that someone.

Image: The Planetary Society

Red Rover Goes to Mars: This trail-blazing public involvement project is an official part of NASA's *Mars Exploration Rover* (*MER*) mission. We have recently delivered the DVD hardware that carries the names of nearly 4 million individuals (including all Planetary Society members) to be included on each of the two *MER* spacecraft. And we're conducting an international contest to select students to work inside mission operations while the *MER* mission is in progress.

Photo: Associated Press

Mars Microphone: We were the first to fly a privately funded instrument on a NASA mission (on board the ill-fated *Mars Polar Lander*). Now, an improved version of the microphone will fly on the French-led *Netlander* mission late in this decade.

Image: MSSS/NASA

Mars Outposts: We're advocating a Mars exploration strategy—systematically building up resources at locations on the Red Planet for science and encouraging public involvement, eventually leading to a human landing. We are now using Mars analog outposts established on Earth to test new technologies that may one day lead to increased scientific exploration and a human presence on Mars.

Photo: Argentine Institute of Radio Astronomy

The Search for Extraterrestrial Intelligence (SETI): We continue our SETI activities in several areas. We sponsor the world's largest distributed computing experiment, SETI@Home, which now has more than 4 million users processing radio SETI data on their home computers. Plus, we support the only dedicated Southern Hemisphere radio SETI projects. The Society is also at the technological leading edge of SETI, funding the growing field of optical SETI, which uses visible wavelengths to search for SETI signals. In addition, we support targeted optical SETI at Harvard and the University of California at Berkeley, and we're building the first dedicated SETI optical telescope in the world at Harvard (it also will be the biggest optical telescope east of the Rockies).

Painting: Lynette Cook

Extra-Solar Planets: We're aiding in the search for planets around other stars with the refurbishment and automation of a Kitt Peak telescope to add to the hunt later this year.

Photo: Jerzy Gierglelewicz

Near Earth Objects (NEOs): We sponsor various activities, primarily through our Gene Shoemaker NEO Grants, which mostly support amateur observers doing NEO discovery, tracking, and characterization. We selected a new round of international winners about a year ago.

Photo: NASA/JPL

Our Exploration Initiative: We're actively pursuing ways to get involved with the myriad upcoming planetary missions, including the Mars *Scout* missions.

Be Proud

As a Planetary Society member and supporter of our projects, you should be proud. You have facilitated and become involved in many space exploration activities, most of which never would have existed otherwise.

Also, know how unique our projects are. To cite two related examples: the Mars Microphone and Red Rover Goes to Mars DVD are the first and second privately funded hardware to fly on NASA planetary missions, and our solar sail project is the first space mission undertaken by a private space interest organization. No one else is doing this! Our connection to all the world's space agencies is unique too.

Many of our projects are firsts in planetary exploration and SETI, as well as firsts in public and member involvement.

Places to Learn More

There are many ways to learn about our projects and the Society's activities. An obvious one is to visit our website, *planetary.org*, where you'll find up-to-date information on all our projects as well as in-depth stories related to the work we're doing.

Plus, we have recently started a weekly half-hour radio show called Planetary Radio. It airs on KUCI in Southern California, but all Society members can find it at our website, including archives. Interviews are with many people involved in planetary exploration, among them leaders of some of our projects.

In addition, you can come see us and fellow members by attending Planetfest '04 in Pasadena, California on January 2–4, 2004. Planetfest will correspond with the landing of the first *Mars Exploration Rover*, of which our Red Rover Goes to Mars forms a part; the *Stardust* flyby through the coma of a comet; and the *Deep Impact* mission launch.

Let's Make a Difference!

As you can probably tell, I'm proud of The Planetary Society—I'm also excited to be working here. I've worked for a planetary science research institute and for NASA headquarters, but it is here that I see the biggest opportunity to make a difference—with the throngs that support planetary exploration and in shaping future space exploration. I look forward to our continuing adventures together and to my sharing things with you here in *The Planetary Report*.

Bruce Betts is director of projects for The Planetary Society and a planetary scientist who has studied the Mars surface, the Galilean satellites, and the Moon. He earned his Ph.D. with Society founder Bruce Murray at Caltech, spent time in the planetary research world, and for three years managed planetary programs at NASA headquarters.

Questions and Answers

Your special* Voyager *issue (September/October 2002) indicates that the spacecraft will venture to a destiny outside our solar system. Yet, in your November/December 2001 issue, the article "The Strange Acceleration of* Pioneers 10 *and* 11*" by John D. Anderson et al. stated that the* Pioneers *are slowing down. The Questions and Answers column later devoted to queries about this article (see the March/April 2002 issue) said that theoretically the* Pioneers *could return to the Oort cloud 355,000 to 485,000 years from now.

Why are the* Voyagers *not subject to the same forces as are the* Pioneers*?

—Harvey Levine
Boynton Beach, Florida

It all depends on the nature of the force affecting the *Pioneers*. The existence of the *Pioneer* anomaly is now undisputed, but its source remains a mystery. For example, if it is caused by gas leaks from the spacecraft, or by the emission of thermal radiation from their electrical power systems, the *Voyagers* would not be subject to the same forces as are the *Pioneers*.

The designs of the *Pioneer* and *Voyager* spacecraft are fundamentally different. Most notable is that the *Pioneers* rely on spin dynamics for attitude control, while the *Voyagers* rely on three-axis stabilization by gas jetting. On the other hand, if the *Pioneer* spacecraft themselves are not the cause of the anomaly—and neither we nor anyone else has been able to make a convincing case that they are—then some new type of physics is a possibility. Presumably, by the scientific principle of universality, any new physics would apply to both the *Pioneers* and the *Voyagers*.

The problem is that there is no theory that predicts the *Pioneer* anomaly, and without a theory, it is impossible to apply the anomaly to the *Voyagers*. Furthermore, the *Voyagers*' gas jetting prevents us from measuring small forces that might be affecting the two spacecraft. However, if we understood the cause of the anomaly, it would no longer be an anomaly at all. It could be applied not only to the *Voyagers*, but to solar system bodies as well.

My pointing out that the *Pioneers*—and, by extension, the *Voyagers*—might not escape the solar system

Factinos

This image, taken by the Mars Orbiter Camera on* Mars Global Surveyor*, shows gullies on a Martian crater wall that may have been carved by melting snow packs. The arrow points to a remnant of the snow pack that appears to have eroded the gullies. This image covers an area 2.8 by 4.5 kilometers (1.7 by 2.8 miles). North is at the top.

Image: JPL/NASA

The now famous gullies on Mars were created by water trickling off melting snow packs—not by underground springs or pressurized flows—argues Philip Christensen of Arizona State University. Christensen, the principal investigator for *Mars Odyssey*'s camera system, came to this conclusion after studying images from the *Mars Global Surveyor* as well as from *Mars Odyssey*'s visible light camera.

In an image of an impact crater in Mars' southern midlatitudes, Christensen noted eroded gullies on the crater's cold, pole-facing northern wall, and right next to the gullies was a section of what he calls "pasted-on terrain." This unique terrain comprises a smooth deposit of material that Mars scientists have determined is volatile. The composition of this slowly evaporating substance is most likely snow.

"I saw it and said, 'Ah-ha!' It looks for all the world like these gullies are being exposed as the terrain is being removed through melting and evaporation," explained Christensen.

To read more about Christensen's findings, visit *http://planetary.org/mars_snow.html.*

—from Arizona State University and NASA

was mere conjecture—they might or they might not. In the absence of an understanding of the anomaly, we really have no idea. It appears that the last signal from *Pioneer 10* was received on January 23, 2003. The last Doppler signal, which provides the only means of determining the spacecraft's trajectory path, was received in March 2002. With *Pioneer 10*'s tracking now complete, we are anxious to determine the *Pioneer* anomaly out to an unexplored distance of 80 astronomical units (AU). (One AU is equal to the distance between Earth and the Sun—150 million kilometers or 93 million miles.) However, NASA has rejected our 2003 proposal to do so. But we have carefully archived the data so that it can be analyzed in the future.
—JOHN D. ANDERSON,
Jet Propulsion Laboratory

Considering the high speeds and densities at which information can be moved around, on or near Earth—say, from television stations via satellite, or from mission control to a shuttle in orbit—why can't spacecraft like* Cassini, Galileo, *or any of the Mars orbiters and rovers send back video instead of still images only?
—Jared Robertson,
Bellingham, Washington

I agree with you that we need a Mars video camera to share the dynamics of Mars exploration with the public. The main obstacle is that the amount of data that can be returned over such large distances is very limited. NASA is currently building an orbiting spacecraft that will have the largest data return of any Mars mission, about 4 million bits per second. By comparison, television video has a data rate of about 30 million bits per second.

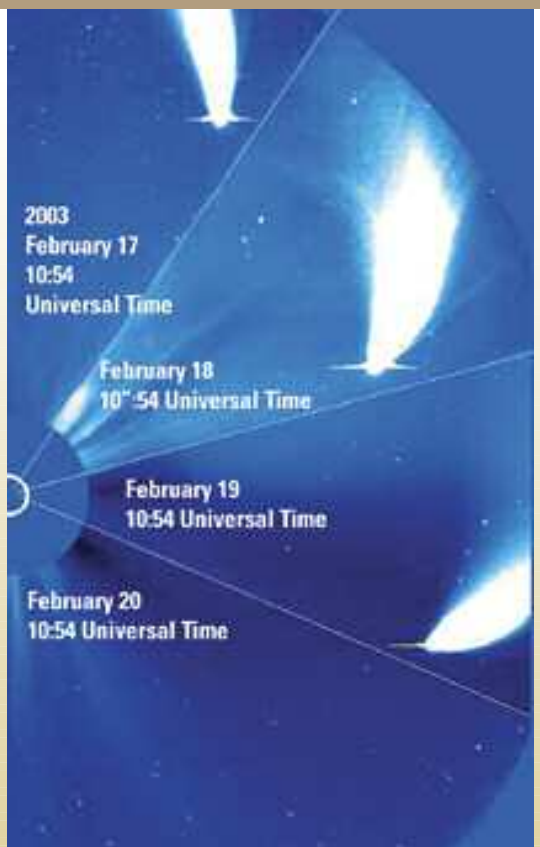
There are two techniques that could be employed to reduce the rate for returning images from Mars. First, the video image could be compressed, applying the same methods currently used by many digital cameras. The second method would be to send back only frames that are different from other frames. In other words, if no motion were shown in an image, the camera would not transmit the data.

The video we really want to see is from the surface of Mars. For example, we would like to watch a vehicle lift off from the surface of the Red Planet. However, the data return rate from Mars' surface is much lower than that from an orbiter—about 100,000 bits per second. And that would be only for the duration of the lander's contact with the orbiting spacecraft: less than 10 minutes. This means that getting video back from Mars' surface is practical only for short-duration special events.

Laser communication is an exciting new technology. A narrow, pencil-width beam of light can bring back a lot of data. A 10-watt laser could transmit 10 million bits per second when Mars is close to Earth. The catch is that a telescope 10 meters in diameter is needed on Earth to retrieve it. Also, the pointing of the laser beam would have to be accurate to 0.5 micro-radian (equivalent to 0.1 inch in the total distance from Los Angeles to New York). Fortunately, the cost of large telescopes has fallen, and we are now building spacecraft with adequate pointing stability. Laser technology also continues to improve, so I am optimistic that we will have video from Mars in the next decade.
—ALAN DELAMERE,
Ball Aerospace

A comet recently discovered as part of the Jet Propulsion Laboratory's Near Earth Asteroid Tracking (NEAT) program put on a fine show as it flew close to the Sun this past February. Comet C/2002 V1 (also called comet NEAT) was captured in the image (at right) taken by the European Space Agency and NASA's Solar and Heliospheric Observatory (SOHO) space probe. It became the brightest comet ever observed by SOHO's Large Angle and Spectrometric Coronagraph Experiment (LASCO) instrument.

The show became even more spectacular in the early hours of February 18, when the Sun unleashed a storm of charged particles, known as a coronal mass ejection. It looked as if this ejection were heading for the comet. Astronomers are now trying to determine if a head-on collision between the two did in fact take place. Comet NEAT remained in the LASCO field of view until February 20.
—from the European Space Agency and NASA



These four images of comet NEAT's swing by the Sun were taken at 10:54 Universal Time by the Solar and Heliospheric Observatory on February 17, 18, 19, and 20, 2003. The white circle near the center of the left margin represents the outline of the Sun.

Images: The European Space Agency and NASA

Society News

Future of Human Spaceflight Workshop

The Planetary Society will conduct a workshop, in memory of the crew of *Columbia*, to discuss the future of human spaceflight. We are doing so in cooperation with the Association of Space Explorers and the American Astronautical Society.

Specifically, participants will examine Earth to Earth orbit space transportation in order to meet the needs of human exploration beyond low-Earth orbit. Participants will include astronauts, space industry and policy leaders, and space transportation experts.

It is important that the Society lead in representing public interest in human and robotic space exploration. Thank you, members and donors, for your ongoing support. You are The Planetary Society, and your commitment to space exploration is especially crucial now. Your membership and your additional gifts make activities like this workshop possible.

For more information about the workshop, or to make a gift, call Andrea Carroll, director of development, at (626) 793-5100, extension 214.

—Andrea Carroll,
Director of Development

Participate in Mars Exploration Through Two New Contests!

The Planetary Society has just announced two new contests as part of the Red Rover Goes to Mars educational outreach experiment on the *Mars Exploration Rover* mission:

1. Name the Astrobots!

On board the *Mars Exploration Rover* spacecraft, set to launch in May and June, are two "Astrobots." These representations of LEGO minifigures form part of the DVD hardware provided by The Planetary Society to carry the names of nearly 4 million people who signed up to send their names to Mars. During the mission, The Planetary Society and LEGO Company will publish fictional "diaries" of the Astrobots—accounts that will be sent back to Earth of the Astrobots' adventures traveling to and landing on Mars.

These characters need names, and The Planetary Society is offering the prize of a LEGO Discovery Saturn V Moon Mission set, signed by *Apollo 11* astronaut Buzz Aldrin, to the person who provides the winning names.

To enter the Name the Astrobot contest, visit the Red Rover Goes to Mars section on our website, *planetary.org*.

2. Build a Better Rover!

Continuing the highly successful Red Rover, Red Rover project, The Planetary Society is establishing a worldwide network of "Mars Stations," Mars dioramas containing LEGO rovers that can be controlled over the Internet. These Mars Stations will be designed to simulate actual locations on Mars, and visitors will be able to drive the rovers via any web browser, seeing the Mars environment through web cameras mounted on the rovers.

In order to ensure the success of the Mars Stations, The Planetary Society has started a contest soliciting robust LEGO rover designs. Contest winners will receive one of two new *Mars Expedition Rover* sets provided by the LEGO Company. For more information, visit the Red Rover Goes to Mars section of *planetary.org*.

—Emily Stewart Lakdawalla,
Science and Technology Coordinator

Declaration of Support for Space Exploration

Thank you, members and friends who have offered your support to NASA in the wake of the *Columbia* tragedy by signing the Society's declaration of support for space exploration. More than 15,000 of you have signed, including members of the Star Trek universe and SETI@home community.

Robert Picardo of Star Trek and a member of The Planetary Society Advisory Council said, "Although the recent tragedy envelops us all, to falter in our commitment to the future of human and robotic exploration of space is a disservice to the dedicated men and women who serve as architects of our future."

Members of the public can continue to show support by signing the petition at *http://planetary.org/petition3/*.

We will present the declaration and signatures to NASA at a future date.

—Monica Lopez,
Web Marketing Coordinator

Planetfest '04

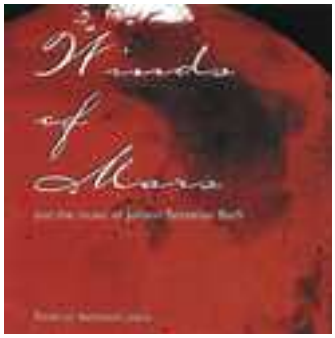
January 2–4, 2004 in Pasadena, California

Visit sunny Southern California for the Rose Parade on January 1 and stay for Planetfest '04, the largest space festival in the solar system.

Join the festivities as we celebrate two space encounters. The spacecraft *Stardust* will fly through comet Wild 2's coma and collect dust particles for a sample return mission on January 2, and the first *Mars Expedition Rover* lands on the Red Planet on January 4.

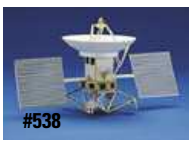
Enjoy lots of activities—including lectures, hands-on experiments for kids, celebrity panels, exhibits, and book signings—that will keep you busy while you wait for the pictures from the encounters to flash on the giant auditorium screen. As more information becomes available about Planetfest '04, we will update you on our website, *planetary.org*.

Continue to Explore!



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**



Spacecraft Science Kits

Build your own spacecraft and learn how it works. All models are accurate representations of the robots now exploring the universe. Intricate, laser-precut paper elements make these models highly detailed yet easy to assemble. All models contain details such as trusses, baffles, and even movable scan platforms and are accompanied by fact sheets giving the particulars of the mission. Each sold separately.
1 lb. **$15.75**

#524 ***Galileo***
#525 **Hubble Space Telescope**
#529 **Keck Telescope**
#530 ***Lunar Prospector***
#531 ***Mars Global Surveyor***
#538 ***Magellan***
#560 ***Voyager***

Mini Mars Polar Lander Science Kit

1 lb. **#778 $3.00**

Cosmos 1 Team Jacket

Planetary Society members are an essential part of the *Cosmos 1* team! Get your official team jacket only through The Planetary Society. These water-resistant jackets are cobalt blue with "*Cosmos 1* Team" embroidered on the front and logos for The Planetary Society, Cosmos Studios, and Russian space agencies printed on the back. Special order only (allow 6–8 weeks for delivery). Adult sizes: M, L, XL
1 lb. **#573 $60.00**

Cosmos 1 T-Shirt

The Planetary Society's *Cosmos 1*, the first-ever solar sail, will take off into orbit in 2003. This commemorative T-shirt is a Society exclusive. Long-sleeved, with glow-in-the-dark ink, it's perfect for dark nights of solar sail watching. Adult sizes: S, M, L, XL, XXL
1 lb. **#570 $25.00**

"Is Anyone Out There?" T-Shirt

Adult sizes: S, M, L, XL, XXL 1 lb. **#586 $19.95**

Carl Sagan Memorial Station T-Shirt

Adult sizes: M, L, XL, XXL 1 lb. **#581 $16.75**

Future Martian T-Shirt

Child sizes: S, M, L 1 lb. **#565 $13.50**

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This poster features Carl Sagan's timeless words and the full frame of the profound image captured by *Voyager 1*. 12" x 30" 1 lb. **#326 $10.00**

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1 lb. **#795 $6.95**

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This stainless-steel, 16-ounce thermal mug filled with your favorite hot beverage will help keep you warm on chilly nights of solar sail watching. A limited-edition Planetary Society exclusive.
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Planetary Society Mug

2 lb. **#607 $10.00**

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1 lb. **#677 $16.00**

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When the cheering crowds, the photographers, journalists, and television crews have gone home, the space explorer keeps working. In *Oh God, How Tired I Am*, Josef Minsky captures the seldom-seen side of one of the most glamorous careers known to humankind—the fatigue that accompanies very hard work.

Josef Minsky (1947–1994), a member of the USSR Artists Union and its Cosmic Group, lived and worked in Moscow. His work has been widely exhibited in Russia and internationally. "The main thing for me," wrote the artist, "is that space exploration has two aspects: technical and human."

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PRINTED ON RECYCLED PAPER
Printed in USA