The PLANETARY REPORT

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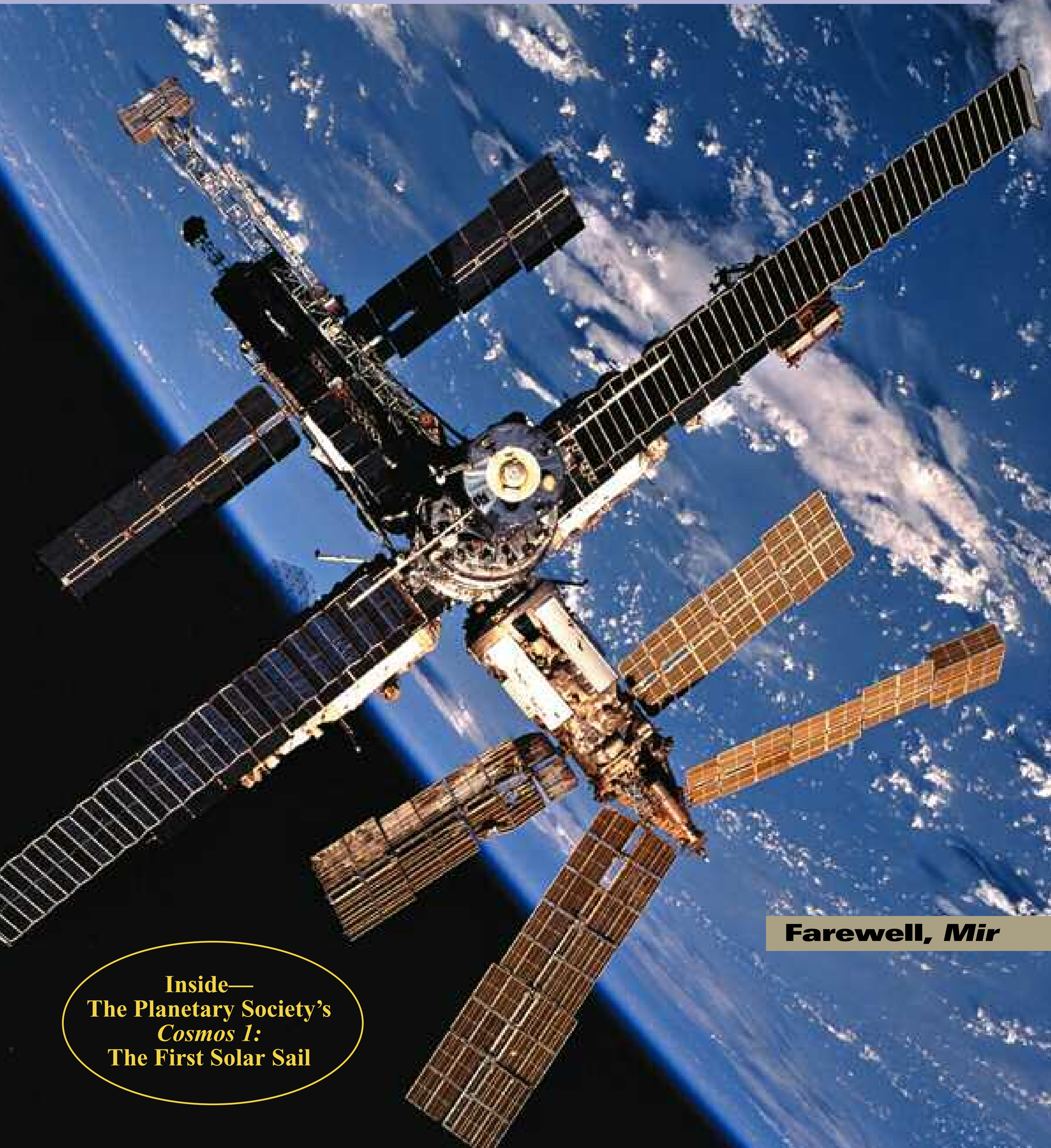

Farewell, *Mir*

**Inside—
The Planetary Society's
Cosmos 1:
The First Solar Sail**

On the Cover:

When *Mir* launched in February 1986, it was a showcase of Russian technology. But after 15 years of hard work, the aged space station has ended its run.

This view of *Mir* over Earth's blue skies was imaged during a fly-around by the space shuttle *Atlantis* following the joint docking activities between the two crews.

Image: JSC/NASA

Table of Contents

Volume XXI
Number 2
March/April 2001

Features

Departments

From The Editor

The Planetary Society is preparing to launch its first space mission: the *Cosmos 1* solar sail. For years we've been hearing from our members that what you'd really like the Society to do is to fly our own spacecraft mission. And so that's what we're going to do.

A remarkable confluence of people and events is making this mission possible. The Russians we've worked with for 15 years on our Mars Balloon, Rover, and Microphone projects saw applications for solar sails in the inflatable spacecraft technologies being developed in their now-scaled-back space program. They brought their ideas to us.

Meanwhile our cofounder Carl Sagan's wife and collaborator, Ann Druyan, was starting a science media and entertainment company, Cosmos Studios, with Internet entrepreneur Joe Firmage. Seeing the solar sail as a perfect fit with their projects, they enthusiastically agreed to sponsor it.

Planetary Society members have steadfastly supported our efforts to develop innovative technologies that can be leveraged into major advances in planetary exploration. We found a project of such great potential, and such manageable cost, that we could do it ourselves. We will do what our members really want us to do: fly our own mission.

So this fall, as you look up and watch our solar sail tack across the sky, you'll know that you and your fellow members made it happen. Be proud.

—Charlene M. Anderson

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Members' Dialogue

Robert Zubrin Responds

The November/December 2000 issue of *The Planetary Report* contained articles by three members of the "planetary protection" community who were apparently very upset by my article in the July/August 2000 issue disparaging the putative threat of back contamination from Mars. (See "No Threat? No Way!" on page 4.) The back contamination worthies need to deal with the following facts:

1. There's not a shred of evidence to support the notion that life of any kind exists on the Martian surface. In other words, the entire case in favor of a back contamination threat from Mars is a null set. But there is plenty of evidence to show that the putative threat does not and cannot exist, including:

• The *Viking* landers tested Martian soil and found it free of organic material down to an accuracy of one part per billion. Mars' dust is mixed on a global basis. If there is no organic material in the dust at the *Viking* landing sites, there is none in any dust on Mars.

• The landers also detected strong oxidizing agents in the Martian dust, which would destroy any microbes exposed to it. So we not only know that Mars soil *is* sterile, we also know *why* it must be sterile.

• Even in the absence of the sterilizing oxidizers detected by *Viking*, conditions on Mars' surface are such as to preclude active microbial metabolism. Life cannot exist without liquid water. There's no liquid water on Mars' surface.

2. If, despite all the above, Mars' surface did harbor microbial life, then it is already here. Earth receives about 500 kilograms (1,100 pounds) per year of meteorites ejected from Mars. A conservative linear extrapolation backward over the past 3.6 billion years indicates the terrestrial biosphere has already received some 1.7 trillion kilograms (3.75 trillion pounds) of samples from Mars, coming from more than a thousand different sites scattered across the planet.

There is also little doubt that sizable fractions of the ejected putative bacteria could survive the interplanetary transfer as well as reentry at Earth. (See "Life From Space" by Benjamin Weiss and Joseph Kirschvink, *The Planetary Report,* November/December 2000, and "Natural Transfer of Viable Microbes in Space" by Curt Mileikowsky et al, *Icarus* 145, 391–427, June 2000.)

3. The planetary protectors also need to explain why building a Maginot Line around NASA's tiny 500-gram (1.1-pound) sample is worthwhile, as Mother Nature continues to deliver, both ways, thousands of kilograms of uninspected and unsterilized materials.

Everyone agrees that measures should be taken to preserve the scientific value of the Mars sample. The issue is whether foundationless fears should be allowed to distort mission design so as to increase the chance of failure. NASA lost two *Ranger* lunar missions as a result of completely pointless spacecraft sterilization measures demanded by the planetary protection folks. As a result of their demands, in 1998 the Jet Propulsion Lab adopted a mission protocol for the Mars Sample Return stating that if a signal confirming sample confinement were lost from a returning sample craft, the return vehicle would be directed to bypass Earth.

We have already spent two decades planning a Mars Sample Return mission, and it's likely we'll spend at least another. Before we're done, at least a billion dollars will have been spent in an effort to get a sample from Mars. Yet the back contamination worthies argue that all that time, effort, money, talent, and potential for discovery should be tossed like garbage to appease tabloid fears over a nonexistent menace.

It is time that NASA rethought its "planetary protection" program. Continuing to lend credence to the irrational could be very costly indeed.
—ROBERT ZUBRIN,
Indian Hills, Colorado

Shaping Young Minds

I want you to know about the contribution you are making to the education of my middle school students. I teach science at William Cowper Intermediate School and conduct an Astronomy Club there for the kids. We get a sizable number of students at each of the twice-weekly meetings, considering they are held at 7:30 a.m., before school begins.

What keeps these kids coming back each week, in large part, is discussion of the issues raised in each issue of *The Planetary Report*. I use the magazine as a springboard to discussion that encourages the kids to take a "minds-on" approach to learning about astronomy. "Minds-on" means they are not just learning, they are learning to question intelligently and to discuss both the benefits and trade-offs of various space missions. For example, the kids are upset that the government seems intent on cutting back the space program. They know it is the space program that has been the source of many of the things we take for granted in modern life. They also know space exploration is essential to learning our origins, and they are excited about the prospect of helping make this happen by supporting our efforts at exploration.

Please keep up the excellent quality of your articles. You are helping produce citizens who will understand the importance of the space program and who are in awe of the wonders of the universe.
—CHERYL DODES,
East Meadow, New York

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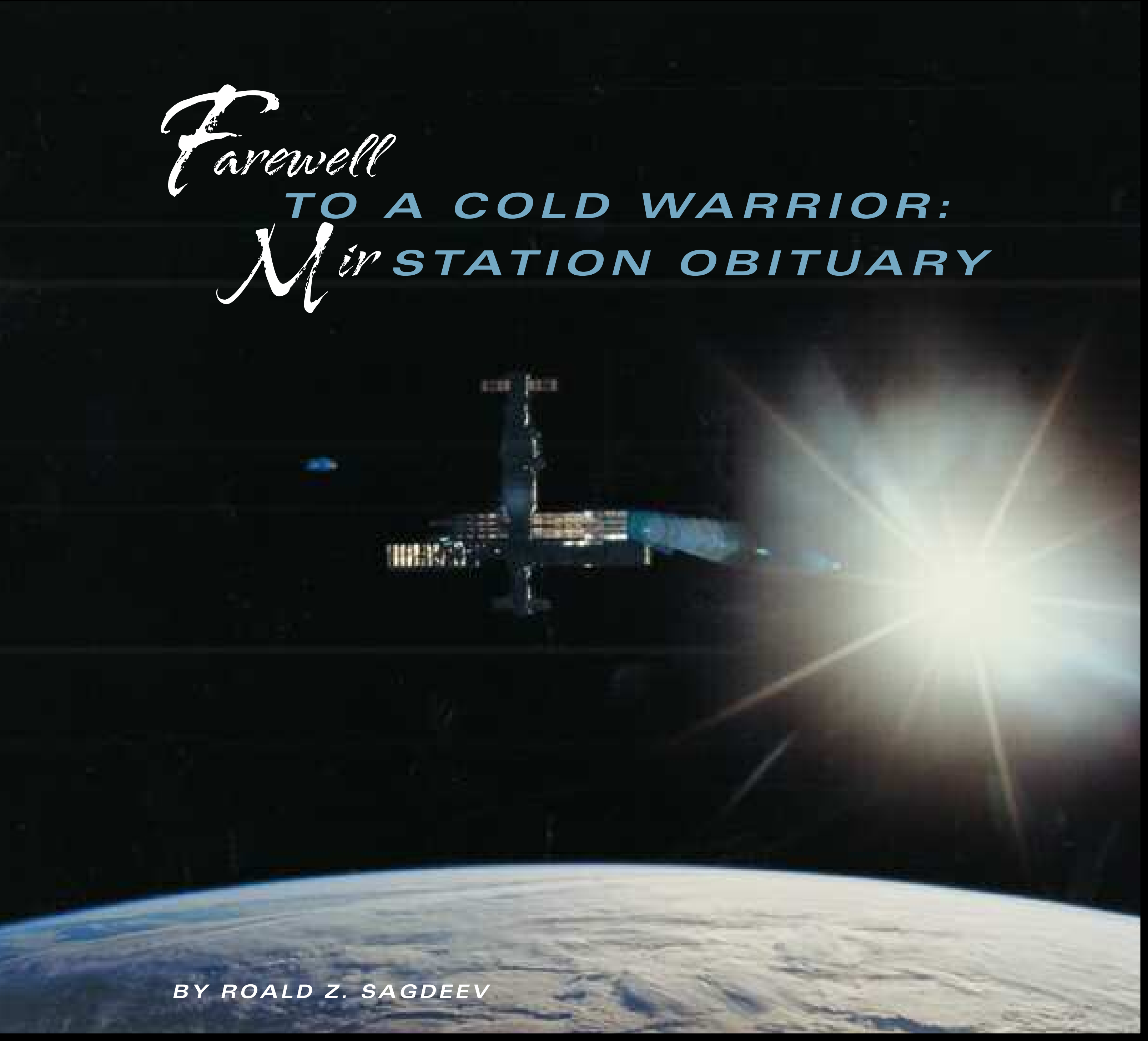


Farewell to a Cold Warrior: *Mir* Station Obituary

BY ROALD Z. SAGDEEV

Mir outlived not only the original manufacturer's warranty but also its parent state, the USSR, by almost 10 years. In 1991 and 1992, cosmonauts were launched to *Mir* from the Soviet Union but they returned to a "different" country: Russia. They discovered that the theory of relativity controls the clocks of history: these move faster on Earth than in space.

Mir's first outpost was launched February 20, 1986, at the peak of Mikhail Gorbachev's perestroika. But it was a product of post-*Apollo* Soviet space policy, adopted as a consolation after the disastrous failure to land a Soviet on the Moon. The Communist Party at the time even codified the development of piloted orbital stations as the "major direction of the Soviet Space program." *Mir* was also the result of successful lobbying by the Soviet aerospace industry. At that epoch, industry leaders were elevated to the level of members of the party's Central Committee. And the Kremlin's political dividends were immediate: tickets to fly foreign cosmonauts became an instrument of Moscow diplomacy. The very selection of guest countries reflected this policy.

Mir was the last (the seventh) in the series of Soviet orbital stations. Its predecessors were known under the name *Salyut* (numbered 1 to 6). Behind their origins were hidden dramas and wars. The USSR's leading rocket scientists competed to get the most prestigious assignments. Sergei Korolev, the father of the Soviet space program, was virtually unchallenged during the first period of this internal space race. However, his death, along with the lunar setback, sparked the competition anew.

Left: Backlit by the Sun, Mir *glistens over Earth in this 70mm Imax frame, photographed on February 6, 1995, during rendezvous operations with the space shuttle* Discovery. *In mid-March, Russia will discard* Mir, *one of the last remaining symbols of the nation's superpower status, by plunging the geriatric spacecraft into the South Pacific halfway between Australia and Chile. The exact date of* Mir*'s demise will depend on solar activity.* Image: JSC/NASA

Right: In this February 1986 photo, technicians put the finishing touches on Mir*'s core module in the assembly and testing shop of the Baikonur Cosmodrome.* Photo: A. Pushkaryov, Fotokhronika TASS

A COMPLEX ANCESTRY

The first design of what later became a typical module of *Salyut* configuration was made in the late 1960s by the team of Vladimir Chelomey. At that time his company had just come up with the Proton, then the most powerful Soviet launcher. Its throw weight capability defined the mass of the orbital station module at about 20 metric tons. Its size (4 meters in diameter) derived from practical restrictions imposed by railway transportation.

That early ancestor of *Mir* had the classified name *Almaz* (diamond) and was supposed to serve the interests of the military. Eventually, the ticket to fly the piloted station went back to the Energia enterprise, into the hands of Korolev's successors. However, the actual manufacture of the principal heavy modules was continued at the Khrunichev plant, formerly part of Chelomey's empire.

The *Salyut* experience allowed designers to conceive of *Mir* as a configuration of several modules, each dedicated to different tasks. For example, the Kvant module carried the first Soviet high-energy astronomy package, combining several gamma- and X-ray telescopes. Prior to the *Mir* station, this branch of space science was almost nonexistent in the Soviet Union. And suddenly, in a huge stroke of luck, Earth witnessed the birth of a new star, Supernova 1987A. Although the Kvant module delivery missed the first few weeks of the supernova, Kvant was still able to collect valuable data on 1987A's post-explosion behavior and monitor its changing brightness. The bulk of these observations came from a science payload contributed by the international community, something unprecedented in Soviet manned flights.

The composition of other modules, added incrementally to the *Mir* configuration, represented almost every community of space scientists. The Kristal (Crystal) module obviously served the material sciences. It carried a number of furnaces and technological devices to study the effects of the microgravity environment on crystal growth and other processes. The optimists (predominantly the aerospace people) awaited a cornucopia of new materials to spring forth once a simple furnace was put in orbit. However, the majority of condensed-matter scientists felt no hurry to hop on a space bandwagon at that time.

The Priroda (Nature) module was designed and equipped with a variety of the Earth surface and atmosphere observation hardware. It included almost everything from the arsenal of the science and technology of remote sensing, such as multispectral cameras and passive and active microwave instruments.

All in all, the total configuration of *Mir* reached the net mass of 130 metric tons. The major question for the designers and users of *Mir* involved the role of the onboard crew in specific experiments. Concerns about engineering as well as assembling and servicing the modules, processing the cargo deliveries (by the *Progress* unmanned spacecraft), and so on were clear. But many experiments could function without human intervention. Others—astronomical observations and crystal growth, for example—would actually benefit from unmanned operation. At the same time, some disciplines, like biomedical studies, required the participation of humans at least as the objects of research. It was no surprise that the latter type of experiment became the major beneficiary of the *Mir* program.

Luckily, there was no lack of support from the Soviet government (and later, to a degree, from Russian authorities) for long-duration flight records and biomedical research. *Mir* did, of course, serve the public relations needs of the space program. That contribution is well documented in *The Guinness Book of Records*. In terms of science output, probably the most extensive results obtained during the *Mir* expeditions were in the area of biomedicine.

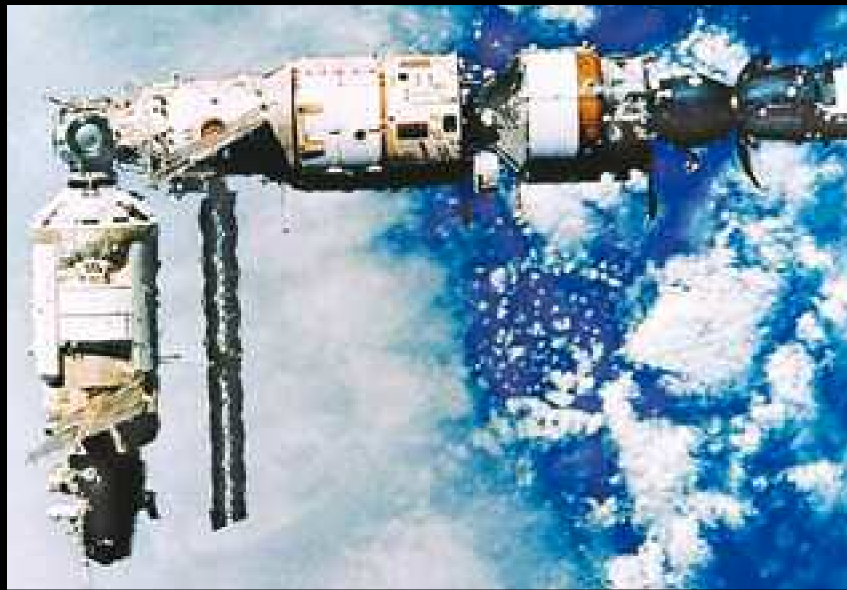
THE ROLE OF SCIENCE

Still, overall, science was brought on board the Mir station to play the role of a junior partner. Since *Mir*'s inception, the interests of aerospace engineering were dominant. At the very beginning, before the first launch, aerospace officials tried to impel the Soviet Academy of Sciences to pretend to be the principal customer. (The author of this article takes full responsibility for saying *nyet* to this.)

Regardless, the prime contractor, Energia, was in charge of the *Mir* station. The cosmonauts' schedules were filled with such tasks as running *Mir*'s systems, continuing to enlarge and expand the station by adding new modules, and upgrading its hardware. Even at that golden period, before unending repair became a major activity, only 8 percent of the crew's time was budgeted to scientific experiments. And *Mir* had to be shared with others, including the military.

Nobody could complain that the multimodule configuration challenged the space program. Also, it was generally understood that eventually the technology and experience gained from *Mir* would open new horizons for scientific uses, for new applications in space and from space, and for human expeditions beyond Earth's gravitational bonds.

To keep the *Mir* program in proper perspective, it should



Left: *Launched on February 20, 1986,* Mir*'s 20-metric-ton core module served as an axle to connect future modules and transports. The core module also served the crew's basic needs, providing living quarters, life support, power, and scientific research facilities.*

Above right: *Here we see both parts of Kvant. The astrophysics module's (right) purpose was to observe galaxies, quasars, and neutron stars, as well as to perform biotechnology experiments. At left, Kvant-2 housed an EVA (extra-vehicular activity) airlock, solar arrays, and life support equipment.*

Right: *In June 1990, Kristal, the third module, was added to* Mir*. Kristal was used to develop biological and materials production technologies in a low-gravity environment. Scientific study, specifically observations of Earth's natural resources and atmosphere, were conducted in the fourth module, Spectr (not shown), added in June 1995. The fifth, and last, module joined to* Mir *in April 1996 was Priroda, shown on our cover. This module's primary purpose was to supplement* Mir*'s remote sensing of Earth.*

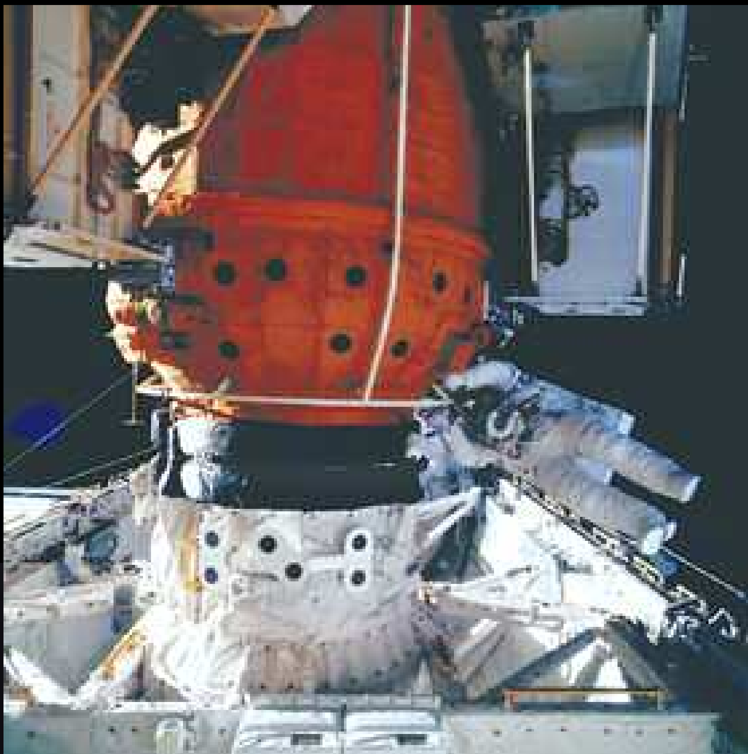
Images: RosAvia Kosmos

be said that at the time of the launch, the station was not a high priority in the Soviet space program (despite the official propaganda). Since the late 1970s, most resources were concentrated on building the counterpart to the US space shuttle. Internal debates on the Soviet response to the shuttle were quite poignant, since almost none of the potential user agencies, including the military, was able to justify spending that much money. However, the Kremlin leadership perceived the American shuttle as a potential strategic disadvantage for the USSR. Many aerospace companies had to fulfill engineering design and manufacturing quotas and to contribute to the finally adopted Soviet program of reusable space transport, classified under the name *Buran*. Finally, the program culminated in two technically very successful launches (of the Energia super rocket in 1988 and the unmanned version of *Buran* in 1989), only to be abandoned almost immediately. The later period of Gorbachev's Soviet Union experienced a serious economic crisis, which began to impact the space program.

AFTER THE FALL

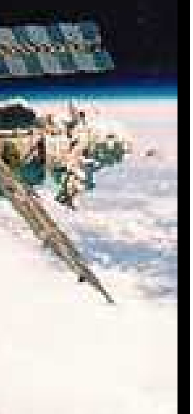
After the dissolution of the USSR, the economically stricken Russia—the successor to the Space Superpower—started rapid downsizing of her space-firing appetites. The one-to-one scale version of the *Buran* spaceplane found its final destination as a restaurant in Moscow's famous Gorky Park. Here was a strong signal that perhaps *Mir* would have endured the same fate had it not already been flying in orbit.

New Russia and her then newly created space agency, RosAvia Kosmos, had to decide the future of the existing



Left: Astronaut Michael R. Clifford works at a restraint bar on Mir*'s docking module during a March 28, 1996 spacewalk. The Russian space station was joined with space shuttle* Atlantis *in this view.* Image: NASA

Below: From 1995 to 1998, seven US astronauts spent a total of nearly 1,000 days on Mir*, learning from the Russians' experience with long-term space flight. Here, astronaut Shannon W. Lucid joins her cosmonaut crewmates Yuriy I. Onufrienko (foreground) and Yuriy V. Usachov (background) inventorying food supplies in* Mir*'s base block module.* Mir *was docked with the space shuttle* Atlantis *when this photo was taken.* Photo: NASA



Mir station, along with that of the team of engineers working on the blueprints of *Mir*-2, long assumed the next-generation successor to the *Salyut* series and *Mir*. The solution to the first of these problems was "market reform": to make *Mir* financially self-sustainable. By the end of the Soviet epoch, one could already see the market potential in flying guest cosmonauts in space.

Indeed, there was some interest among space hopefuls such as Japan and countries in Europe. This type of customer was driven by the need to prepare for the future International Space Station (ISS). Another category of clients included wealthy individuals willing to spend money on a ticket to space. (I personally tried to help the late John Denver purchase such a ticket during Gorbachev's time.) The Energia team eventually managed to build an entire program around guest cosmonauts.

However, the major breakthrough was Russia's joining ISS. Leaving aside the political overtones of this fateful decision, it became possible to build on the instructive adventures of *Mir* and its predecessors, the *Salyut*s. At the same time, the *Mir* station assumed a new task: to serve as a test bed for the future operation of ISS. The Soviets/Russians had acquired so much experience in long-duration flights, it would not have been wise to simply ignore them, saying "We don't want them in the driver's seat" (as if we have never hailed taxicabs in New York City).

AN AGING SURVIVOR

This international agreement provided the resources to keep the *Mir* station going. NASA was sending one shuttle mission after another to dock with *Mir*, and US astronauts were part of long-duration flights, unattainable on shuttle missions. The several positive outcomes of this cooperation included access to the latest American technology for upgrading the biomedical leg of *Mir* activity.

However, the space version of the *Survivor* series could not continue indefinitely. The aging *Mir* demanded an ever-growing scale of efforts to keep it aloft. A fire in February 1997, followed by a self-inflicted wound during unsuccessful docking with a cargo ship, signaled a serious warning. In internal Russian debates, only extreme "ultra patriots" and some sectors of the aerospace community with a parochial interest in running the station supported its continuing operation. In the end, General Director of RosAvia Kosmos, Yury Koptev, concluded there was no sense in keeping *Mir* in orbit when 80 percent of the cosmonauts' time was spent on repairs. The international community, meanwhile, expressed concern that the Russians were distracted from their responsibilities to ISS. At the time, work on critical Russian modules was delayed by lack of government funding.

Thus, by all counts, after 15 years of its odyssey in space, *Mir* became a liability and had to be dumped from orbit. Still, its contribution to the Russian and international space programs remains an outstanding one, and an example not only for ISS but also for future human missions beyond the Earth. Rest in peace, *Mir*, you lived a great life in your time—now it is time for a new generation and, we hope, new achievements.

Roald Z. Sagdeev holds a joint appointment as Distinguished Professor of Physics at the University of Maryland and Director Emeritus of Russia's Space Research Institute. He has served as a Planetary Society Adviser since 1983 and is now a member of the Society's Board of Directors.

A BOLD NEW **VOYAGE:** THE PLANET

ARY SOCIETY PREPARES TO FLY A SOLAR SAIL

BY LOUIS D. FRIEDMAN

The Planetary Society is launching a bold new voyage—we're going to fly a solar sail spacecraft! Together with Cosmos Studios, sponsor of this new venture, we will attempt the first space mission undertaken by a public membership organization.

It's risky. It's audacious. It sets precedents—just as The Planetary Society should do. We're launching on a converted intercontinental ballistic missile (ICBM) from a submerged Russian nuclear submarine. We're contracting with a Russian space company to build and fly the spacecraft. We're blazing a new trail in media company-public interest group partnership. We're testing technology that may lead to a low-cost interplanetary shuttle. And we're taking what could be humanity's first step to the stars.Launch is scheduled for this year! The incredibly quick, low-cost project was initiated last September with the goal of an Earth orbit flight before the end of 2001. Currently, the launch is scheduled for some time between October and December 2001. A suborbital flight to test the deployment of the sail (see map, opposite) is scheduled next month—April 2001.

The technology making all this possible is solar sailing—a concept first discussed by Fredrich Tsander in the Soviet Union in 1924. Solar sailing involves a spacecraft traveling between the planets and someday to the stars—without using fuel. Instead the craft travels by the pressure of sunlight.

I led the first NASA solar sail development project in the 1970s in an effort to rendezvous with Halley's comet. That didn't happen; neither NASA nor the technology was ready. Even now, although both NASA and the European Space Agency (ESA) currently have solar sail development programs, no flights are firmly planned. However, The Planetary Society's solar sail project is fully committed, thanks to our sponsors and to our international partners in this endeavor.

The spacecraft will be developed and launched in Russia under a contract with the Society. Contract arrangements draw on the Society's 15-year experience with two Russian space organizations, Babakin Space Center and the Space Research Institute. Our association has allowed us to take advantage of pioneering technology engineered by these organizations: inflatable deployment structures, which make an economical initial solar sail flight possible. Also available to us are the Russians' low-cost, highly reliable rockets.

Cosmos 1, ***the first solar sail, will begin its epic voyage from underneath Earth's Barents Sea. The mission, as well as its suborbital test flight, will be launched on*** Volna ***rockets (converted intercontinental ballistic missiles of the type once aimed at the United States) from a Russian nuclear submarine.*** *Painting: Michael Carroll*

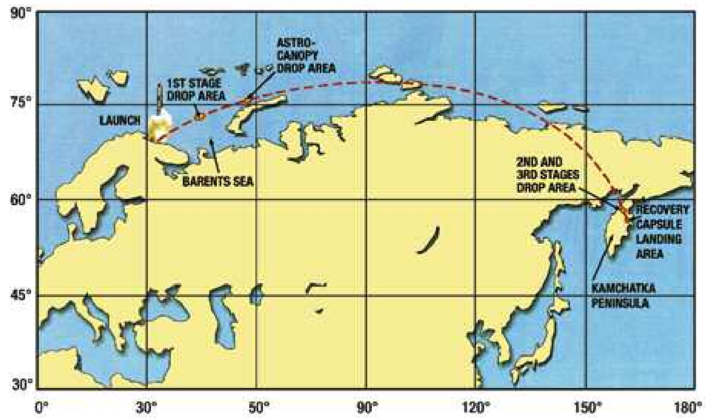
Beating Swords Into Plowshares

Those of you old enough to remember the Cold War may recall footage of submarine-launched ICBMs test fired from the Barents Sea or the Pacific Ocean near Kamchatka. As a result of arms limitation treaties, Russia must now destroy such rockets, once poised to strike the United States, or else launch them into space. Currently, the Russians are trying to convert these rockets for commercial applications as civil space launch vehicles. One relatively small such rocket is the *Volna*, a derivative of the SS-N-18 missile that is capable of reaching suborbital flight with a maximum altitude of 800 kilometers (500 miles).

We are going to use that rocket! Imagine—a public membership organization promoting peaceful space exploration ready to employ a converted ICBM. This is a perfect example of beating swords into plowshares! Furthermore, to achieve the orbit, the Russians will adapt another piece of military technology: a deorbit motor originally used to drop spy satellites from orbit. This time it will be used as a "kick" stage—to inject our solar sail spacecraft into Earth orbit at approximately 850 kilometers (530 miles) in altitude.

We will consider our flight successful if we can increase the orbit energy under the dominant influence of sunlight

SOLAR SAIL SUBORBITAL FLIGHT PATH



We plan to conduct a suborbital test flight about 30 minutes long around April 20, 2001. The spacecraft will launch from the Barents Sea in northwestern Russia and fly east to Kamchatka. Once the craft nears a maximum altitude of 411 kilometers (about 255 miles), two sail blades will be deployed, a step that will take about two minutes. After five minutes the reentry capsule will separate, returning the commercial digital camera placed on board to record the deployment. There will be no telemetry other than this. Entry, aerobraking, descent, and landing will take a total of 15 minutes. The aerobraking will be assisted by an inflatable reentry shield. Recovery teams in Kamchatka hope to find the capsule on the same day it lands. *Illustration: Babakin Space Center* pressure. That means we'll declare success if the spacecraft moves away from Earth with no push from anything other than sunlight.

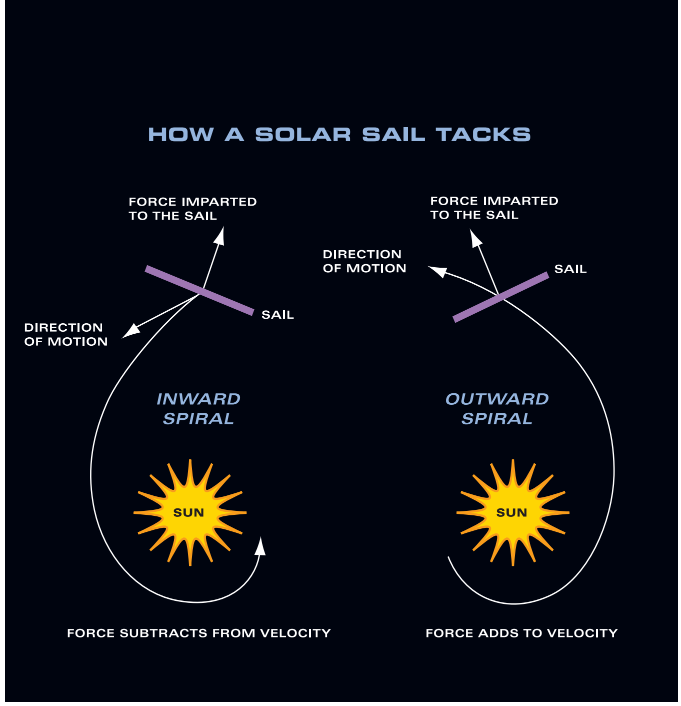
If the mission lasts only a few days, it will be a success—the Wright Brothers, after all, flew their first airplane for a mere 12 seconds. Yet our goal is to last weeks, perhaps even months, traveling progressively farther from Earth—although very slowly.

Sailboats don't like harbors, and Earth orbit is a harbor for a solar sail. Still, we have to start close to shore before we can roam interplanetary space.

Calculating the Risks

The mission poses many risks. But taking on these risks sends us on a worthy adventure. We invite the world to follow along in the adventure and to share success or failure with us via our website, *planetary.org*, and that of our sponsor, Cosmos Studios, *Carlsagan.com*.

Just what are the risks? Well, we are operating on a low budget, without redundancy and with a brand-new design, the first of its kind. Moreover, the launch will be the first to attempt to reach orbit using the *Volna* (although the rocket boasts a nearly perfect suborbital launch record).



The sail dynamics are extremely difficult to model and to test on Earth—how the vehicle will behave in space is almost unknown. Plus, the sail could become electronically charged, causing arcing to threaten the integrity of the solar sail. Then there is the constant danger of micrometeroids punching a hole through the sail itself.

Additionally, there are political pitfalls: we will be working internationally, relying on the Russian space industry, and inventing new ways of doing business as a private venture and as a public membership organization. We are conducting a multimillion-dollar mission when our previous flight experience has been limited to the $100,000 Mars microphone (which crashed with the *Mars Polar Lander*).

We believe our members want us to take such risks. In fact, for years I have routinely answered letters from members asking why we can't ourselves pursue private space missions. I have answered in the negative because I was addressing the feasibility of planetary missions; that is, missions that require many tens to hundreds of millions of dollars without any commercial return. However, a small-scale mission to demonstrate a technology is something we can try—especially with Cosmos Studios willing to underwrite the risk, given the opportunity to promote an exciting new commercial development in the media.

The plan for this mission is admittedly audacious—not because of any particular difficulties but because we are attempting on a very low budget to set so

SAILING NOT WITH THE WIND

Space sailing is accomplished not with the wind but with reflected light pressure propelling giant sails—continuously adjusting a spacecraft's orbit energy and velocity. The technique uses sunlight pressure to drive spacecraft between the planets, inward to Mercury or outward to Jupiter. Beyond Jupiter and out to the stars, the source of light is instead powerful lasers focused over long distances in space. The lasers themselves could be powered by solar energy.

As photons of light reflect off the large ultrathin metallized mirrors that are the sail, the spacecraft gains momentum in a continuous thrust—which increases or decreases its orbital energy depending on the direction the sail is tilted relative to the direction of sunlight.

This raises the question "How does the spacecraft tack (change direction)?" An ordinary sailboat tacks by manipulating forces generated at the interface of two media: wind and water. It is thus the position of the sail to the wind and the rudder that allow the boat to turn.

So, too, with the solar sail. Here, however, the two forces are solar pressure (photons from the Sun) and gravity. If the sail is tilted one way, the orbital velocity increases and the spacecraft travels away from the Sun; if it is tilted the other way, velocity is subtracted and the spacecraft travels toward the Sun (see diagram above).

How much velocity is added depends on the ratio of area to mass. Large area, small mass means larger velocity changes. So we use gossamer structures to lower the mass over large areas. Our solar sail spacecraft will weigh about 40 kilograms (88 pounds), and the sail area will be about 600 square meters. The ratio of 66 grams (2.3 ounces) per square meter is barely good enough to add velocity to the spacecraft in Earth orbit. If we are ever to go to the stars, it will be with spacecraft that weigh considerably less, say, 6 grams (0.2 ounce) per square meter. Still, we have to start somewhere!

Of course, sailing in Earth orbit is no easy task. A spacecraft orbiting the Earth constantly changes its angle relative to the Sun, making tacking difficult. Consequently, the sail's orientation requires constant monitoring. Moreover, orbiting too close to the atmosphere can slow a spacecraft. To demonstrate the viability of solar sailing, we must fly above our own atmosphere. *—LDF*

Left: The solar sail changes its orbital velocity by controlling the direction of the reflected force from sunlight pressure. Sunlight bounces off the mirror-like sail, imparting momentum to the vehicle. The force is imparted in a direction controlled by the angle of the sail with respect to the sunlight, which can either increase or decrease the velocity of the spacecraft depending on the direction of the force.

Diagram: Louis Friedman, redrawn by B. S. Smith

Right: A test model of a solar sail blade before it unfurls in a zero-gravity simulation. Through these tests and experiments, the engineers are determining the final configuration for the solar sail's blades.

Far right: Engineers watch a zero-gravity simulation of the sail deployment and test its mechanical configuration. This photo was taken in January 2001 at NPO Lavochkin, the world's largest manufacturer of robotic spacecraft.

Photos: Louis Friedman

many precedents.

The Technological Challenge

NASA has just this year initiated solar sail technology development and is pursuing the use of ultrathin, ultralight structures in space. ESA has a smaller solar sail development project with cooperative funding from the German National Space Agency. The Russian Energia company actually deployed two solar sail-like devices in space—to test the deployment of large mirrors for beaming reflected light to remote regions on Earth. Yet the deployed devices, which were observed from *Mir*, never achieved a sufficiently high orbit to actually fly as solar sailers. And while NASA is currently discussing an Earth orbit flight in 2004, and ESA in 2002, these are only deployment tests—they won't fly high enough to sail under the primary influence of solar pressure.

Our major difficulty has been getting a low-cost launch vehicle—one that can get us out of low Earth orbit, above the sensible atmosphere, to an altitude where space is essentially a vacuum and the only nongravitational force on the spacecraft is solar pressure. The solar force can then be leashed to raise the orbit energy—the definition of a solar sail flight.

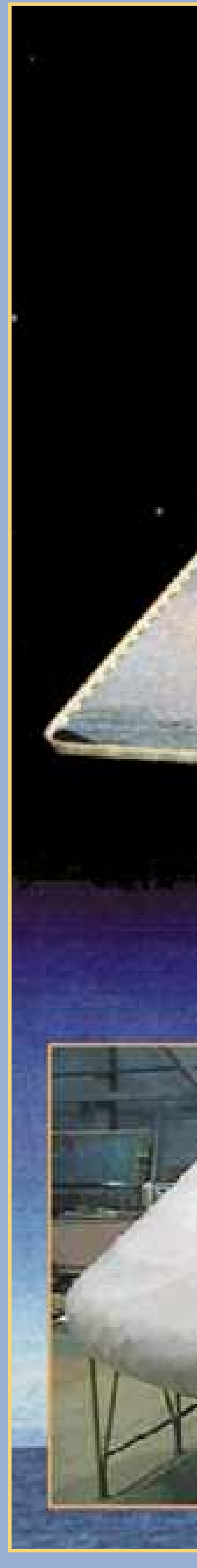
The required minimum altitude is anywhere between 600 and 800 kilometers (380 and 500 miles), depending on the density of the atmosphere, which can be compressed or expanded by the changing force of ultraviolet radiation. (Don't be confused—solar sails fly by reflecting photons from the Sun, not by the solar wind; nevertheless, the solar wind affects the atmospheric density.) The solar wind follows a predictable 11-year cycle, and we are pretty near solar maximum—which is why we have set 800 kilometers (500 miles) as the lowest altitude for our orbit injection.

To reach 800 kilometers, well above the orbits of the space station and *Mir*, we need expendable rockets to reach the minimum altitude. (When I led the JPL program in the mid-1970s, we proposed a shuttle-launched test flight with an orbital "kick" stage, which could push the test spacecraft into higher altitude. We've determined that while feasible, it was too expensive.)

The Russian Connection

A fortuitous set of conditions makes a low-cost launch possible—and may explain why The Planetary Society can accomplish this mission. The Russians possess thousands of missiles once targeted at the United States during the Cold War. The *Volna* is just one example. Developed essentially as a production-line item for the military, these rockets are highly reliable and can be launched at minimal cost. Restrictive policies, de-

(continued on page 14)



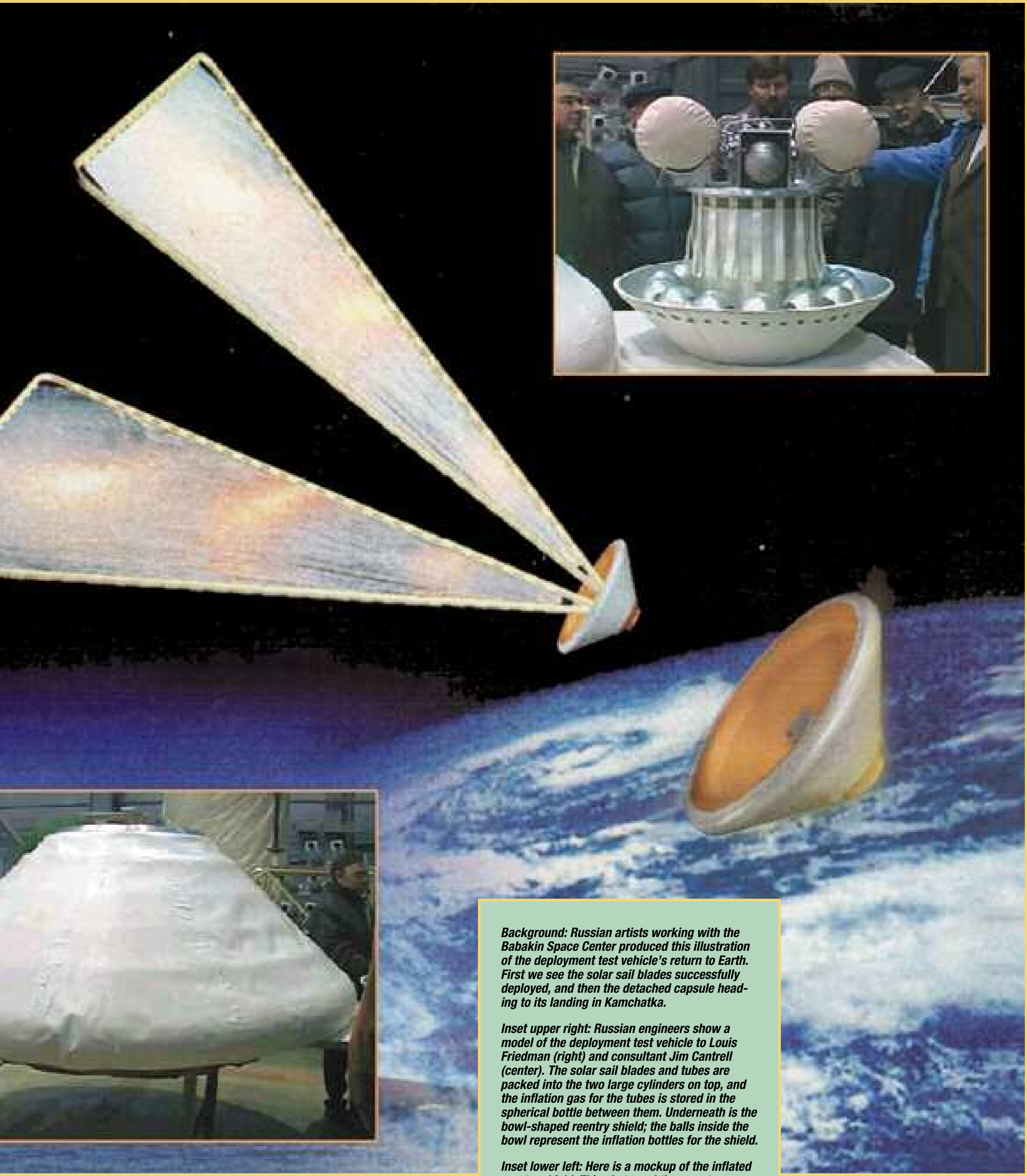
The solar sail floats over Moscow just before sunrise. Cosmos 1 *is scheduled to fly sometime between October and December 2001. The* Volna *rocket and another piece of military technology (a de-orbit motor once used to drop spy satellites from orbit) will "kick" the 40-kilogram (88-pound) spacecraft into an initial Earth orbit with an altitude of 850 kilometers (530 miles). The orbit will be inclined 78 degrees to Earth's equator, and, hence, we hope the sail will be visible from most of the world.*

Cosmos 1 *is made up of eight triangular blades, arranged into two planes of four blades each. The sail's total area of 600 square meters is roughly circular, with a radius of about 15 meters. Two cameras, one built in Russia by the Space Research Institute and the other built in the United States by Malin Space Science Systems, will be mounted above the sail. The cameras, looking out along the blades, will make views like this possible.*

Ground stations near Moscow will pick up telemetry from the mission, and the darkness before dawn will give us on Earth the best view of the sail. Depending on its position, Cosmos 1 *may shine as bright as the full Moon (though it'll appear as only a point in the sky).* *Painting: Michael Carroll*

This is the prime tracking station for receiving the images returned by Cosmos 1*. Located at Bear's Lake near Moscow, this station, with its 12-meter S-band antenna, is currently monitoring commercial satellites. That's Louis Friedman, Executive Director of The Planetary Society and Project Director for* Cosmos 1*, walking toward the camera.*

Photo: John Garvey



Background: Russian artists working with the Babakin Space Center produced this illustration of the deployment test vehicle's return to Earth. First we see the solar sail blades successfully deployed, and then the detached capsule heading to its landing in Kamchatka.

Inset upper right: Russian engineers show a model of the deployment test vehicle to Louis Friedman (right) and consultant Jim Cantrell (center). The solar sail blades and tubes are packed into the two large cylinders on top, and the inflation gas for the tubes is stored in the spherical bottle between them. Underneath is the bowl-shaped reentry shield; the balls inside the bowl represent the inflation bottles for the shield.

Inset lower left: Here is a mockup of the inflated reentry shield. This photo and the one at upper right were taken in late January 2001 at NPO Lavochkin, the Russian space organization where most of the solar sail is being constructed. Babakin Space Center, the mission's primary contractor, is a spin-off company of NPO Lavochkin. *Illustration and photos: Babakin Space Center*

TAKING A STEP TOWARD THE STARS

One question Planetary Society members may raise is "Why would our Society undertake this mission?" Or, "What does this Earth orbit mission have to do with planetary exploration?"

The answer is that solar sailing is key to interplanetary shuttles and interstellar flight. Travel between the planets requires either a rocket with lots of fuel to burn or a sail-type spacecraft able to tack back and forth in interplanetary space without dependence on narrow planetary alignment geometries. This is the concept behind the interplanetary shuttle.

Interstellar flight is probably more than a century away. But the most promising technology identified for its execution is space sailing—using highly focused, powerful lasers instead of the Sun for light pressure. The sails would be enormous and much thinner than the relatively heavy sail (at 5 micrometers, or 0.0002 inch, thick) we are contemplating for our flight.

The evolution from the Wright flyer to the supersonic transport took less than a century. Will the development from solar to laser sailing take any longer? We can't wait to find out. *—LDF*

(continued from page 11)

signed to protect American launch vehicle manufacturers, as well as to limit technology export associated with weapons, have prevented these rockets from being used much in commercial markets—at least so far.

The *Volna* is a converted SS-N-18 submarine-launched ballistic missile. Its manufacturer, the Makeev Rocket Design Bureau, has forged an agreement with our colleagues at the Babakin Space Center to develop *Volna* (and another rocket, *Shtil*) for civil space missions. Babakin is outfitting the vessel with a well-tested motor capable of inserting a spacecraft into orbit at an altitude of 850 kilometers (530 miles).

So it is the availability of rockets, along with The Planetary Society's association with the Russian space industry, that makes this mission possible. The low cost derives from the Russians' piggybacking on their success developing an inflatable reentry vehicle—a ballute. The same technology will be used for the solar sail deployment. Once injected into Earth orbit, the sail will be deployed by inflatable tubes swelling into "masts" to support the sail.

The sail itself is constructed of eight "petals," or blades, roughly triangular in shape. They can be turned, or pitched, like helicopter blades, and depending on how they are pitched, the sunlight will reflect in different directions. This controls the attitude of the sail spacecraft and allows the spacecraft to maneuver (see "Sailing Not With the Wind," page 10).

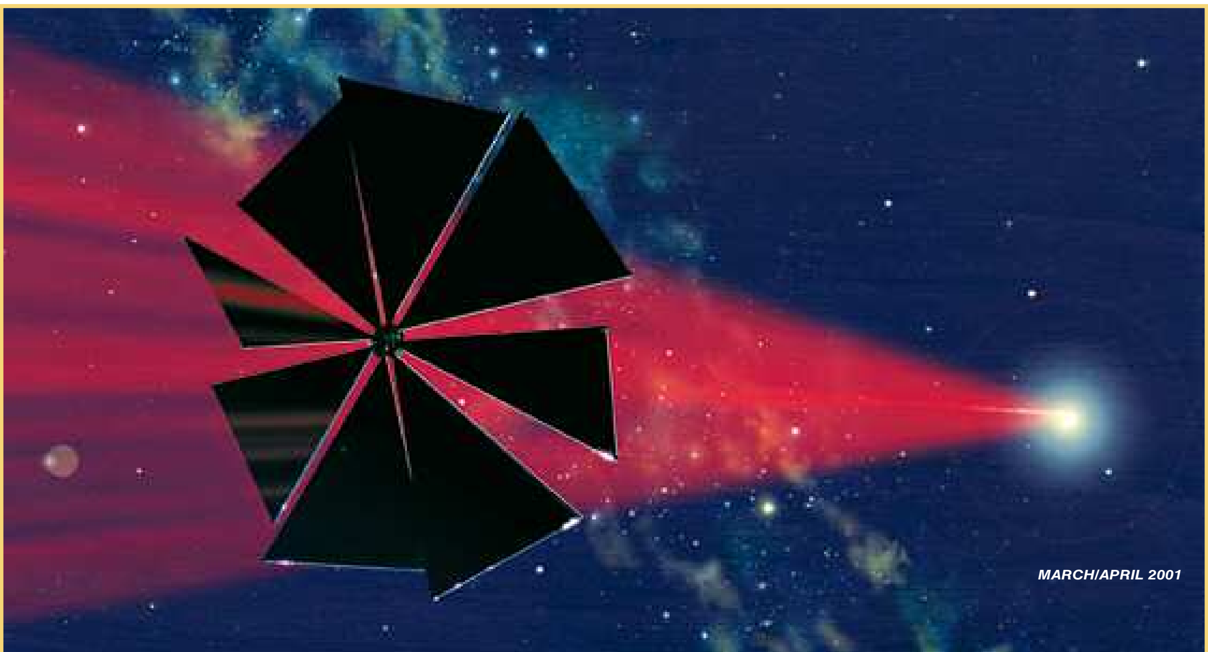
Keeping Our Eyes on the Goal

If we fly successfully for even a few orbits, raising the orbit energy, we will have demonstrated solar sailing. Our goal is one week of constantly raising the orbit altitude. But we could last longer—perhaps even months. Of course, sailing in harbors is notoriously difficult, and Earth orbit is definitely a harbor. Future flights will ideally begin farther away from Earth—perhaps at geosynchronous altitudes (approximately 40,000 kilometers, or 25,000 miles).

Our goal is simple: fly as a solar sailer in a high enough orbit to demonstrate that we can. How will we measure success? First, tracking the spacecraft from Earth will allow us to calculate the orbit parameters, particularly the altitude and the energy. We can then determine if these are increasing. In addition, sensitive accelerometers on the spacecraft will measure the solar pressure force, so we will be able to detect an increase in orbit energy. And finally, several cameras will be on board to beam pictures to all the people of Earth—on the websites of The Planetary Society and Cosmos Studios, and, we hope, in broadcast reports.

We will thus actually see the sail deployed in space. We might also be able to witness the sail from Earth (although only at particular times, depending on the orbit and the sail's position in the orbit). The drama of the venture will therefore be the world's to share with us.

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



Intense solar-powered space lasers could someday shine a focused beam on huge lightweight sails, allowing a spacecraft to reach enormous speeds and result in practical interstellar flight.

Painting: Michael Carroll

The 2001 Shoemaker NEO Grant Awardees— A World of Observing Experience

by Daniel D. Durda

When comets Hyakutake and Hale-Bopp came calling in 1996 and 1997, their beauty captivated us. But the enchantment produced by these celestial visitors and their cousins, the asteroids and meteoroids, would turn ugly fast if one were to plow into us. While not yet a household phrase, near-Earth objects, or NEOs, are rapidly becoming a topic of interest, and concern—not only to scientists but to the public in general This photograph of Hale-Bopp was taken the night of March 17, 1997 through the ruins of the John S. Cook bank building in Rhyolite, one of Nevada's largest ghost towns. Photo: Paul Cichocki

As scenarios featuring near-Earth objects (NEOs) inspire doomsday predictions as well as sci-fi plotlines, Planetary Society members can rest assured they've done their part to prepare for an encounter. In 1997, the Society began the Shoemaker NEO Grant program in honor of planetary geologist Eugene Shoemaker, who pioneered our understanding of the role of impacts on Earth and who dedicated much of his life to NEO research. The purpose of the Shoemaker NEO Grant program is to increase the rate of discovery and follow-up studies of NEOs by providing dedicated amateurs, observers in developing countries, and professional astronomers with seed funding to greatly increase their programs' contributions to critical NEO research.

Since founding the Shoemaker NEO Grant program, the Society has awarded grants to more than half a dozen recipients in countries spanning the globe. In late December 2000, an international selection committee of respected asteroid researchers combed through 23 proposals for the latest round of grants and selected five outstanding programs for funding.

On the following pages we present brief profiles of the authors of these programs.

Herman Mikuž and the Črni Vrh Observatory

Herman Mikuž helms the Črni Vrh Observatory in Slovenia, which has observed comets regularly since 1985. With a record of high-quality observations at the observatory site, Mikuž initiated a collaboration with the Faculty of Mathematics and Physics of the University of Ljubljana. They aided the program by providing a 0.36-meter f/6.7 telescope and computers.

In 1997, Mikuž and his colleagues decided to start an asteroid-observing program, concentrating on follow-up measurements of the positions of newly detected near-earth asteroids (NEAs) as well as on discovering new NEAs themselves. The project is called PIKA, after the Slovene acronym for Comet and Asteroid Observing Program. Mikuž and his collaborators designed and built a computer-controlled telescope mount for the 0.36-meter telescope, including the stepping-motor electronics and the movement control software.

Črni Vrh rapidly became one of the most prolific suppliers of NEO observations to the Minor Planet Center, which, under the auspices of the International Astronomical Union, serves as the clearinghouse for all discovery and observation data on comets and asteroids. Since the beginning of 1999, Črni Vrh has submitted more than 11,000 observations. Recent improvements, including a larger CCD camera, have further increased its capabilities.

Still, the existing 0.36-meter telescope system showed limitations in NEO detection, particularly for fast-moving objects that appear as faint trails in typical exposures. Mikuž concluded that the only solution to this problem was to increase the light-gathering ability of the Črni Vrh Observatory.

With funding largely out of their own pockets, Mikuž and his colleagues have begun a new project to build an even larger 0.6-meter telescope and to outfit it with a state-of-the-art CCD camera—allowing them to survey roughly 30 square degrees of sky per hour using one-minute exposures. This new project has severely challenged their finances, however. The Planetary Society has awarded Mikuž and the Črni Vrh Observatory $7,500 to help support the completion of this very capable program.

David Dixon and the Jornada Observatory

David Dixon at the Jornada Observatory in Las Cruces, New Mexico operates two 0.3-meter telescopes in an astrometry program focused on the recovery and follow-up of NEOs. Dixon selects his asteroid quarry primarily from NEOs in need of priority observation coverage. (NEOs are relatively fast-moving objects, so if they are not quickly reobserved, they may be lost.) At Jornada Observatory, Dixon has labored to automate both telescope domes and to equip both telescopes with sensitive CCD cameras capable of observing very faint NEOs.

The Planetary Society has awarded Dixon $7,300, which he will add to his own funds to acquire a new large-format CCD camera. Used with Jornada Observatory telescopes, this camera will reach a limiting magnitude exceeding V = 21, allowing Dixon to detect and do astrometry on NEOs more than a million times fainter than can be seen with the naked eye—objects as faint as those being discovered by professional programs like the University of Arizona's Spacewatch.

One outcome of the Shoemaker NEO Grant award that Dixon did not foresee when he wrote his proposal was an immediate and related application being found for the medium-format CCD that will be replaced with the large-format CCD acquired with the grant. The medium-format CCD will find a home a few hundred yards away from Dixon's domes in an observatory operated by fellow amateur astronomers interested in pursuing their own NEO recovery program.

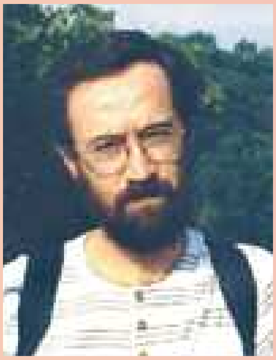
Jana Tichá and the Klet Observatory

Jana Tichá is the Director of the Klet Observatory in the Czech Republic. Tichá's team has been making astrometric follow-up observations of NEOs since 1994, when they started pursuing CCD observations for confirmation, follow-up, and recovery of NEOs using the observatory's 0.57-meter telescope. The Klet Observatory is a small professional institution, closely connected with the České Budějovice Observatory and Planetarium, that enables Tichá and her colleagues to present the NEO hazard and the results of their research to the Czech public. The Klet Observatory follow-up program, which has grown into one of the most prolific in the world, will soon become even more capable as it completes work on a new 1-meter telescope.

This large new telescope will allow Tichá to make confirmatory observations and position measurements on all but the very faintest NEOs now being discovered by programs such as the Lincoln Near Earth Asteroid Research program (LINEAR) and Spacewatch. The new telescope project was started in 1997 and has until now been able to make use of existing infrastructure at Klet Observatory: the observatory's older dome houses the new telescope, and the original mounting has been upgraded with an optoelectronic control system. Unfortunately, due to poor-quality optical glass, the first 1-meter mirror obtained for the project turned out to be unsuitable for the precise NEO observations planned by Tichá and her colleagues. The Klet Observatory and the regional government are providing the majority of the funding for a new mirror.

The Planetary Society has awarded Tichá $6,000 to help complete the entire optical system, mainly the optical cor-

rector, which will be built in the optical facility of the Charles University in Prague.



Tabaré Gallardo and OALM

Just over 19.3 kilometers (12 miles) north of Montevideo, the capital city of Uruguay, Tabaré Gallardo works on the staff of the Faculty of Sciences Department of Astronomy of the Los Molinos Astronomical Observatory (OALM). OALM, which depends financially on Uruguay's Ministry of Education and Culture, has operated since 1994 and has been mainly devoted to follow-up studies of asteroids and comets. The observatory's principal telescope is a 0.35-meter f/6.4 Cassegrain.

During each of the approximately 240 clear nights a year at OALM, an observer operates the telescope to attempt to locate objects listed on the Minor Planet Center's NEO Confirmation Page or to observe unusual asteroids or comets. Gallardo and his collaborators concentrate their efforts on objects in the southern skies, since northern objects are fairly well observed by observatories farther north. The OALM group has been quite productive, despite the fact that the only CCD camera available to it has been a comparatively old and finicky one with a bad shutter.

The Planetary Society has awarded Gallardo and OALM $5,000 to purchase a new CCD and filter wheel that will allow them to make position measurements and important color and lightcurve studies of many of the fainter NEOs now being discovered. Also, part of The Planetary Society's grant will be used to upgrade the electronics that assist in automating the acquisition of NEO targets and processing and analyzing the recorded data.

Cristóvão Jacques (far left) poses with his team (from left to right): Luiz Duczmal, Joao Ribeiro, Jose Duczmal, Giancarlo Nappi, Eduardo Pimentel, Nuno Cunha, and Carlos Magno.

Related URLs:

PIKA at the Črni Vrh Observatory
http://www.fiz.uni-lj.si/astro/comets/

Los Molinos Astronomical Observatory (OALM)
http://www.fisica.edu.uy/oalm/

The Klet Observatory
http://www.klet.cz

Jornada Observatory
http://www.cybermesa.com/~ddixon/

CEAMIG Observation Program
http://www.ceamig.hpg.com.br/en/coord/astrom.htm

Cristóvão Jacques and CEAMIG

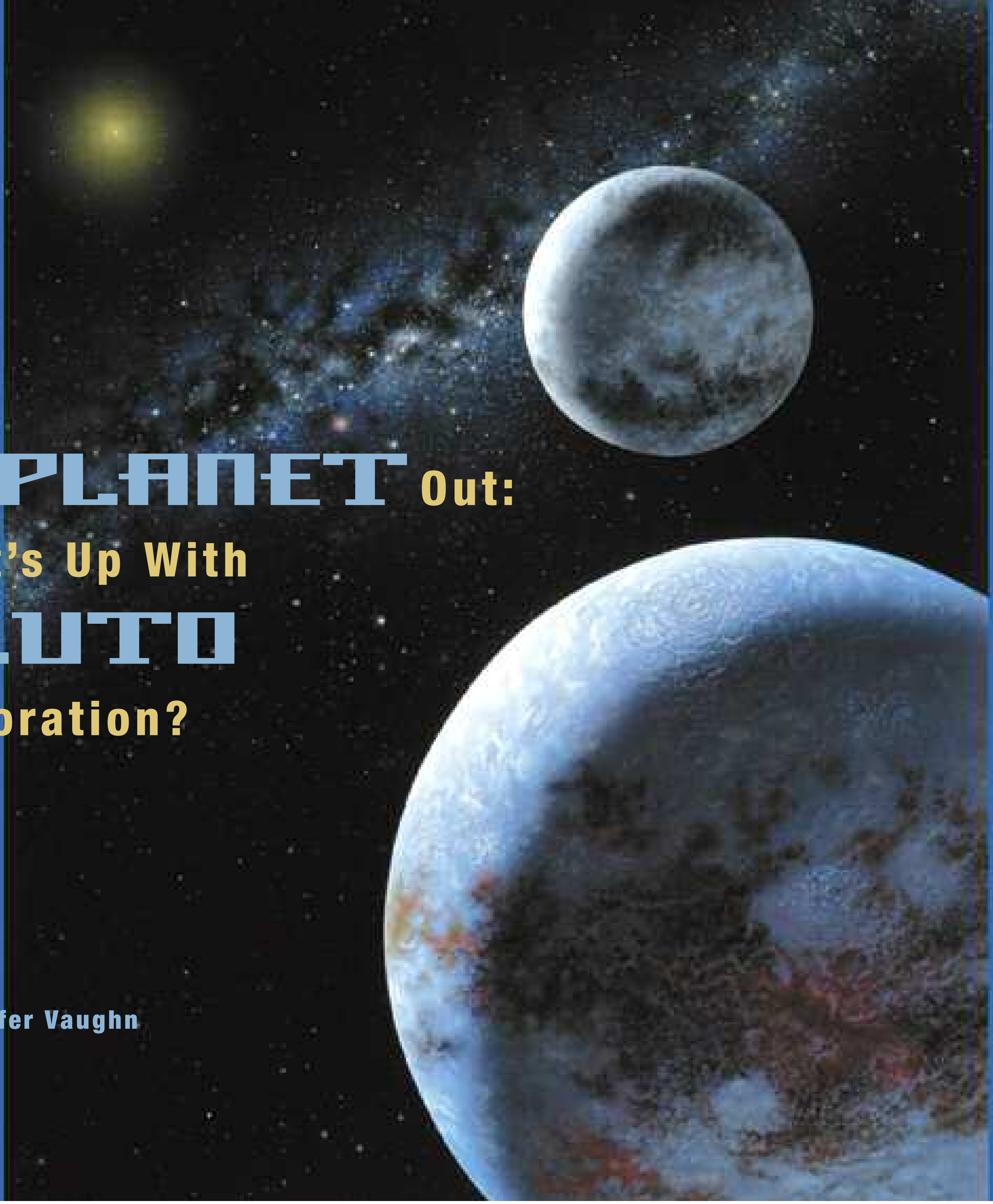
Cristóvão Jacques is the Scientific Director of the Centro de Estudos Astronomicos de Minas Gerais (CEAMIG) in Belo Horizonte, Brazil (just north of Rio de Janeiro). In 1998, CEAMIG inaugurated the Wykrota Observatory, and Jacques began exchanging e-mail with Paulo Holvorcem (one of last year's Shoemaker NEO Grant awardees) on how their group might begin to help observe NEOs. The dome of the Wykrota Observatory then housed a 0.3-meter f/10 Schmidt-Cassegrain telescope. With a CCD camera, CEAMIG began reporting its first preliminary asteroid position measurements to the Minor Planet Center.

In August 2000, the asteroid-observing capabilities of the CEAMIG group improved dramatically as its newly built 0.63-meter f/4 telescope saw first light. Now with two telescopes dedicated to follow-up studies of NEOs, Jacques asked The Planetary Society for funding to add to the observatory's CCD capabilities. This would allow faster-moving and fainter asteroids to be observed with the 0.63-meter telescope, while brighter and more easily observed objects could be tracked simultaneously with the 0.3-meter telescope.

The Planetary Society has awarded Jacques and CEAMIG $7,900 to purchase an additional, state-of-the-art CCD camera for the 0.3-meter telescope. Both telescopes will be operated in an autonomous mode, each observer choosing from a list of high-priority NEOs. When the larger, 0.3-meter telescope is not following up on already detected NEOs, it will be devoted to surveying regions of the southern sky for new discoveries, regions not observable by the big, professional surveys in the Northern Hemisphere.

With the awarding of its Shoemaker NEO Grants, The Planetary Society affirms its support of international cooperation in exploring our universe. From east to west, north to south, observers will be setting their sights on extraterrestrial travelers whose impact may alter the future of humankind. In the form of dues and donations translating to supplies and equipment, Society members join the round-the-globe vanguard of watchers of our skies.

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



Odd PLANET Out: What's Up With PLUTO Exploration?

by Jennifer Vaughn

Far from the Sun's illumination, tiny Pluto remains shrouded in mystery. Telescopes can show us only so much—even Hubble's far-reaching eye sees only a fuzzy round body in shades of gray.

In the hinterland of our solar system, Pluto follows a highly inclined orbit, more eccentric than that of any other planet in our solar system. In fact, although generally referred to as our ninth planet, Pluto regularly comes closer to the Sun than does Neptune.

To learn even the most basic information about this puzzling planet, we need to actually go there. Until that happens, we are literally in the dark about Pluto.

In 1989, *Voyager 2* encountered Neptune, making Pluto the last planet in our solar system unexplored by spacecraft. Sadly, 12 years later, Pluto remains unvisited, and plans for the long-awaited *Pluto-Kuiper Express* mission have been scrapped.

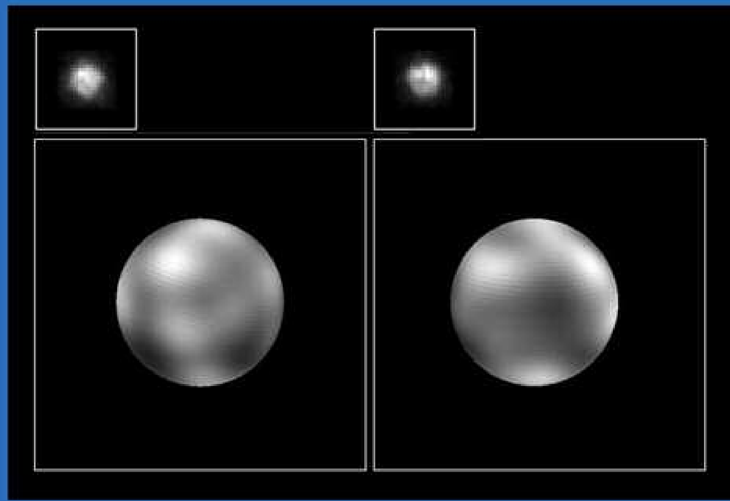
Mission: Red-Lighted

Ten years ago, in what would have been a logical conclusion to the reconnaissance of our solar system, work began on the *Pluto Fast Flyby*. The mission, originally meant to be a fleeting flyby of the planet, was soon redesigned to accommodate

Left: In the boondocks of our planetary community live a couple of oddballs named Pluto and Charon. These bodies are unusually close in size—Charon's diameter is just over half of Pluto's—and their eccentric orbit takes them an average distance of 40 astronomical units (AU) from the Sun. (An AU is equal to 150 million kilometers [93 million miles], or the distance between Earth and the Sun.)

Not much is known about this eccentric pair because so far all attempts to send a spacecraft have failed. But Planetary Society Members deluged Congress with requests to save the Pluto-Kuiper Express *mission, and NASA took notice. The space agency is now accepting proposals for a new mission to the last unexplored member of our solar system.*

Painting: ©1998 Lynette Cook



Right: Because its disk is too small to be resolved from this side of Earth's turbulent atmosphere, Pluto has appeared as nothing more than a point of light in even the largest ground-based telescopes. But these Hubble Space Telescope (HST) images, produced in blue light, reveal Pluto to be an unusually complex world with more large-scale contrast than any planet except our own.

The two smaller pictures of Pluto at the top of the frame were taken in June and July 1994 by the European Space Agency's Faint Object Camera aboard HST. Each pixel represents an area more than 161 kilometers (100 miles) across.

Computer image processing on the HST data produced the larger images at bottom depicting two opposite hemispheres of Pluto. Some variations across Pluto's surface may be topographic. But most surface features (including the northern polar cap) are likely produced by the complex distribution of frosts that migrate across the planet's surface with its orbital and seasonal cycles, or they are chemical by-products deposited out of Pluto's nitrogen-methane atmosphere.

Image: Alan Stern, Southwest Research Institute; Marc Buie, Lowell Observatory; NASA; and ESA

additional scientific instruments along with a probe to study Pluto's atmosphere.

With the redesign came a new name: *Pluto Express*. Then the mission—and its name—evolved yet again. Now dubbed the *Pluto-Kuiper Express*, it promised to be the first mission to study the planet's composition, surface features, flimsy atmosphere, and large moon, Charon, before traveling on to investigate smaller icy bodies in the Kuiper belt, a vast region of space encircling the Sun beyond Pluto.

Through its many redesigns, not to mention schedule setbacks and budget troubles, the mission managed to survive. Finally, launch was planned for December 2004 (the last opportunity for more than a decade to take advantage of a Jupiter gravity assist), with *Pluto-Kuiper Express* set to arrive at the outermost planet a decade later. Work continued, the spacecraft was on schedule, but then, rumors of impending cancellation surfaced.

It wasn't long before The Planetary Society got wind of these rumors. Then came the official word: NASA had issued the Jet Propulsion Laboratory a stop-work order on *Pluto-Kuiper Express*.

The Public Mobilizes

The Planetary Society promptly acted to rally public support for Pluto's exploration. Through an Internet and direct mail campaign, we urged members and other concerned individuals to inform their congressional representatives of their support for a mission to the planet.

Tens of thousands contacted their congresspersons via the Society's website, *planetary.org*. And, in a sign of grassroots support for the mission, 17-year-old Ted Nichols II started his own Web-based campaign at *www.plutomission.com* to save the *Pluto-Kuiper Express*.

All in all, The Planetary Society received more than 10,000 "Support the *Pluto-Kuiper Express*" postcards to send to Congress. Half were addressed to Representative Dana Rohrabacher, Chair of the House Space and Aeronautics Subcommittee, and half to Senator Bill Frist, Chair of the Senate Science, Technology & Space Subcommittee, in Washington, DC. All carried a single message: restore funding to the *Pluto-Kuiper Express* mission now! The postcards were sorted, bagged, and sent on their way to Capitol Hill, where Society President Louis Friedman and Board Member Bill Nye the Science Guy delivered them in person.

Pluto in 2015?

The Planetary Society's campaign demonstrated the public's support for completing the reconnaissance of all nine planets in our solar system, and although it is too early to claim victory, NASA heard the public outcry.

While not reinstating the actual *Pluto-Kuiper Express* mission, NASA is now seeking proposals from principal investigators and institutions worldwide to develop a new mission to Pluto, banking on competition to produce a favorable budget. While there are no restrictions on the launch date, there is a goal: to reach Pluto by 2015. There's also a budget cap of $500 million for the new mission. (*Pluto-Kuiper Express* had escalated to roughly $800 million.)

Proposals for the new Pluto mission are due in to NASA Headquarters by March 19, 2001. NASA, however, is not committing itself to approving any of them. If the agency does identify an appropriate candidate, the winning proposal will be announced by August 2001.

The proverbial runt of the litter, Pluto engenders doubt that it truly belongs to our solar system's family of planets. At this writing, the debate still rages whether or not to strip Pluto of its planethood and reclassify it as a trans-Neptunian object or possibly rename it "King of the Comets." What does this mean for the future of Pluto exploration? An official boot from planethood could justify NASA's rejection of sending a spacecraft to Pluto. On the other hand, the ongoing debate points out the need for a closer examination of this intriguing celestial object.

Jennifer Vaughn is managing editor of The Planetary Report.

As we go to press, President George W. Bush released his proposed fiscal year 2002 budget, which apparently lacks funds for a Pluto mission. The president's budget will still have to negotiate the congressional budget process before becoming final. The Planetary Society will be actively involved in that process. For developments, please check our website, *planetary.org*.

Questions and Answers

If a medium-size comet in a long-period orbit does not crash into anything, how long can it last?
—M. A. Merril Antoney,
Mattakkuliya, Sri Lanka

The length of time a comet can last is very poorly determined, but whatever it is will be strongly dependent on the comet's perihelion (distance from the Sun at closest passage). The nucleus of a comet that gets only as close to the Sun as the distance of Earth's orbit (one astronomical unit, or AU) will lose about a meter of ice per perihelion passage. This means that average-size cometary nuclei might last about a thousand perihelion passages.

We don't really know how long it takes for a comet to build up a crust able to seal in the ice, but again something like a thousand orbital periods is probably correct.
—MIKE A'HEARN,
University of Maryland

Some time ago, the Hubble Space Telescope (HST) produced a vague but interesting map of Pluto. (See the image on page 19 of this issue.) It occurred to me that mapping the asteroid Ceres—maybe even Pallas, Juno, and Vesta—should be comparatively simple too.

As far as I know, no one has done this yet. Why not? We have HST and all those 4- to 8-meter telescopes, and yet we still see these bodies only as dots. If it is possible to map the largest asteroids from Earth, shouldn't someone try?
—Sergey Borovik,
Didsbury, Manchester, England

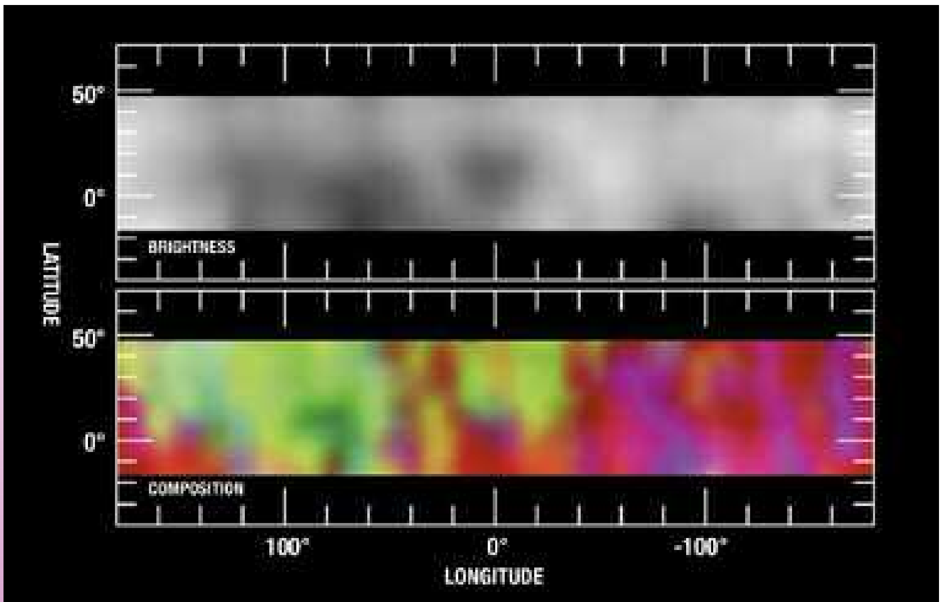
You are right, the Hubble Space Telescope is a fantastic imager and is indeed capable of making crude maps of large asteroids. Of course, those maps aren't as good as the ones spacecraft like *NEAR* and *Galileo* (and soon *Rosetta*) can make from their much closer perches. However, HST can reveal shapes and broad surface provinces and can search for everything from polar ice on Ceres to crater basins on Vesta.

By the way, an asteroid about 250 kilometers (155.4 miles) in diameter, 2.5 AU from Earth, would appear the same size to HST as Pluto does from 30 AU. Only four known asteroids (Ceres, Pallas, Vesta, and Hygiea) are estimated to have diameters that size or larger.

In the mid- and late 1990s, Joel Parker of the Southwest Research Institute and I, along with a handful of others around the country, used HST to map portions of Ceres. And a team led by Ben Zellner of Georgia Southern University, Richard Binzel of the Massachusetts Institute of Technolgy, and Peter Thomas of Cornell University made maps of Vesta (see image at left), revealing what appears to be a huge crater basin near the south pole.

A quick check of the HST data archive indicates that Juno, Pallas, and several other notable large asteroids have not yet been observed. Perhaps they will be soon, but to make that happen, researchers will need to write persuasive proposals in order to win the necessary observing time against the fierce competition to explore stars, galaxies, and other planetary objects in our solar system.

Late this year or early next year, NASA will launch a new camera to HST with revolutionary new capabilities. This instrument, called ACS (Advanced Camera for Surveys), may be just the spark to ignite interest in mapping more large asteroids with HST!
—ALAN STERN,
Southwest Research Institute



These two maps are derived from images of asteroid 4 Vesta taken by the Hubble Space Telescope between November 28 and December 1, 1994. They cover 322,000 square kilometers (125,000 square miles) of Vesta's 515-kilometer (320-mile) diameter. The surface brightness map on top indicates that, unlike those of most asteroids, Vesta's surface is significantly varied, with both a dark and a light hemisphere. Below that, the false-color surface composition map shows that all of Vesta's surface is igneous, meaning that either the entire surface was once melted or lava flowing from its interior once completely covered its surface. Scientists interpret the red and purple hemisphere to be composed of a basalt that forms when lava cools and solidifies below a planet's surface. Another basalt, formed when lava cools and hardens on a body's crust, is represented in the yellow and green areas. *Image: Ben Zellner and NASA*

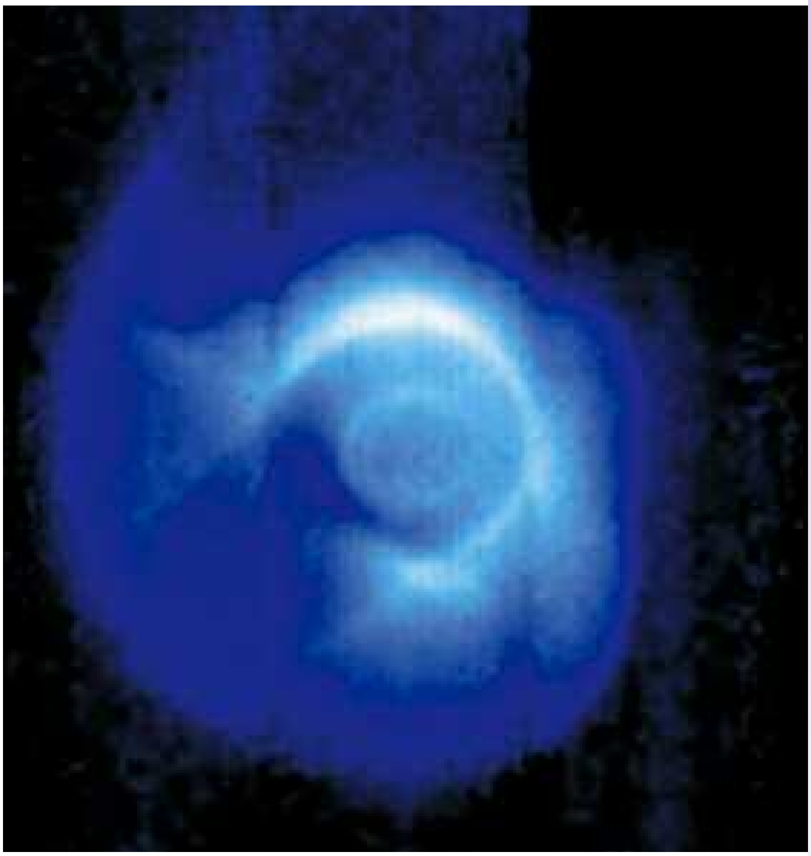
In the article "Scientific Results of the Mars Pathfinder Mission," (see the January/February 1999 issue of **The Planetary Report*****), author M. P. Golombek says, "During the mission the sky was a light yellowish-brown color." How much of the time was it yellowish brown, and why was it this color? I thought the Martian sky was a salmon-pink color.***
—Christopher J. Fry,
Fort Worth, Texas

Mars' sky has always been light yellowish brown due to the continuous presence of fine-grained (micron-size) dust in the atmosphere. A great deal of effort has been put into accurately calibrating the color of Mars using *Viking*, *Mars Pathfinder*, and Hubble Space Telescope images, and the results are all consistent. Mars is actually not red. It really is a light yellowish brown according to comparisons with standard color charts.

This hue is produced by the omnipresent dust, which appears to be a very fine-grained phase of hematite. So while Mars is not actually red in color, it is reddish, and a revision of its nickname, the Red Planet, is not warranted.
—M. P. GOLOMBEK,
Jet Propulsion Laboratory

Would it not be an interesting experiment to send along in a Mars mission the frozen carcass of a chicken, to be deposited in the warmest possible place on Martian soil and in view of a camera? If Martian bacteria exist, some sort of action should be evident in a matter of days or weeks, and this observed by a dedicated camera.
—E. Mike Loniello,
Madison, Wisconsin

The frozen chicken carcass will harbor bacteria from Earth. Given that a potential warm spot, warm enough to thaw the chicken, is identified, these Earthly bacteria will begin their work. Thus, it would be impossible to demonstrate with just a camera, and without a microscope, that the changes in the chicken were related to any possible Martian bacteria.
—ARNAULD NICOGOSSIAN,
NASA Headquarters



The ultraviolet glow from relatively cold plasma—the transparent, electrified gas trapped inside Earth's magnetic field—is depicted in this image captured by the Extreme Ultraviolet imager aboard NASA's IMAGE spacecraft. A hook-shaped "tail" of plasma streams toward the Sun at the top of the picture. The small, faint circle near the center of this image is the ultraviolet glow from Earth's aurora. *Image: NASA*

Factinos

Scientists recently announced they have found the most bizarre solar systems yet, raising new questions about what constitutes a planet, how planets interact, and how solar systems form in the first place. One of the systems is home to a body at least 17 (and possibly up to 40) times the mass of Jupiter—so large it stretches the notion of what a planet may be. "This is the 'whopper,'" said R. Paul Butler of the Carnegie Institute of Washington at the American Astronomical Society's January 2001 meeting. It is not known if the "whopper" is a very large planet, a very small brown dwarf, or something entirely new. "I call it a mystery object at this point," said Butler.

The other system contains two planets "humming in harmony" as they spin in orbits so synchronized that scientists compare them to nested Russian dolls. "Both planetary systems are unique and a bit frightening," said Geoffrey W. Marcy of the University of California, Berkeley, leader of the science team that's found about two-thirds of the 55 known extrasolar planets.

The two smaller planets were detected in a system around Gliese 876, a dim red dwarf star just 15 light-years from Earth. The inner planet orbits the star every 30 days, while the outer planet goes around every 60 days. The two planets gravitationally "shepherd" each other into synchronization, according to Berkeley team member Debra Fischer.
—from the *Los Angeles Times*

With simple, everyday chemicals, scientists from NASA Ames Research Center and the University of California, Santa Cruz have created, for the first time, "proto" cells. The researchers duplicated the harsh conditions of cold interstellar space and created primitive cells that mimic the membranous structures found in all living things. The scientists believe the molecules needed to make a cell's membrane, and thus necessary for life, are all over space. "This discovery implies that life could be everywhere in the universe," said the team's leader, Louis Allamandola. "This process happens all the time in the dense molecular clouds of space," he added.

These new findings suggest that the early chemical steps believed important for the origin of life do not require a ready-made planet. Instead they may take place in deep space long before planet formation occurs. This implies that outer space is filled with chemical compounds that, if they land in a friendly environment like Earth, could readily jump-start life.
—from NASA Ames Research Center

The first large-scale images of Earth's magnetosphere are now available (see image at left), including proof of a suspected but previously invisible "tail" of electrified gas. NASA's Imager for Magnetopause to Aurora Global Exploration (IMAGE) spacecraft took pictures of the tail, which streams from Earth toward the Sun.

It's difficult for any one spacecraft, or even a small fleet, to capture a coherent view of activity in this vast region, because the magnetosphere extends beyond the Moon on Earth's night side. "IMAGE is providing for the first time global views of the Earth's charged particle populations at multiple wavelengths and energies on time scales of a few minutes, which is sufficient to track the dynamics of the magnetosphere," said the project's Principal Investigator, James Burch of the Southwest Research Institute in San Antonio, Texas. Burch is the main author of a report on these findings, published in the January 26, 2001 issue of *Science*. —from NASA Headquarters

Society News

Red Rover Goes to Mars Student Scientists Make History

Nine international Student Scientists from the Planetary Society's Red Rover Goes to Mars Training Mission directed the Mars Orbiter Camera aboard the *Mars Global Surveyor* (*MGS*) Spacecraft on Monday, February 12, 2001. This makes them the first members of the public to operate an instrument aboard a NASA planetary exploration mission.

The students, ranging in age from10 to 16, traveled to Malin Space Science Systems in San Diego, California, where commands to the *MGS* spacecraft camera are generated. At Malin the students, who have conducted independent research about Mars since October 2000, met their fellow team members for the first time.

The first three pictures released to the press on Friday, February 16, 2001 showed areas of Mars the students selected as the most interesting imaged from the spacecraft's February 14 orbital path. Watching the data being downloaded from the spacecraft and converted to images, the students were among the first people on Earth to see these new views of Mars. One image revealed large dark boulders that are mystifying professional planetary scientists. All three images are now posted on our website, *planetary.org*, and will be featured in the next issue of *The Planetary Report*.

Images of the students' chosen landing sites for some future sample return mission will be taken when the orbit of *MGS* passes over these areas sometime in the coming months. The images will be released closer to the program's next event in October 2001, in conjunction with a significant announcement about the program.

The Society thanks our LEGO sponsor, Malin Space Science Systems, and, of course, NASA and the Jet Propulsion Laboratory for the *Mars Global Surveyor* mission.

—Linda Kelly, Education Manager

Red Rover, Red Rover Back Online

The Planetary Society's Red Rover, Red Rover website is back online. The hacker attack last spring hit Red Rover, Red Rover particularly hard, and we have had to totally rebuild our website and our Mars Base here at the Society. (Although the Mars Base has been active since the fall, the website has been restored only recently.) We have taken the opportunity to add a few features to the website. Check out the new site via the link from the main Society webpage, *planetary.org*.

We apologize for being unable to offer our online service to Red Rover, Red Rover team members during the period the site was down, and we encourage all team members to revisit the site and make sure their contact details are still valid. To log in initially, simply enter your Member ID number as both ID and password—you will then be prompted to check your details online. The Member ID can be found on the front cover of your Red Rover, Red Rover manual.

Welcome back! We would like very much to hear from you and to update you about your Red Rover, Red Rover activities. So please don't hesitate to contact us via the Web and send us pictures or URLs. For further information, contact us at our new e-mail address: *redrover@planetary.org*.

—Alan Pritchard, Technical Staff

Groundbreaking on New Optical SETI Observatory

In late December, groundbreaking began at the future site of an Optical SETI observatory, funded entirely by The Planetary Society. The new structure will house a brand-new optical telescope, to be used exclusively for optical SETI research. The site is at the Oak Ridge Observatory in Harvard, Massachusetts.

The leader of the project, Professor Paul Horowitz of Harvard, is a longtime associate of The Planetary Society and one of the world's leading SETI investigators. In addition to the new project, Horowitz and his team run two other Planetary Society-funded SETI ventures: Project BETA (Billion Channel Extraterrestrial Assay), which uses an 84-foot (25.6-meter) radio telescope to scan the skies for a radio signal from an intelligent source, and a targeted optical SETI project, which collects light discarded by an existing 61-inch (155-centimeter) telescope used for other purposes. All three projects are based at the Oak Ridge Observatory.

The start of observations, probably late in 2001, will mark the first time a large telescope in the US is used exclusively for optical SETI research. At 72 inches (183 centimeters), the telescope is large indeed: it is, in fact, the largest telescope in the US east of the Rockies.

The new project brings the total number of optical SETI projects funded by The Planetary Society to four. Two, based in UC Berkeley, are run by Dan Werthimer and Geoff Marcy, respectively, and two, based at Harvard, are run by Horowitz. The Society, which has pledged $350,000 to the new venture, is conducting a pledge drive to raise the necessary funds.

—Amir Alexander, Web Editor

A Global Celebration for Space on Yuri's Night

On April 12, 2001, it will be 40 years to the day since Yuri Gagarin made his historic launch and opened the era of human spaceflight. It will also be 20 years since the first Space Shuttle thundered into orbit from the Kennedy Space Center.

A worldwide initiative, Yuri's Night, is now being developed by a group of young people of the "space generation" (born after 1961). They plan to throw a global party on this day to celebrate space. The Planetary Society supports their initiative in creating a global celebration.

To be part of the celebration, visit the Yuri's Night website at *www.yurisnight.net*, or contact *alan@planetary.org*.

—AP

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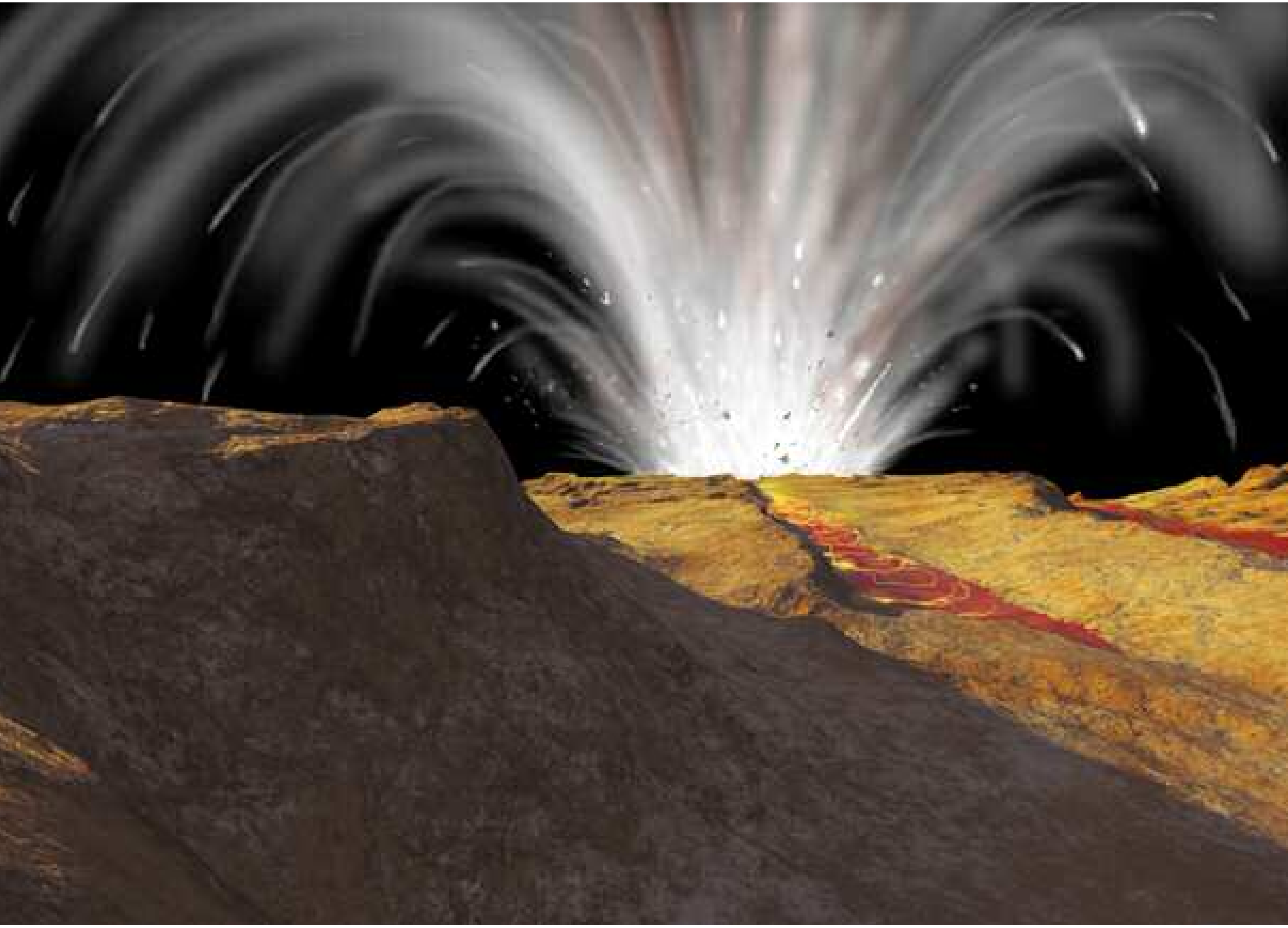

In *Io Volcano*, molten lava explodes onto the surface of Jupiter's innermost satellite. New images from *Galileo* and *Cassini* show Io to be so volcanically hyperactive that nearly its entire surface is likely to be lava in various stages of cooling. The extreme heat of the lava erupting on Io makes that world a model for the type of volcanism Earth experienced billions of years ago.

Ron Miller is an illustrator and writer who lives and works near Fredericksburg, Virginia. Some of his original paintings are currently on exhibit at the Norman Rockwell Museum in Stockbridge, Massachusetts and the Bruce Museum of Arts and Science in Greenwich, Connecticut.

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