The PLANETARY REPORT

Volume XX Number 2 March/April 2000

Optical SETI—At Last!

On the Cover:

Every day, it seems, our vision of the Milky Way is enhanced, our knowledge of it expanded. With optical SETI, the search for laser signals from other stars, we have a fresh strategy for attacking the cosmic question: are we alone in this vast place?

This view of Ara OB1, a star-forming region deep in the southern sky, was taken in April 1999 by the European Southern Observatory's 2.2-meter telescope in La Silla, Chile. This complex of bright and dark nebulae is located about 4,000 light-years from Earth in the constellation Ara (the Altar).

Image: European Southern Observatory

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Where do we go from here? The Planetary Society has invested so much time and resources into being part of NASA Mars missions that we have, admittedly, been set back on our heels by the failures, particularly that of the *Mars Polar Lander*, which carried our Mars Microphone. That loss is behind us, and we are already planning to build a new one for a future mission. More pressing is the question of what to do about Red Rover Goes to Mars, which would have enabled students from around the world to control the *Marie Curie* rover on the *Mars Surveyor 2001* lander. Then, what about our advocacy of NASA's Mars program, which was to have begun preparing to return a sample from that planet in the next few years? Executive Director Lou Friedman shares his thoughts about the future of Mars exploration and The Planetary Society.

8 Flash! Optical SETI Joins the Search

We've been listening for 18 years in The Planetary Society's SETI program for any signal from an extraterrestrial civilization. No luck yet, and we'll keep trying, but meanwhile we've decided to try another technique: looking for laser signals through optical telescopes. As you'll read, the idea for optical SETI appeared soon after the invention of the laser and came from the inventor himself. But the timing was bad. Radio SETI had already captured the imaginations of energetic young astronomers, and that search was on. Then, as in many things, technological advances changed the playing field, and optical SETI became a very, very attractive idea—so attractive that the Society is now funding new OSETI projects.

16 Imagining Mars: The Hollywood Version

At The Planetary Society, we seek to strengthen the hold of Mars on the public's imagination and so advance scientific exploration of the Red Planet. In turn, the 1997 success of *Mars Pathfinder* in stimulating the public's imagination and interest has influenced the mass media, especially in movie-making. In the next few months, two new films about expeditions to Mars will open. We do not review or endorse films in this magazine, but we can examine them for what they suggest about humanity's long fascination with Mars, past, present, and future.

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From The Editor

Well, I said it was hard. A few columns ago, just after the loss of *Mars Climate Orbiter*, I used this space to remind us all of what John F. Kennedy said while setting humanity on a course to the Moon: "We do these things because they are hard." Getting to Mars is proving him right, again.

While this issue is in the mail to you, the special NASA committee investigating the losses of *Mars Climate Orbiter* and *Polar Lander* will issue its report. This report will be doubly significant for The Planetary Society: our president, Bruce Murray, is serving as a special consultant to the committee, and our Red Rover Goes to Mars project was to be part of the *Mars Surveyor 2001* mission.

The entire future of planetary exploration depends on how we, members of The Planetary Society, and the rest of the space community react to the committee's findings. A harsh report could call into question the foundation of NASA's planetary program. It will undoubtedly call for major changes and perhaps a complete restructuring. And change, even for the good, can be hard and painful.

It will be up to us to demonstrate that even though it is *hard*, planetary exploration is worth the cost. To walk on another world, to search out new abodes for life—these accomplishments are within our reach, if we commit ourselves to doing what is hard. And we are willing to do it.

—Charlene M. Anderson

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Members' **Dialogue**

Faster. Cheaper. Better?

Louis Friedman's apologia for NASA's faster, cheaper, better policy misses or ignores two key points (see "Faster, Better, Cheaper Is Still the Way" in the January/February 2000 issue of *The Planetary Report*).

First, the real statement should be *cheaper*, faster, cheaper. (I don't know what "better" means in this context. It certainly doesn't mean more reliable.) The political reality, as Friedman states, requires "cheap" above all. What he doesn't touch is that we have a Congress and an administration that is, as usual, scientifically ill-informed and that believes in magic. In this case, magic equals success without quality control.

The second point is that cheaper *always* means poorer quality control, whether we are talking about assembly-line manufacturing, food processing, customer service, or aerospace. A number of observers, both inside and outside NASA and its contractors, have commented on the poor quality control.

A lot of that goes back to the bean-counter style of management mandated by a stingy Congress and administration, run exclusively by the Office of Management and Budget, and the need for NASA to pander to politicians who, in turn, must suck up to a scientifically uninformed electorate in order to stay in office.

Faster, better, cheaper may indeed be a justifiable approach, but the emphasis must be on *better*, faster, cheaper—in that order. Until "better" is defined, and "cheaper" is de-emphasized, Friedman will have to write more apologies for the policy—one for every few of the inevitable, and frequent, failures.

—K. A. BORISKIN,
Bellingham, Massachusetts

It would be unfortunate if the faster, cheaper, better philosophy that has revitalized planetary exploration were a casualty of the latest Mars failures. Instead, Daniel Goldin's vision should be realized by adapting an innovative process now being used by the Department of Defense (DoD). For many programs, the DoD establishes a broad "statement of objectives," then tasks government and industry teams to create the most cost-effective plan and the best technical approach to meet those objectives within the budget. This approach could be applied to the Mars program, if NASA adopted a statement of objectives such as the following:

1. NASA declares the exploration of Mars an important national scientific objective for which it will make an annual (inflation adjusted) investment of $300 million over the next 20 years.

2. NASA makes the Mars exploration program a partnership between itself, international space agencies, and the private sector to encourage broad industrial participation and the application of technologies from all sources.

3. Within budget limitations, NASA attempts to launch two dedicated missions plus as many micromissions as possible for each launch opportunity. Dedicated missions (that cost $150 million to $200 million) use a launch vehicle "dedicated" to a Mars flight; micromissions (of less than $50 million) are flown piggyback on commercial vehicles launched for other purposes.

4. NASA directs that these missions have four goals: (a) create the information infrastructure needed to return scientific data more efficiently; (b) evaluate alternative technologies and operations concepts to reduce the risk of future missions; (c) return a continuous stream of ever more valuable scientific data; (d) broaden international public participation, understanding, and support of Mars exploration.

5. NASA assigns JPL to perform the top-level mission architecture, system engineering, and technology evaluation work, with the detailed execution to be carried out by a number of international industrial teams, with independent oversight by a group of program management and technical experts from throughout NASA, DoD, academe, and industry.

This approach would get the program back on track towards successful and affordable Mars exploration.

—TOM HEINSHEIMER,
Rolling Hills, California

After 25 years as an engineering manager and vice president, I strongly disagree with NASA's directive of faster, better, cheaper. The problem with this approach is that it provides the wrong focus to the people designing and implementing. Quality must always be the prime directive—it is the fastest and cheapest way to the end result. If costs have to be cut, then one must review and improve methods and processes and create an environment of innovation to overcome the limitations in budgets.

While faster, better, cheaper may not be the only problem, it is definitely the wrong leadership directive and should be changed. My prediction is that future results will be only faster but not better and cheaper.

—JOSEF MADER,
Bend, Oregon

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THE PLANETARY SOCIETY PRESSES FORWARD

BY LOUIS D. FRIEDMAN

Cheaper, better, and more quickly than expected, The Planetary Society became a true part of the space program and flew to another world.

In the early 1990s, for the Russian *Mars '96* mission, the Society developed a CD library and an experiment on a microchip to collect data passively for whatever future explorers might recover it. But the spacecraft never made it out of the Earth's atmosphere.

Then in 1996, *Mars Pathfinder* launched, carrying the names of all Planetary Society members and a duplicate of our microchip experiment (unbeknownst to us until after the landing). These bits of the Society now reside on Mars on the Carl Sagan Memorial Station.

And last year, our Mars Microphone rode on the ill-fated *Mars Polar Lander* (*MPL*), and with *MPL* is now unheard from. Our microphone was the first privately sponsored instrument to fly to another world.

Members of The Planetary Society have always and loyally supported the innovations in exploration that we advocate. You have responded enthusiastically to projects that enhance our presence on other worlds. The Mars Microphone was built with your support. Now you are supporting Red Rover Goes to Mars—another first for citizens in space exploration. As you know, Red Rover Goes to Mars was scheduled to be part of the *Mars Surveyor 2001* mission.

But that spacecraft, now almost completed at Lockheed Martin in Denver, may not fly. The loss of *Mars Polar Lander*, its nearly identical twin, for unknown reasons has led NASA to consider canceling the mission. In the face of setbacks, we are forced to confront questions like "Is it worth the effort?" "Can we justify the cost?" "Will we ever fly again?" The answer to all those questions is "Yes!"

All our efforts in research and development, our team building to "make it happen," our navigation through the space-agency labyrinths to make the necessary arrangements are costly in time, energy, and money. Yet over and over again, through your enthusiastic support of our special appeals and projects, Society members have demonstrated that it is worth it all.

That is the most concrete evidence of your support, but there are other indications. Recently I looked at the Members' Galaxy section of our website, **planetary.org**. There I found another part of your answer. In the postings there, and in much of the mail we've received since *MPL* vanished, we find wonderful encouragement to keep trying.

At Planetfest '99, we found great cause to go on—even as we realized that the spacecraft had failed, attendees shouted encouragement, not just to us but to the people from NASA and the Jet Propulsion Laboratory who were there as well.

So, with your help, the Mars Microphone will fly again. Despite its loss, the first microphone brought us enormous attention, and everyone, including mission teams and people around the world, complimented The Planetary Society on our efforts to get such an imaginative device to Mars. Our team, which includes researchers at the University of California, Berkeley and the Russian Institute for Space Research, is looking at future lander plans.

Red Rover Goes to Mars promises to be even more involving as we seek new opportunities to put students at the controls on a real space-science mission. The LEGO Company has pledged its continued involvement even if the 2001 lander mission is delayed. We are also working with Malin Space Science Systems to give students a chance, in the event the 2001 mission

THE FUTURE OF MARS EXPLORATION

BY DANIEL S. GOLDIN

Last year, I was invited to join the president of Romania at the Romanian National Observatory to view the solar eclipse. I wanted to see my first-ever total eclipse, but my enthusiasm was purely intellectual.

Then it began. Right before my eyes, the sky grew darker and darker. I could see Venus in the middle of the afternoon. And the air grew noticeably cooler. The temperature dropped 15 degrees in a matter of minutes.

My intellectual curiosity quickly gave way to open-mouthed awe as I watched the incredible forces of Nature at work. And at the height of the eclipse, I looked upward and thought to myself, "A window has opened up on the heavens."

That window to the heavens is what the space program is all about. We at NASA want to jump through that open window on our way to Mars and beyond.

We are rapidly moving toward a day when humans will establish a permanent presence on Mars. Already, we have gathered amazing data from missions like *Mars Pathfinder*, the *Sojourner* rover, and *Mars Global Surveyor*.

More recently, we have had two setbacks in our Mars program. We at NASA know that having big dreams means taking big risks, and we are learning everything we can to make our dreams of Mars come true.

Two years from now we will send another craft, which will test our air purification and storage systems by converting Martian carbon dioxide to breathable air and storing it in bottles. Another mission will measure and analyze surface dust, winds, and weather conditions.

We have four more missions planned after that for 2003 and 2005. →

Opposite page: On July 7, 1980, Viking 1 *gathered the images that make up this global mosaic featuring the Hellas area of Mars. At that time, it was late northern summer on Mars. The bright white region near the bottom of the image is carbon dioxide frost in the Hellas impact basin, which is about 2,000 kilometers (1,200 miles) in diameter. The large, yellowish region at the top is Martian Arabia.*

The mosaic covers the region from latitude –70 degrees to 50 degrees and longitude 260 degrees to 360 degrees, showing the planet as it would be seen from some distance out in space. The color variations have been enhanced, and the resolution is 1 kilometer (0.6 miles) per pixel. Image: NASA/USGS

Left: A Mars hopper such as the one envisioned by space artist Pat Rawlings could be a way for humans to maneuver through Mars' diverse landscape. Here Rawlings depicts a hopper hovering over the layered terrain of a deep canyon.

Painting: Pat Rawlings

These will collect more than 90 surface samples and deploy rover robots for further mapping and analysis.

This is just the beginning of our leap through that window, the beginning of our Martian odyssey. Once we learn about what is really on Mars' surface, we will begin to develop robot colonies. These robots will rely on self-coding and self-correcting hardware, giving them human-like capabilities.

We expect these robots to demonstrate group characteristics. They will interact with each other, choose leaders, display and respond to emotions, and protect themselves and the colony. These intelligent robots will build the infrastructure on Mars to support human life—storage tanks for breathable air and drinkable water, habitation facilities, transportation systems, power plants, and health care facilities.

When the robot missions are completed, we will send humans to Mars to live, work, conduct science experiments, and develop the infrastructure necessary to launch humankind ever deeper into the cosmos.

In many ways, the campaign we are waging on Mars is similar to a military campaign.

Both endeavors require similar infrastructure—navigation systems; ground and atmospheric surveillance and monitoring; advanced engineering and communications systems; and water, food, and supplies for our personnel.

The operation is somewhat like naval and air fleets going across an ocean, building a dock or a runway, and setting up a living, working city on the other side of the sea.

In this case, though, the other side of the sea is millions of miles from Earth, so the challenges are daunting.

We need a novel approach to reach our goal. NASA's budget is not likely to spike up as it did during *Apollo*. During that era, NASA's budget was 5 percent of total federal spending. Today, we are less than one percent.

So we're doing more with less, yet the NASA team continues to do amazing things.

To meet these challenges—to ensure a human presence on Mars—we need a technological revolution. Maybe that means developing biologically inspired technologies. Maybe it means exploiting the advantages of nanotechnology. Or maybe it will take technologies we don't even dream of today.

Opening the space frontier is a lofty and worthy goal, and it is inherently risky, as we have all been recently reminded. But we must learn from the bitter lessons of our setbacks as well as the sweet lessons of our successes if we ever hope to send humans to Mars.

That's why NASA is committed to learning all we can from every Mars mission and to moving forward in exploration of the Red Planet.

We are heeding the lesson of Georges Danton, a leader of the French Revolution: "In order to conquer, what we need is to dare, still to dare, and always to dare."

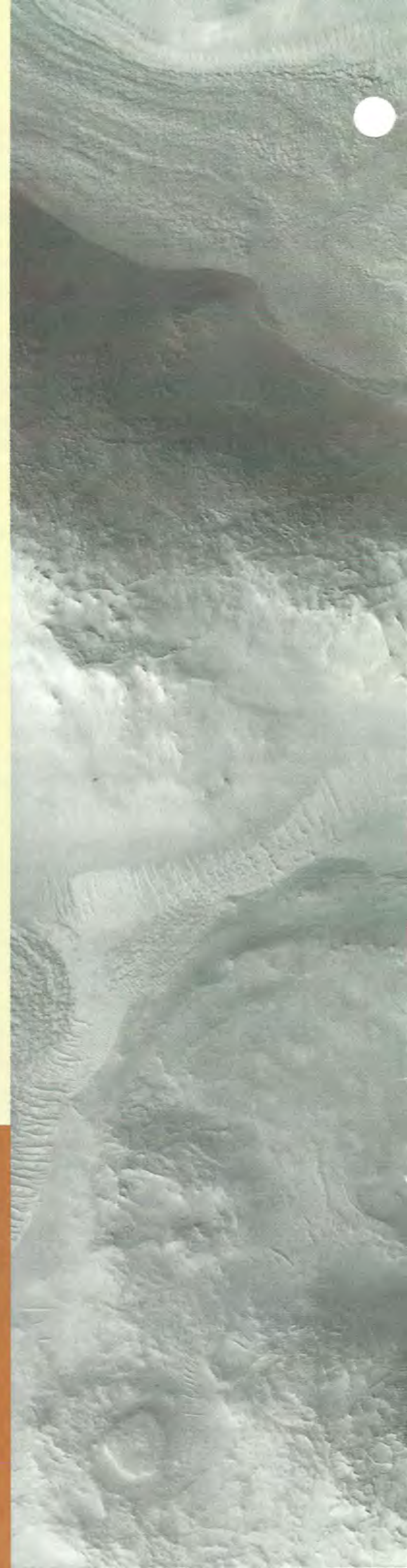
NASA will continue to dare to do great things. It's the only way we will ever jump through that window to the heavens on the way to Mars and beyond.

As NASA Administrator, Daniel S. Goldin is in charge of US space-exploration programs.

is delayed, to use the *Mars Global Surveyor*'s Mars Orbital Camera in training activities.

While we do not have any commitments yet, I am confident that microphones will fly on future missions and that students will participate in the control of a Mars rover and conduct experiments on the Martian surface, and The Planetary Society will continue to play an important role in making these things happen.

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



As the clock rolled over to 2000 AD here on Earth, the Mars Global Surveyor *Mars Orbiter Camera (MOC) was busily snapping its daily global weather maps and high-resolution images. The MOC began taking pictures from orbit in September 1997. Its primary mission will end in January 2001, although NASA is considering an extended mission allowing the camera to continue its activities well into 2002 or beyond. This image, taken on January 1, 2000, is one of the first high-resolution views of Mars from the MOC. The image captures a region of the northern hemisphere among the mesas and buttes of the Nilosyrtis Mensae, around 33 degrees North, 297 degrees West. Small, bright, windblown drifts and a wide variety of surface textures in this image seem to be caused mainly by unknown, perhaps uniquely Martian, geologic processes. The image covers an area 3 kilometers (1.9 miles) across at a resolution of 4.5 meters per pixel, and the Sun illuminates the scene from the lower left.*

Image: Malin Space Science Systems/NASA

World Watch

by Louis D. Friedman

Special Mars Update Edition

Paris—The European Space Agency (ESA) has now officially approved the *Mars Express*. This orbiter mission, carrying a British lander, *Beagle 2*, will launch in June 2003 and arrive at Mars in December 2003. The mission's main objective is to search for subsurface water. According to ESA, "Europe has waited a long time for the opportunity to mount its own mission to Mars, and that dream is about to become reality."

The orbiter will carry a science payload of seven instruments (some of them duplicates of instruments lost on *Mars '96*), including a stereoscopic imager from Germany, an infrared spectrometer from France, and a radar sounder from Italy, in which the US is participating. The orbiter will also serve as a radio relay for the *Beagle 2* and, perhaps, for international Mars Sample Return missions being planned for 2003 to 2007.

The *Beagle 2* lander, developed and built at the Open University in the United Kingdom (UK) under the direction of Colin Pillinger, will use an airbag landing system, similar to that of *Mars Pathfinder*. After bouncing to a stop, the lander will open like a clamshell to deploy solar panels and instruments.

Beagle 2 has a robotic arm with a drill attachment to obtain samples from within pristine rock. It will also carry a "mole" that will traverse the surface (by "hopping") until it hits a boulder. The mole will then burrow down at least one meter beneath the boulder, where there should be more pristine material, to collect a soil sample, which will then be heated and analyzed in situ.

ESA hopes that *Mars Express* will demonstrate the agency's ability to do missions "faster, better, cheaper" and more flexibly. The orbiter is making extensive use of already developed spacecraft systems. It was proposed as an addition to an existing space-science mission plan because it could be done quickly at relatively low cost. *Beagle 2*'s funding was uncertain for a long time, because ESA is not paying for it. A novel combination of UK government funding and private funds is enabling its development.

Moscow—Despite curtailed government funding in Russia for space exploration, industry and science groups are studying the design of a human Mars mission for sometime in the next 20 years. Leonid Gorshkov, a principal engineer in International Space Station development, is heading up the study. Gorshkov shared his ideas about this human Mars mission in the November/December 1988 *Planetary Report*.

The study is being coordinated with European space engineers and, to a lesser extent, with NASA. The Planetary Society co-sponsored a meeting in Moscow for study participants and is planning another meeting this year.

Washington, DC—After eight years of declining NASA budgets, the Clinton administration has proposed a significant boost in spending for fiscal year (FY) 2001. The NASA budget sent to Congress asks for a little over $14 billion, an increase, after adjustment for inflation, of 3.1 percent.

Notably, proposed funding for space science increased by about $200 million from the current $2.2 billion. Over the next five years, the administration projects a 63 percent increase in funding for space science to $3.6 billion. By comparison, NASA's overall budget is projected to increase about 14 percent over the same period. Much of the growth is due to declining costs for the space station, for which about 85 percent of the hardware has been completed. Funding for the station dropped from $2.3 billion in 2000 to $2.1 billion in 2001. This projection assumes no major problems in the station and no new initiatives in human spaceflight.

Despite, or because of, the losses of three Mars missions last year—*Mars Climate Orbiter, Mars Polar Lander*, and *Deep Space 2*—the Clinton administration is asking for an increase of $78 million for the Mars program, including initiation of a Mars telecommunications satellite network. The network was assigned to the Goddard Space Flight Center, which has experience managing the Tracking and Data Relay Satellite System (TDRSS).

We strongly support this year's planned increases, but they are by no means certain. Congress has to act on the budget, and we have begun to hear from congressional staff that some in Congress want to keep spending at the current level plus inflation. This formula, when applied in the congressional budget process, would lead inevitably to program cuts. For the latest information, be sure to watch our website.

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

The Mars Program Independent Assessment Team and other review boards looking at recent Mars mission failures are making recommendations about what to do in the Mars program and are scheduled to make their report public by March 15, 2000. Check our website for details: **http//planetary.org**.

FLASH! OPTICAL SETI JOINS THE SEARCH

by Paul Horowitz

The Planetary Society has been a major force in SETI—the Search for Extraterrestrial Intelligence—going back at least to 1981, when it co-sponsored the Suitcase SETI project, which packed 131,072 channels (incredible for then!) of digital spectrum analyzer into a package not much larger than a set of fancy matched luggage for two (see "SETI and The Planetary Society," *The Planetary Report*, January/February 1986).

Since that time the Society has joined in funding the follow-on META and BETA searches at Harvard-Smithsonian (millions and billions of channels, respectively); the META II search in Argentina; and the University of California, Berkeley SERENDIP projects at Arecibo in Puerto Rico. The Society is a major sponsor of SETI@home, which has energized more than a million intelligent creatures on this world to analyze the SERENDIP-IV data for evidence of intelligent creatures on another world.

Each of these projects represented a major advance over previous searches; the most recent are, literally, billions of times more powerful than Frank Drake's pioneering project Ozma of 1960. Yet all of them have been searches for *radio* transmissions, using existing large radio-telescope antennas to collect the faint signals that would reach Earth.

In an exciting recent development, The Planetary Society has expanded its SETI program to include searches for *optical* signals, now using existing optical telescopes to seek laser signals from advanced civilizations. The rationale is sound, and really interesting. The possibility of interstellar communication via microwaves—that is, radio waves of very high frequency, in the region of gigahertz (billions of cycles per second)—was suggested 40 years ago by Cocconi and Morrison in their famous paper, "Searching for Interstellar Communications" (*Nature*, 184, 844, 1959). At that time, we did not have lasers.

But within a year, Schawlow and Townes achieved the Nobel Prize-winning invention of the laser, and the very next year there was published the first suggestion of laser SETI: "Interstellar and Interplanetary Communication by Optical Masers" (*Nature*, 190, 205, 1961). At that time, lasers were new, tricky, low-power devices; by contrast, radio technology had been developing for decades and was relatively mature. Perhaps that is why most searches for signals from advanced civilizations have been carried out in the microwave region of the spectrum, most commonly at the special emission frequency (1.4 gigahertz) of neutral atomic hydrogen—the most abundant atom in the universe—the so-called "21-centimeter line." The rapid development of laser technology since that time, along with the discovery of many other microwave lines of astronomical interest, has lessened somewhat the allure of hydrogen-line SETI. Indeed, here on Earth the exploitation of photonics has revolutionized communications technology, with high-capacity fibers replacing both copper cable and the long-haul repeater chains of microwave towers.

Furthermore, calculations and observations show that the galaxy is not kind to gigahertz radio waves; in particular, the ionized hydrogen in the interstellar medium causes "dispersion,"

We now know for sure that there are planets around other stars in the Milky Way. Optical SETI provides us with another tool to search for signals from intelligent life on such planets. This panorama of the Milky Way shows some of the most complex areas of the galactic plane visible from Earth's northern hemisphere. It covers about 90 degrees of sky along our galaxy's equator. The colors you see here are exaggerated to show the differences in light and dark structures.

Panorama: © John P. Gleason, Celestial Images

a smearing out in time that degrades transmitted signals. At this stage of Earth's scientific development, it is not at all clear from technical considerations alone whether an advanced civilization would prefer radio or optical methods to communicate between stars. Although current thinking generally favors microwave (radio) transmissions, there are some important advantages in favor of optical (laser) communications.

First, transmitted beams from optical telescopes are far more slender than their radio counterparts, owing to the high gain of optical telescopes—for example, 10^{15} (150 dB) for the Keck Telescope versus 10^{7} (70 dB) for Arecibo amounts to a relative factor of 100 million in favor of the optical Keck Telescope, which is nothing to sneeze at!

Second, dispersion, which broadens radio pulses, is completely negligible at optical frequencies.

Third, the capability of radio transmitters has reached a stable maturity, while the power of optical lasers has shown an annual Moore's-law doubling over the past 30 years.

And, finally, the computational power and sophistication of microwave searches today is unnecessary for optical SETI. Optical detection can be quite simple—all you need is a pair of fast photon-counting detectors in coincidence.

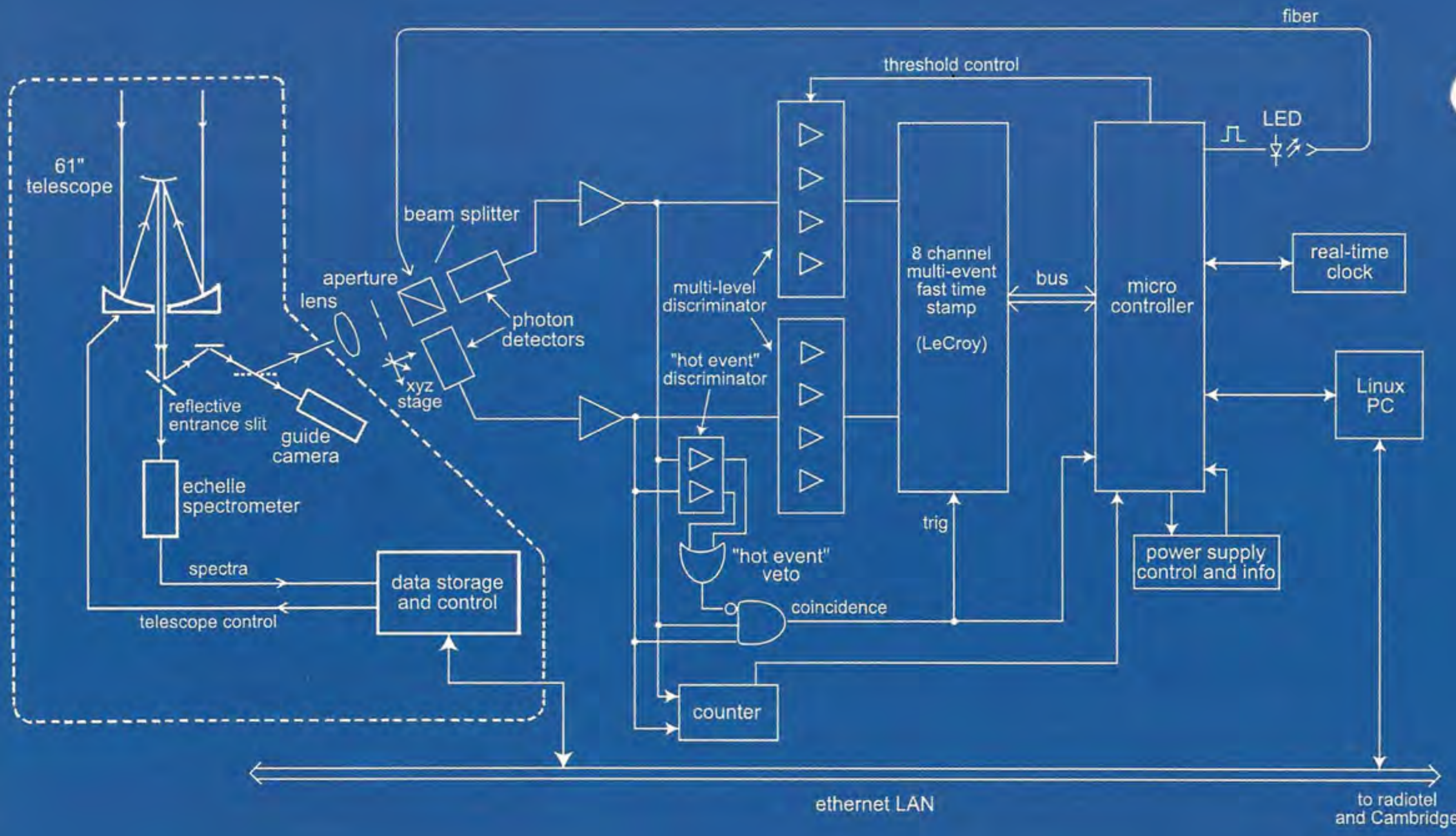
Arguments like these were cogently assembled by Townes in a beautiful article nearly 20 years ago ("At What Wavelength Should We Search for Signals from Extraterrestrial Intelligence?" *Proceedings of the National Academy of Sciences*, 80, 1147, 1983), in which he concluded that optical methods are comparable, or perhaps slightly preferred, if what you care about is maximizing the ratio of received signal to background noise, for a given transmitter power.

As laser technology has matured, the SETI community has begun to listen to Townes and other optical SETI pioneers, such as Betz, Kingsley, Rather, Ross, Schwartz, and Shvartsman. A series of workshops conducted by the SETI Institute encouraged researchers to take a fresh look at SETI strategies, both radio and optical. From these workshops arose the optical SETI projects at Harvard-Smithsonian and at Berkeley, sponsored jointly by The Planetary Society and the SETI Institute.

Laser Beacon Scenario

What should we be looking for? Lasers can transmit short pulses, continuous beams, or anything in between. They can be modulated. And they can operate at wavelengths from ultraviolet to infrared. Although we have no current interest in *transmitting*, a good way to choose among search alternatives is to imagine plausible scenarios of optical transmitters and corresponding detection schemes. It was just these sorts of *gedanken* (thought) experiments, after all, that led to the now-legendary Cocconi and Morrison paper of 1959.

To be conservative, let's assume for the moment that a transmitting civilization has nothing better than "Earth 2000" technology—the lasers and other optical hardware that we have now, or soon will. Our technology already can produce



The optical SETI experiment at Harvard-Smithsonian rides piggyback on an existing spectroscopic search for unseen stellar companions (dashed outline). A flash of light picked up simultaneously in the pair of detectors triggers a burst of activity, logging the intensity of the flash at sub-nanosecond timescales. The data are quickly sent to a PC, where they enter a searchable database; the PC also sends us e-mail the next morning! Illustration: Paul Horowitz

continuous million-watt laser beams, and very short pulses of 10^{15} watts (a million billion watts, roughly a thousand times greater than the total instantaneous output of all electric power plants on Earth).

A large optical telescope like the 10-meter Keck, used like a searchlight mirror, could direct a laser beam efficiently. Let's imagine ourselves in the transmitting role, pointing such a laser transmitter toward another star system and firing a single, nanosecond-long flash of light.

So the question is: what would such a laser pulse look like when it reaches a distant civilization that we have targeted with its slender beam? Of course, they would see a hefty background of light from our Sun, so we hope that the laser light is strong enough to be seen against its dazzle.

The answer is surprising: our laser transmitter would easily outshine the light from our Sun. In fact, during its brief pulse, and in the direction of its slender beam, *it would appear about 5,000 times brighter than the background light from our Sun!*

This stunning fact is independent of distance, since both laser light and sunlight diminish at the same rate (inverse square) with distance. And it is free of any assumption that the receiving civilization knows, or has to guess, the laser's wavelength; the disproportion of signal to starlight will show up in any search that uses a broadband, "white light" detector—for example, a simple photomultiplier or photodiode.

Now, we must not forget that *advanced* civilizations are supposed to be more advanced than we are! "Earth 2000" should be a lower limit on the technical sophistication of extraterrestrial civilizations. Extrapolating another two to three orders of magnitude in delivered flux (which can hardly be considered daring given the Moore's-law pace of the optical laser industry), we conclude that a moderately advanced civilization should have no trouble outshining its parent star by six or more orders of magnitude.

Strategies for Receiving

How would one use a laser transmitter to establish contact? In other words, what should we be searching for? In one scenario, such a pulsed laser could be used to target one star after another, aiming and firing at perhaps 100 targets per second. At that rate the sending civilization could hit all Sun-like stars within 100 light-years in 10 seconds. For complete coverage out to 1,000 light-years (within which there are roughly a million Sun-like stars), they might deploy a network of a hundred such laser transmitters, which would complete the target list in 2 minutes. Of course, when they finished, they would do it again repeatedly, forever (we hope).

One might imagine the advanced civilizations in our galaxy agreeing to divide up the task, each illuminating its immediate neighbors, so that every star potentially harboring life would be on some civilization's list. Then, to one of the targeted stars (that's *us*!), the sending civilization would appear as a star that's flashing periodically—in nanosecond pulses, for example—with a brightness far exceeding the average brightness of that star.

Assuming a strategy like this for transmitting, our complementary search strategy would be to look successively at all nearby stars (perhaps of plausible spectral class), dwelling at least a few minutes on each. One of them will reward our efforts by exhibiting laser pulses of astounding intensity. And the team that discovers that signal will have made the greatest discovery in the history of humankind.

This is just one of many scenarios that is easy, and fun, to imagine. In the SETI Institute workshops, the optical SETI team (led by Dan Werthimer) explored various possible transmitting strategies, including pulses and continuous beams, and particular choices of wavelength. We concluded that the time is right for an initial search for pulsed laser beacons, in addition to some limited "data mining" from the high-resolution spectra that have come from the recent (and very successful) planet searches. It is important to realize that the kinds of laser signals we have been talking about would not have been detected by any previous astronomical observations.

The Harvard-Smithsonian Search

We have built a system to detect a pulsed-laser signal, using a relatively simple high-speed optical detector, at Harvard's 61-inch optical telescope. This telescope, located at the same site as the 84-foot radio telescope used for The Planetary Society's BETA search, is currently engaged in a continuing radial-velocity survey of 2,500 nearby solar-type stars, conducted by David Latham and Robert Stefanik.

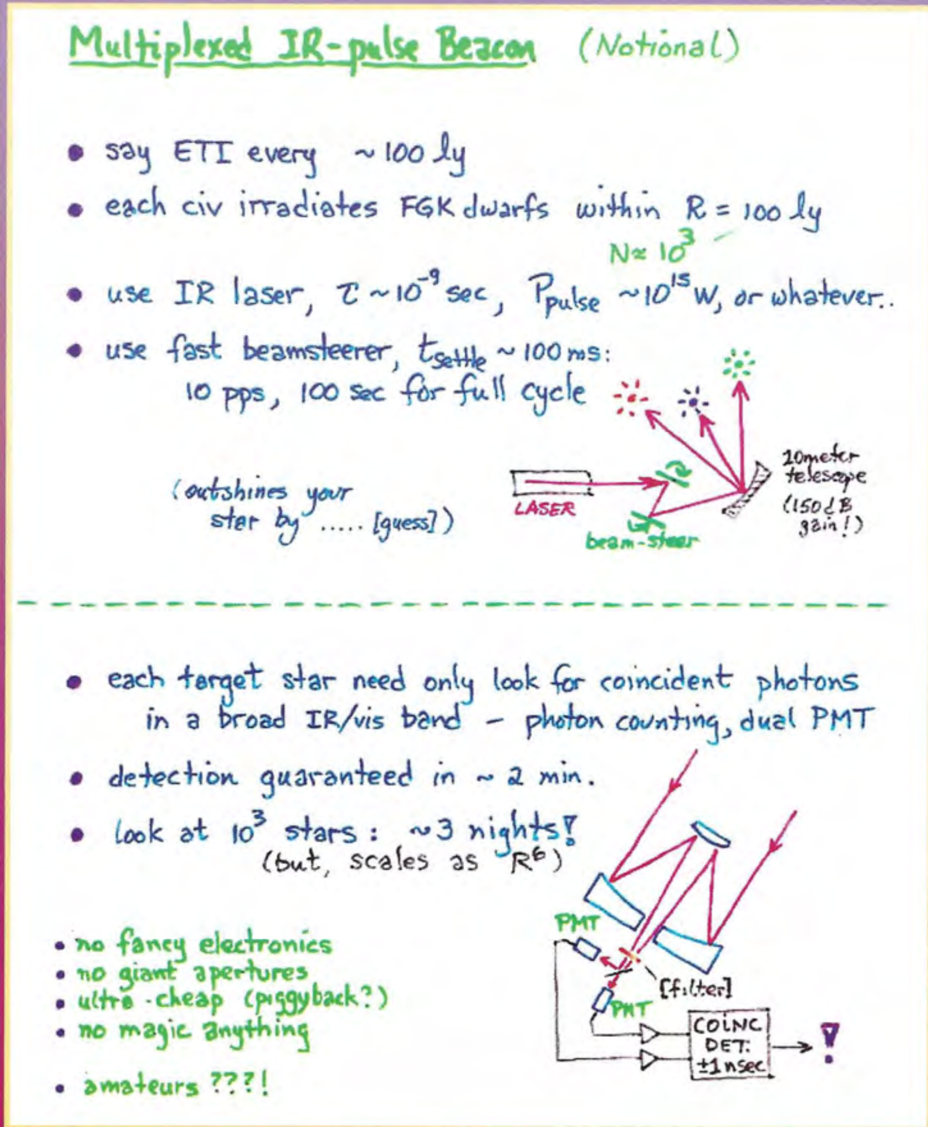
The optical SETI detector piggybacks on their experiment, working with the portion of incoming starlight that cannot be used by their echelle spectrograph. The block diagram [on page 10] shows how our system works. We extract a beam containing approximately one-third of the full focused-beam intensity from the 61-inch telescope.

After some preliminary observations, Dan Werthimer found it was necessary to use a beam splitter and a pair of fast photodetectors in "coincidence" as a means to reject occasional "hot events" that occur, without provocation, in today's fast photodetectors. These hot events look just like the laser pulses we seek (for the technically minded, they arise from internal pathologies such as positive ion "afterpulses," glass scintillation from both radioactive potassium decay and electron impacts, and flashes induced by cosmic-ray muons). With the two-detector setup, the camera almost never (well, hardly ever) sees a flash.

When the paired detectors *do* respond simultaneously,

(continued on page 14)

A spiral galaxy metamorphoses into DNA, the twisted ribbon that defines who and what we are. Chemical structures and chromosomes float around its familiar double helix, all symbolizing the life that SETI searchers hope to find. Painting: © Lynette R. Cook



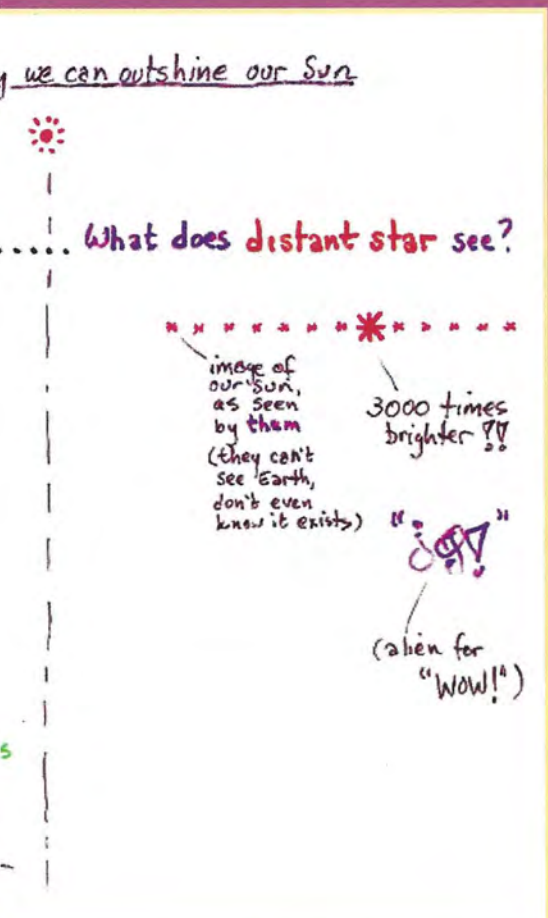
We drew this slide originally to show a plausible scenario for optical SETI to a group of technically savvy scientists. It shows a transmitting strategy (top half) with a complementary receiving strategy (bottom half). The idea is that each sending civilization fires laser pulses successively at all the Sun-like stars ("FGK dwarfs") out to some maximum range (roughly, the distance to the next laser sender; in this case we picked an optimistic 100 light-years). The laser sends a nanosecond flash to each of the 1,000 stars, hitting 10 stars per second (that's why the steering mirrors have to "settle" to the right position in 100 milliseconds); at this rate it takes just 100 seconds to finish the job. The system would repeat this cycle indefinitely. The slide coyly asks you to guess how bright the flash appears (we didn't want the slide to steal our oratorical thunder!). The right answer is about 5,000 times brighter than the star itself.

A searching civilization like ourselves would look at nearby stars for occasional (and repetitive) bright flashes. Under this particular scenario, we would receive our first flash within two minutes, when we looked at the right star; in a few nights we could check out all 1,000 possible stars. It's a simple search, far simpler than the sophisticated microwave searches we and others have been doing. It might even be accessible to amateur astronomers; jaded by the boredom of observing variable stars night after night, they might embrace eagerly a chance in a million of making the greatest discovery, ever!

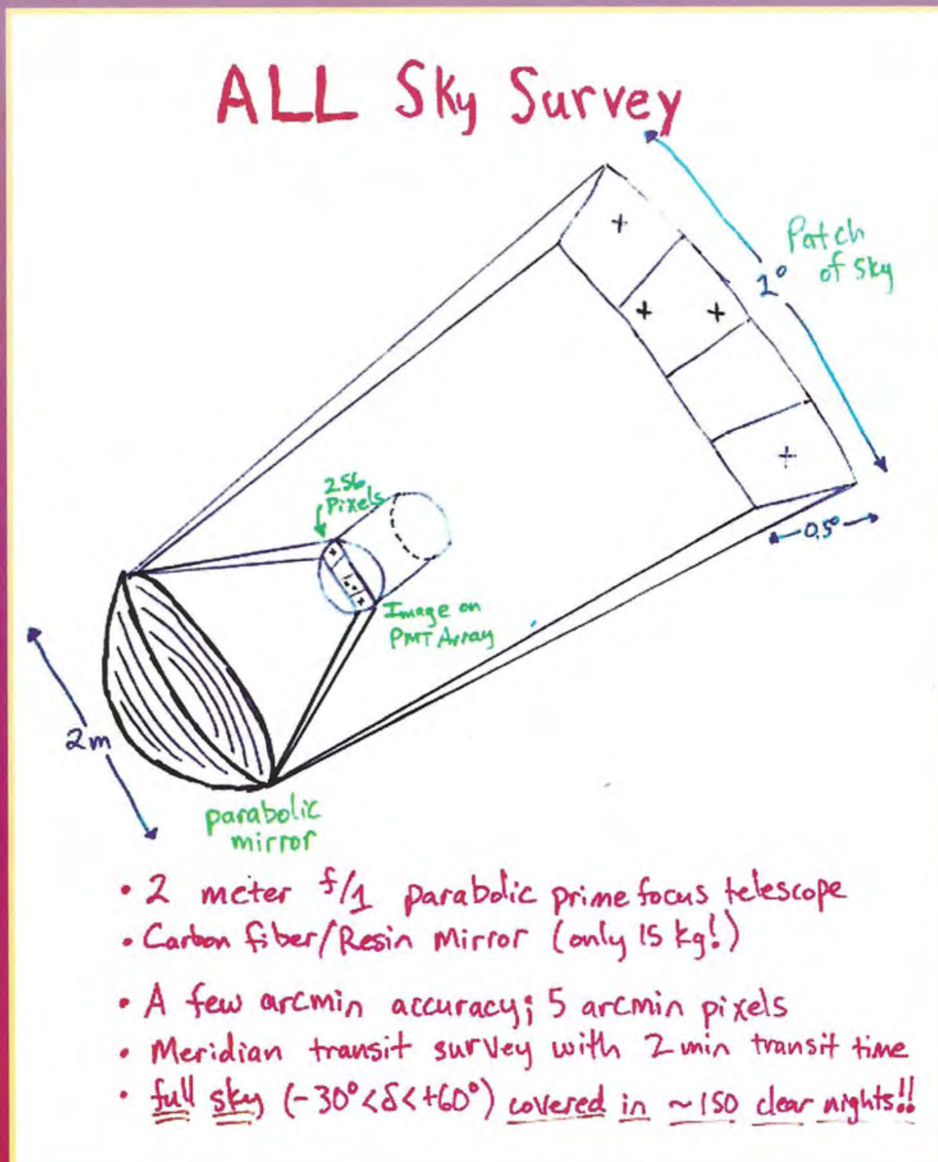
At scientific conferences
overhead transparencies to s
the theory, apparatus, resul
three slides we used recen
optical SETI. They are hand-
levels of tec

This cartoon captures the essenc
terms. Here we're imagining that
mitting, using our best laser (the Li
completed) and telescope (the Keck
power (that's a million billion watts
civilization looks at our star, they w
outbursts of light; someone out the
slide, our rough calculation gave a
refined calculation, the ratio is 5,0

…ese days, we usually use …ow what we're trying to do— …ng data, and so on. Here are …y to explain the idea behind …awn "cartoons," at various …nical detail.



…f the previous slide in nontechnical …e—"Earth 2000"—are doing the trans- …more laboratory Helios design, not yet …o fire nanosecond pulses of petawatt …at a distant star. When an observing … be amazed by occasional brilliant … will say, "Wow!" (When we drew this …ightening ratio of 3,000; with a more …



Our current search follows the scenario in the other two cartoons, observing individual stars one at a time. But we are planning a new search to check out the whole sky. This cartoon was drawn for a technical audience, so it's full of numbers—the size and shape of the mirror, the number and size of simultaneous picture elements ["pixels"], the amount of time any given object spends in our gaze, and the range of sky latitudes covered in this northern-hemisphere search. What matters, though, is the bottom line: we will be able to search the entire northern sky in just 150 clear nights. We're excited about this and hope someone will fund it. Illustrations: Paul Horowitz

(continued from page 11)

the event that triggered the coincidence is analyzed by the "multi-level time-stamp" circuitry; that's fancy language saying that we keep track of the flash intensity, nanosecond by nanosecond, to help us decide if we really saw a laser flash (rather than static electricity, or someone's flash camera, or whatever).

You can see pictures of our optical SETI camera and get additional information at our project website: **www.oseti.org**.

Results and Plans

From October 1998 through November 1999, we have made some 8,500 observations of about 2,500 stars (most objects are observed more than once). Although you might think that an optical detector pointed at bright nearby stars would see lots of candidate signals, in fact we see very few, because we insist upon coincident detection in a pair of independent detectors. We average one such event for every 5 to 10 hours of observation. These events are distributed more or less evenly over about 100 stars, with a handful of stars having more than one event. To date, we have no evidence for intentional laser signals.

Simultaneous Observations. Given our rate of roughly one event (of nanosecond timescale) per good observing night, it is highly desirable to make simultaneous observations from a pair of widely spaced observatories. An event seen at both observatories simultaneously from the same source would likely be an intentional laser signal, or a previously unknown astrophysical phenomenon (also of great interest).

We are cooperating with Dave Wilkinson and colleagues at Princeton University to duplicate our electronic and optical hardware on their 36-inch optical telescope. This system should be online sometime this year. With identical electronics, the Princeton experiment will be automated to follow the Harvard telescope. Each site will use an accurate real-time clock to tag incoming events with a relative accuracy of a millisecond or better.

All-Sky Optical Search. Our present search for pulsed optical beacons tacitly assumes that extraterrestrial signals will originate from the neighborhoods of nearby stars. In focusing so narrowly on a set of a few thousand stars, the search covers only a millionth of the total sky area. Perhaps one should not be so timid!

We are in the initial stages of developing an all-sky optical-pulse search, analogous to the META and BETA all-sky radio searches. We envision a large, wide-field optical telescope performing a meridian transit survey: the night sky will drift through the gaze of our stationary telescope, equipped with an insect-like array of 512 closely packed detectors. With such an arrangement, we could cover the full northern sky in about 150 clear nights. During that period of time, every object in the northern-hemisphere sky would have transited our detector array (covering a stripe of 2 degrees North-South by 0.5 degrees East-West) with a minimum observation time of two minutes. We plan to use a prime-focus "light bucket" telescope about 2 meters in diameter, made of carbon-fiber composite or of glass. If we can find the funds, this new experiment will likely be placed in an existing dome at Harvard's Oak Ridge Observatory.

The Berkeley Searches

In addition to its two radio SETI searches (SETI@home and SERENDIP), the University of California, Berkeley operates two new optical SETI searches.

Spectroscopic Data Mining. This project is a search for continuous (rather than pulsed) laser signals. This search, directed by Geoffrey Marcy (one of Earth's most productive extrasolar planet finders), examines 1,000 stars for narrow, "coherent" (laser-like) signals in the extremely high-resolution stellar spectra collected during the ongoing search for planets. The strategy is to look for laser light at some distinct wavelength (color), visible even against the "white light" background of the parent star.

These observations take place at the Lick observatory in California, the Keck observatory in Hawaii, and the Anglo-Australian observatory in Australia. All the spectra are carefully examined for ultra-narrowband features, the signature that distinguishes a laser-like artificial beam from the relatively broad emission lines of natural astrophysical objects.

Optical Pulse Search. Berkeley's other optical SETI program is similar to the Harvard pulse search, seeking intense but extremely short pulses (a billionth of a second or so), transmitted perhaps by a distant civilization's powerful pulsed laser. The target list includes mostly nearby stars of classes F, G, K, and M, plus a few globular clusters and galaxies.

Left: With the OSETI camera mounted on the 61-inch telescope in the background, the crew here (left to right) consists of Cos Papaliolios (astronomer, professor), Chip Coldwell (graduate student, computer guy), Paul Horowitz (professor, boss), and Jonathan Wolff (master of all trades). The telescope is completely under computer control, but in this shot you can see the ancient manual control console in the foreground—it looks like something you would find in a World War II submarine. The telescope is equatorially mounted, as all such instruments were in the 1930s when this one was built; you can also see the giant declination gear and setting circles.

Above: Here's the cozy control room in the northwest corner of the building. That's Robert Stefanik, the observatory director, standing behind Chip and Jonathan. You can see a stellar spectrum on the monitor at right and various observing parameters on the screen in the center of the picture.

We like hanging around in the control room because it's nice and warm and you can eat snacks, watch football, and surf the web while the telescope does its thing out in the cold, dark dome.

Right: This closeup of the OSETI detector and one of its proud inventors was taken late at night on the occasion of its debut at the observatory. The 70-pound instrument is firmly bolted to the side of the echelle spectrograph, which has been engaged in a survey of nearby stars. In 1989, the spectrograph's owner/operators (astronomers Dave Latham and Robert Stefanik) discovered the first good candidate for an extrasolar planet, orbiting a star whose name is HD 114762. Photos: Harvard SETI Group

This search, directed by Dan Werthimer, uses Berkeley's 30-inch automated telescope at the Leuschner observatory, with a camera that Werthimer built in 1997. This camera, which predated the Harvard detector, uses an optical arrangement similar to that shown in the block diagram on page 10 (it differs by omitting the time-stamper). The telescope's light is split, then fed to a pair of ultra-high-speed photomultiplier tubes (PMTs), coupled to a pair of high-speed amplifiers, fast discriminators, and a coincidence detector. The camera responds to light pulses in half a billionth of a second! As described earlier, we need two detectors to reject false alarms, which can happen often in a single PMT but almost never in both PMTs simultaneously. The pulse search has examined about 300 stars so far but hasn't turned up any signals suggestive of intentional laser pulses.

The Bottom Line

Laser SETI is taking off, thanks to recent developments in laser technology on Earth (which makes an interstellar laser scenario plausible), along with new detector technologies (both pulse and spectroscopic). No one knows for sure whether optical communication will turn out to be the method of choice for advanced civilizations seeking to establish contact. But a directed laser beacon is altogether reasonable, from all we know. The Planetary Society is at the forefront in sponsoring this exciting exploration.

Paul Horowitz is Professor of Physics at Harvard University.

Acknowledgments

The Harvard group includes Joe Caruso, Charles Coldwell, Andrew Howard, Samuel Klein, David Latham, Costas Papaliolios, Robert Stefanik, Anne Sung, Jonathan Wolff, and Joe Zajac; its optical SETI activities receive additional support from The Bosack-Kruger Foundation and the SETI Institute.

The Berkeley SETI group includes David Anderson, Stuart Bowyer, Jeff Cobb, Eric Heien, Michael Kang, Eric Korpela, Mike Lampton, Matt Lebofsky, Michelle Riedel, Charles Townes, and Dick Treffers. Key sponsors are The Planetary Society, the SETI Institute, Sun Microsystems, the University of California, and several corporations and individuals around the planet.

Imagining Mars: The Hollywood Version

The producers of the movie* Mission to Mars *hired scientific consultants to help them simulate the landscape of the Red Planet. Matt Golombek, project scientist for the* Mars Pathfinder *mission, was among those consulted. The designs for habitats and rovers were based on ideas from NASA's Johnson Space Flight Center.

Photos: ©Touchstone Pictures

by Charlene M. Anderson

This year will see a somewhat unexpected result from the *Mars Pathfinder* mission: two major feature films will soon be released about missions to the Red Planet—*Mission to Mars* from Touchstone Pictures and *The Red Planet* from Warner Brothers Studios.

Meanwhile, *Titanic* producer James Cameron, who knows something about what the public will pay to see, is developing a five-part television miniseries and an IMAX film about Mars. Hollywood has decided public interest in the Red Planet is high enough to make these film productions profitable. There is money in Mars.

Mars Pathfinder Project Scientist Matt Golombek is quick to emphasize the connection between real planetary missions and the fictional missions that will soon fill movie screens around the world. "There probably would not be these movies without the success of the *Pathfinder* mission," he said. "The fact that they exist at all shows how science and exploration, what we do in the NASA program, really has an effect. The movies represent the feedback between the [science and exploration] community and the public that supports them."

The fact that *Pathfinder* was a mission of scientific exploration has also not been missed by filmmakers, who have hired consultants from the science and engineering communities to provide guidance in "getting the facts right." They recognize that the public is fascinated by the quest to know and understand our neighboring worlds, a quest engagingly conducted during the short three months of *Pathfinder*'s lifetime.

One of the films, *Mission to Mars*, was produced by Tom Jacobson for Touchstone Pictures, a subsidiary of the Disney Company. Jacobson purchased the rights for *The Case for Mars* by Robert Zubrin to use as a basis for the engineering for the human missions.

As Golombek observed, "Disney has gone through remarkable pains to understand what reality is. The first thing they did was seek and receive NASA approval. NASA headquarters read the script, made suggestions, gave approval. It's mostly to make sure that NASA is portrayed properly. That opened the doors of NASA so [the producers] could get help."

The *Mission to Mars* producers engaged consultants from the science and exploration community. Legendary shuttle astronaut Story Musgrave gave advice on how astronauts would live and work in space. (Since leaving NASA, Musgrave has joined Disney as a Disney Fellow.) Other leading consultants included Kathryn Clark, NASA's Chief Scientist of the International Space Station program, and *Pathfinder*'s Golombek, whose infectious enthusiasm charmed so many during that mission.

As part of their attempt to engage the science and exploration community, the *Mission to Mars* group also contacted The Planetary Society. They participated in Planetfest '99 as one of our largest sponsors and joined our efforts to bring sounds from our Mars Microphone to as many people as possible. They shared our disappointment when the *Mars Polar Lander*, carrying the microphone, disappeared, prematurely terminating our public-involvement project.

Because of this relationship, The Planetary Society was allowed to see the script for *Mission to Mars*. We should mention here that we were not paid consultants to the film; we made no suggestions or recommendations to the producers. But we can offer some of our insights to Society members, who, after all, form the portion of the public that most enthusiastically supports future missions to Mars.

The Mission

Mission to Mars handles the elements that will make up the first real mission with reasonable verity. The producers portray a sustained program of planetary exploration, one that proceeds step by step to the ultimate goal of a human base on Mars. The flights are scheduled around launch windows, when the relative positions of Earth and Mars allow for the shortest, most efficient trajectories between the planets. The first team leaves at one launch opportunity; the second team must leave at the next launch window.

In its Mars planning since the 1998 missions, NASA has scheduled launches every 26 months, which is the interval between proper alignments of Earth and Mars. In the film, however, the timing of launch windows is a bit off, and they seem to come at shorter intervals.

The film portrays a program in which the capability to support a human presence on Mars is built up by a combination of robotic supply ships and spaceships carrying human crews. This method is being seriously studied by Mars mission planners. The most difficult and expensive requirement of any human mission is launching and supporting the living cargo. If much of the inanimate cargo can be launched on cheaper robotic craft, it will lessen the demands on spacecraft designers, as well as on taxpayers, and increase the amount of supplies and equipment the human explorers will have available on Mars.

On the way to Mars, the astronauts travel in a spaceship that spins to provide artificial gravity. As we've learned from decades of experience in low-Earth orbit, long periods in weightlessness can trigger harmful changes in the body. Spinning spacecraft are likely someday to ferry real astronauts to Mars.

Once on Mars, the astronauts spend much of their time safe in their habitat, while a robotic explorer does the reconnaissance. Such a partnership of robots and humans will probably be the preferred mode of exploration. Astronauts will "teleoperate" robotic vehicles that are more robust than fragile human machines. A field geologist with pickax in hand, collecting samples, will be a relatively rare sight on Mars.

Living and working on Mars will demand that explorers cope with more than just the necessity of cocooning within an artificial habitat or pressurized spacesuit. There is also the problem of low gravity (Mars has only one-third the gravity of Earth). The actors looked to space-station scientist Kathryn Clark, an exercise physiologist by training, for advice on how they would function on Mars. Actor Don Cheadle plays the character who stays the longest in reduced gravity, and Clark particularly enjoyed working with him to convey low-gravity effects.

The Planet

The portrayal of Mars will depend on the quality and accuracy of the special effects, and as of this writing no one has seen the final product. Mars itself was Golombek's primary concern as a consultant to the film. "I read the script to determine what was scientifically reasonable—things like the color of the surface, the color of the sky, and what the landing site would look like."

Much of the filming was done in Vancouver, British Columbia, where the producers constructed a 55-acre set. "They took a gravel pit and made it into Mars," Golombek said. Working with data collected from *Pathfinder*, the set builders mixed a paint to match the Martian color and sprayed the ground of the outdoor set brownish orange.

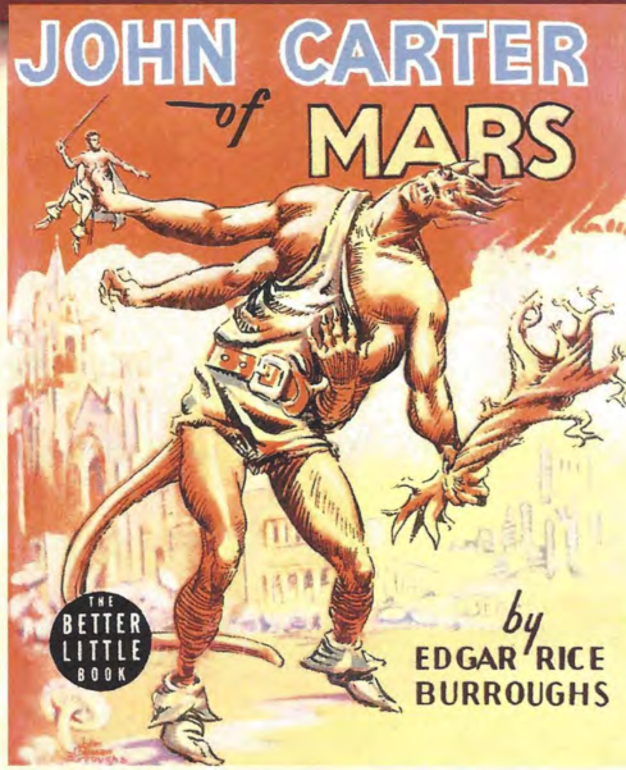
Of course, the filmmakers couldn't spray over the blue terrestrial sky. The pinkish sky of Mars is being added as a special effect. "I made the trip to DreamQuest [the effects house] to see the sky, the atmospheric vortices, and so on," Golombek added. "The people there were very interested in

Fooled by seeming patterns of dark and light on Mars, Percival Lowell thought he discovered more than 200 "canals" crisscrossing the planet. He developed a theory that an advanced, ancient civilization built the canals for delivering water from the planet's polar caps to its desert regions. His popular books and articles influenced the work of countless science fiction writers and artists. Here are some examples of classic works inspired by Lowell.

Right:* *Edgar Rice Burroughs authored 11 books starring John Carter of Mars, a soldier and adventurer who was transported mysteriously to the Red Planet to, among other things, combat the natives, become Warlord of Mars, and win the hand of the local princess.
Painting: John Coleman Burroughs; book cover photo reprinted courtesy of Edgar Rice Burroughs Incorporated.

***Far right: This illustration from 1898, entitled* Martian Fighting Machines*, appeared in a Belgian translation of H. G. Wells' novel* War of the Worlds.** *Illustration: Alvim Correa*

***Below: Science fiction and fantasy artist Michael Whelan produced this painting for the cover of the modern paperback edition of Ray Bradbury's 1940s collection of short stories,* The Martian Chronicles.** *Illustration: Courtesy Michael Whelan*



what Mars really is, but the final effects will be up to the director."

As with the timing of launch windows, the script takes a few liberties with distance on Mars. The first base is set in Chryse Planitia, near the site of the *Viking 1* landing. But much of the action takes place on the plains of Cydonia, some 1,000 kilometers away. The astronauts travel with alacrity between the two locales. Mars is a small planet, but not that small. Its surface area is about equal to the dry-land area of Earth. Time is still a factor every traveler must deal with.

An Inanimate Character

Without revealing the plot, we can mention that the so-called Face on Mars plays a role in the film. This feature first entered the public's ken on July 31, 1976 in an image from the *Viking 1* orbiter. The accompanying press release from the Jet Propulsion Laboratory (JPL) noted the rock formation's resemblance to a human head, "formed by shadows giving the illusion of eyes, nose and mouth."

As Dave Pieri, then a member of the *Viking* team and a student of Carl Sagan, remembers, "Scientists and press assembled in the *Viking* press area that morning noticed the

peculiar feature with some humor." He also remembers sitting with Sagan and picking out the initials of every member of the *Viking* team, seemingly "embossed" on Big Joe, a large boulder only a couple of meters from the *Viking 1* lander. "It was good fun," he recalls.

Since then, the story of the "face" has not always been fun. A small group of people actively believe that this feature is an alien artifact. Some have even charged NASA with conspiring to hide "the truth" from the public. *Mars Global Surveyor* (*MGS*) has recently imaged the feature with much greater resolution than the *Viking* orbiters were capable of (see the July/August 1998 *Planetary Report*). In these *MGS* images, the geological feature was revealed as a naturally eroded hill, no longer resembling a human visage. But that hasn't ended the debate over the origin of the "face."

Pieri, now on the staff at JPL, takes the geologist's view. He notes that there is a "remarkable hemispherical dichotomy that divides the planet." To the north are smooth, sparsely cratered lowland plains; to the south are rough, heavily cratered highlands. Along the boundary between the two regimes, there are fields of isolated mountains that appear to be the eroded remnants of the scarp that marks the transition. The "face" lies in such a region. Pieri and virtually all Mars geologists regard it "as an unremarkable individual within a field of isolated massifs in Cydonia."

A discussion of a movie is not the place to talk in depth about the Face on Mars. Consider instead the role some other controversial Martian features played in some of the most popular science-fiction books and films of the last century.

Another Mars

Humans have a long and sometimes distinguished history of seeing artifacts of advanced civilizations on Mars. Percival Lowell, patrician and astronomer, built an observatory in Flagstaff, Arizona devoted to the examination of the Martian surface. He equipped it with one of the best and most powerful telescopes then built. Working at the limits of the best resolution possible, he saw canals crossing the planet's surface.

His reasoning that these must be artificial features went something like: such perfect, unbroken lines crisscrossing the surface could not appear in nature. Therefore, some advanced civilization must be responsible for creating them. Some scientists rejected Lowell's interpretation; some accepted it. With a talent for exposition, Lowell went to the public with his story, lecturing around the world and publishing several best-selling books about Mars.

As techology improved, and better image processing became available, the canals shrank into unconnected blots on the globe. Lowell, working with instruments that couldn't clearly resolve features on the planet's distant face, had been fooled by the human mind's tendency to draw lines between the dots. Even after that realization, it took years for the canals to disappear from the imaginings of the most hopeful among us. But the spacecraft flybys of the 1960s, which revealed the lifeless, cratered face of the planet, finally consigned to oblivion Lowell's lost civilizations of Mars.

In George Pal's 1953 film adaptation of H. G. Wells'* War of the Worlds, *we saw only a fleeting glimpse of the Martians themselves—which made them all the more terrifying.

Photo: Courtesy Eddie Brandt's Saturday Matinee

Through much of the 20th century, Lowell's popularizations inspired writers to populate the Red Planet with beings of their own creation. H. G. Wells' *War of the Worlds*, Edgar Rice Burroughs' series of John Carter books, and Ray Bradbury's *Martian Chronicles* all trace their descent directly to Lowell's vision of Mars.

And from the many books, plays, radio dramas, and movies based on these works, new generations found the inspiration to enter the challenging fields of astronomy and planetary science. Carl Sagan, namesake of the Carl Sagan Memorial Station now standing on the *Pathfinder* landing site, was among those inspired.

So here we see another feedback between the entertainment and science communities. Movies such as *Mission to Mars* are made because the filmmakers see a fascination for that planet reflected in the public's enthusiastic response to the *Pathfinder* mission. And planetary scientists have found inspiration to undertake their explorations in the fictional worlds created to entertain the public. As feedback loops go, this is a very beneficial one.

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

Percival Lowell took this photograph of Mars from Lowell Observatory on July 12, 1907.

Photograph: Lowell Observatory

Questions and Answers

On page 12 of the July/August 1999 issue of* The Planetary Report, *Michael Belton talks about a coordinated observational effort between* Galileo *and* Cassini. *For years* Galileo *has been forced to operate at a greatly reduced communications bandwidth due to the failed deployment of its main antenna. Is it possible for* Galileo *to use* Cassini *as a communications relay station while it is in the vicinity of Jupiter?
—Barry Belian,
Fairfax Station, Virginia

Thank you for this excellent question. *Cassini* will indeed be flying by Jupiter on December 30, 2000. And as we know, because *Galileo*'s high-gain antenna (HGA) did not open properly, the rate at which data can be downlinked to Earth is limited. The spacecraft uses its low-gain antenna (LGA), which performs at a fraction of the HGA's design capability.

But *Cassini* will not be able to act as a relay for *Galileo* for several reasons. First, *Galileo* is doing very well with its limited downlink rate. Advanced onboard software selects and compresses *Galileo*'s data. New error-correcting code has been implemented for the spacecraft, and many functions in the receiving systems on Earth have been upgraded. As a result, over 70 percent of *Galileo*'s main mission data have been returned. In addition, more data have been generated and returned during its extended mission.

Second, *Galileo* only transmits its data at S-band radio frequencies, since it cannot use its HGA, which would have enabled the higher-frequency X-band downlink. *Cassini* has an S-band receiving capability, designed to collect data from the *Huygens* probe during its mission at Saturn's moon Titan. However, its frequency capability is hundreds of megahertz away from *Galileo*'s, and it is not programmed to handle *Galileo*'s data format.

Even if *Galileo* and *Cassini* radio frequencies and data processing were compatible, schedules are tightly constrained for *Cassini* and the Deep Space Network. Plans to make the best of limited resources could not be revised without considerable sacrifice to *Cassini*'s planned science operations at Jupiter. The same is true with *Galileo*'s ongoing operations.
—DAVE DOODY,
Jet Propulsion Laboratory

Factinos

This image mosaic of Eros was taken by NEAR on February 18, 2000 from a distance of 360 kilometers (about 220 miles). The spacecraft was over the shadowed southern hemisphere looking north at a crescent Eros.
Image: The Johns Hopkins University Applied Physics Laboratory/NASA

Data from NASA's Near Earth Asteroid Rendezvous (NEAR) mission indicate that 433 Eros is no ordinary space rock. Scientists from Johns Hopkins University's Applied Physics Laboratory have been busy studying data returned from the spacecraft's Valentine's Day encounter with Eros. Although it will take time to answer deeper questions about Eros, scientific returns from NEAR's final approach and first days in orbit are serving up tantalizing glimpses of an ancient surface covered with craters, grooves, layers, house-sized boulders, and other complex features (see image at left).

"Work is just starting, but it's already clear that Eros is much more exciting and geologically diverse than we had expected," said the mission's lead scientist, Andrew Cheng of the Applied Physics Lab. The researchers have determined that Eros' mass is similar in density to Earth's crust, about 2.4 grams per cubic centimeter—a near match to estimates derived from NEAR's 1998 flyby of the asteroid.

"With this new data, it now looks like we have a fairly solid object," said Donald Yeomans of the Jet Propulsion Laboratory. "There's no strong evidence that it's a rubble pile like Mathilde," the asteroid NEAR flew past and imaged in 1997.

Pictures from the NEAR's multispectral imager suggest that Eros is an older asteroid. Uniform grooves across its craters and ridges hint at a global fabric of underground layers, which Cheng says could indicate that Eros was once part of a larger body.
—from The Johns Hopkins University Applied Physics Laboratory

If gas giant planets have only small solid cores, how were they able to accumulate, and hang onto, the massive gas bodies that they have now? Why aren't their atmospheres blown away by the solar wind?
—William Lee Kohler,
Eugene, Oregon

There are currently two competing models for giant-planet formation. In one, a gravitational instability in the solar nebula (the lens-shaped disk of dust and gas from which the Sun and planets formed) triggers the collapse of a giant protoplanet that gradually contracts into a giant planet. In this case, there may not even be a core, so we don't have to worry about the answer to the question; the planet starts out with a massive atmosphere. But this planet must still accumulate an excess of heavy elements compared with solar abundances, because we observe such an excess today. These additional heavy elements could be contributed by infalling planetesimals that dissolve in the outer envelope of the planet during the later stages of its formation.

In the second model, a solid core accretes first, from planetesimals that contain both icy and rocky materials. As this core approaches a size of 8 to 10 Earth masses, its gravitational field becomes large enough to attract surrounding gas from the solar nebula and form a giant planet. So in this case, the answer to the question is that the mass of the core is not so small; it is large enough to capture and hold an atmosphere. This model was favored when observations seemed to show that all four giant planets had central cores of about 10 Earth masses. However, the most recent data show that the uncertainties in these observations are such that Jupiter may not even have a central core.

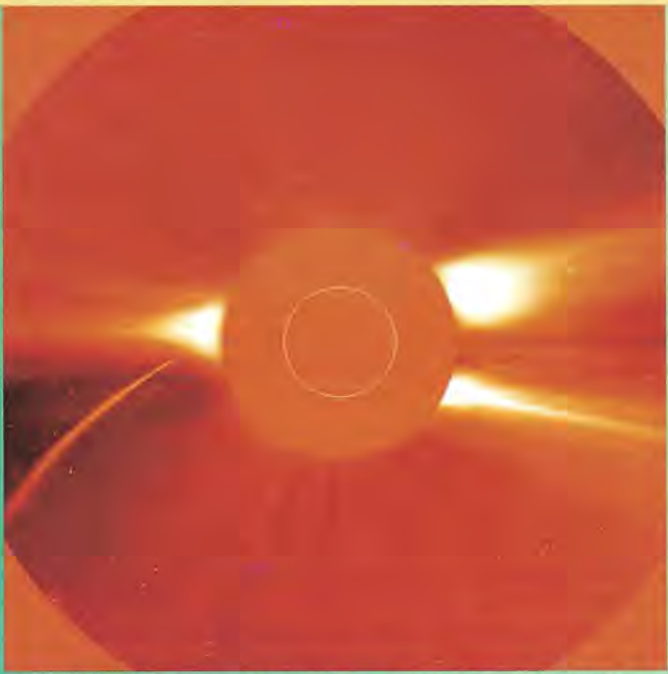
We clearly need some new outer planet missions that would include spacecraft in polar orbits close enough to the planets to give us accurate information on their interior structures.
—TOBIAS OWEN,
University of Hawaii

If a spacecraft lands on Europa, will the ice break?
—Kyla Lendroth (age four),
Sierra Madre, California

Here on Earth, walking on very thin ice can be dangerous. The ice on a frozen lake might be only an inch thick, so it is possible to fall right through into the cold water below. But there are some places on Earth (like the Arctic) where it is very cold all winter long. Lakes and seas in the Arctic can be so cold in winter that when the water freezes, the ice becomes many feet thick. Some scientists dress in their warmest winter coats and go to the Arctic to study this thick ice, which can hold the weight of people, cars, and even helicopters without breaking. But they have to leave before spring comes and the ice melts.

Europa is much colder than anyplace on Earth, so the ice there is probably very thick. Scientists have different views on how deep it is, but in most places the ice may be more than 16 kilometers (10 miles) thick! Some day we'll send a spacecraft to Europa, and it will be difficult to choose a place to land. If we want to find an ocean that may be under the ice, it would be best to send the spacecraft to the warmest place, where the ice is thinnest.

But spring never comes to cold Europa. Even where the ice is as thin as it gets, we can be pretty sure that the spacecraft will not fall through.
—ROBERT PAPPALARDO,
Brown University



This picture of the "Christmas Comet" was captured on December 23, 1996 by the LASCO instrument on the Solar and Heliospheric Observatory. This comet, officially called SOHO-6, is one of a hundred kamikaze comets that the spacecraft has detected. The shaded disk in this image is a mask that blots out direct sunlight. The white circle placed inside the disk shows the actual size and position of the Sun. Image: NASA and the European Space Agency

A comet detected by a Lithuanian scientist on February 4, 2000 is the 100th comet to be discovered with the Solar and Heliospheric Observatory (SOHO). Launched four years ago by NASA and the European Space Agency, SOHO has revealed an amazing number of kamikaze comets plunging into the Sun's atmosphere, making the spacecraft the most prolific comet finder in the history of space science. The image at left shows SOHO-6, another kamikaze comet.

Like nearly all of SOHO's discoveries, the 100th comet appeared in images from the LASCO instrument, a set of coronagraphs that view the space around the Sun out to 20 million kilometers (12 million miles) while blotting out the Sun itself with a mask. LASCO watches for mass ejections from the Sun that threaten to disturb Earth's space environment. The comet discoveries are a big bonus.

SOHO scientists spot many of the comets as soon as the images come in. But still pictures and movies from LASCO are freely available on the Internet to astronomers around the world, who can discover less obvious comets without leaving their desks. This was the case when Kazimieris Cernis of the Institute of Theoretical Physics and Astronomy in Vilnius, Lithuania found SOHO 100. To see more images of sungrazing comets discovered by SOHO, go to: **http://sohowww.nascom.nasa.gov/hotshots/2000_02_07/**.
—from NASA and the European Space Agency

Society News

Welcoming The Planetary Society of Japan

San (3) . . . *ni* (2) . . . *ichi* (1): blast off! November 10, 1999 marked an exciting international development for The Planetary Society—the official launch of a sister organization, The Planetary Society of Japan (TPS/J).

TPS/J is an independent affiliate of The Planetary Society. Tamiya Nomura, the former High Commissioner of the Space Activities Commission in Japan, heads the newly formed organization as its President. Yotaro Kobayashi, Chairman of Fuji-Xerox Co., Ltd., is the Vice President. Jihei Akita, Senior Fellow and Japan Representative of MIT Media Laboratory, as well as being a member of The Planetary Society's Advisory Council, is the Executive Director of TPS/J.

Society President Bruce Murray calls the organization of our new affiliate "a global milestone in public participation in planetary exploration and the search for extraterrestrial intelligence."

TPS/J will publish its own newsletter, operate a website linked to The Planetary Society's website, distribute *The Planetary Report* with a Japanese translation, host public events in Japan, and provide special programs for Japanese students to enhance their understanding of space exploration.

—Susan Lendroth, Manager of Events and Communications

Searching for Charter Members

Twenty years ago, when The Planetary Society first began, we honored our first members by giving them the special title of Charter Member. We know that many of you original members are still dedicated members today; unfortunately, we no longer have a listing of Charter Members. Early databases have been lost or destroyed. We've managed to find quite of few of you out there, but we're certain we haven't found everyone. If you remember receiving a Charter Membership card nearly two decades ago, please e-mail Melanie Lam at tps.ml@planetary.org, or call (626) 793-5100 and let us know who you are.

—Melanie Lam, Membership Manager

Design Our New Logo for the New Millennium

We are proudly celebrating our 20th anniversary, and that, coupled with the onset of a new millennium, gave us the idea to get a new look.

Space artist Jon Lomberg created our original logo in 1980, working from art that he created for Carl Sagan's book *The Cosmic Connection*. Lomberg linked the explorers of the Renaissance, who sailed Earth's uncharted oceans, with today's space explorers, who sail into the expanses of the cosmos.

Our original logo is both unique and historic and will always be a part of the Society. Still, we are ready for a new look for the 21st century.

This is your Society, so who better to turn to for logo ideas? We're not asking for finished products; you don't need to worry about your artistic abilities. Rather, we're looking for a great logo concept. We will have the winning logo professionally rendered, so your entry can be a carefully designed, "finished" piece of art or just a rough sketch with descriptive text explaining how the logo should look.

Here are a few guidelines:

• We want an adaptable, easily recognizable logo that will look good in black-and-white as well as color and in a variety of sizes. Ideally, this new logo would appear anywhere our name or web address appears, including the title bar on *The Planetary Report* and our website.

• This contest is open to Planetary Society members only. Name, address, phone number, and member ID number must be attached to the entry.

• Entries must be received at The Planetary Society by 5:00 p.m. (PST) on Friday, June 30, 2000.

Send entries to:

Logo Contest
c/o Jennifer Vaughn
The Planetary Society
65 North Catalina Ave.
Pasadena, CA 91106-2301

The Planetary Society will announce the winning design on September 1, 2000. The new logo, and its designer, will be featured in the November/December 2000 issue of *The Planetary Report*.

—Jennifer Vaughn, Assistant Editor

Society Co-Sponsors "Origins" Session in Caracas

The Planetary Society co-sponsored a very successful session at the Ibero-American School of Astrobiology in Caracas, Venezuela. The session, entitled "Origins from the Big-Bang to Civilization," met from November 29 to December 8, 1999. One of the highlights of the session was a direct link to Planetfest '99 during the time of the planned landing of the *Mars Polar Lander*, when the Society's live webcast (still archived on our website) featured Christopher McKay, planetary scientist and member of the Society's Board of Directors. Society Advisors Frank Drake and Adriana Ocampo presented lectures to more than 125 attendees at the school.

—Louis D. Friedman, Executive Director

Attention Northern California Members

The Planetary Society will host a public event on Tuesday, April 4, 2000 in connection with the First Annual Astrobiology Science Conference at NASA Ames Research Center. For details, contact Susan Lendroth at tps.sl@planetary.org, or call (626) 793-5100. *—SL*

NEW! **Mars in 3D Poster**
Experience virtual Mars. Put on your red/blue glasses and step onto the Martian surface where *Mars Pathfinder* still rests today. Out on the horizon, the Twin Peaks loom over a garden of alien rocks. Red/blue glasses included.
10" x 36" 1 lb. **#306 $9.00**

Planetary Society License Plate Holder
Let your Planetary Society spirit travel with you on our members-only license plate holder.
1 lb. **#675 $5.00**

Search, Discover, Explore Mug
Start off each day with this inspirational slogan.
2 lb. **#579 $7.00**

Planetary Society Cap
Our new planetary.org cap is 100% cotton with an adjustable Velcro band.
1 lb. **#673 $12.00**

Planetary Society Lapel Pin
This striking pin is approximately 1 1/4 inches long, with a vibrant blue background and gold lettering.
1 lb. **#680 $3.00**

Discover Planetary Shopping!

Mars Microphone T-Shirt
Adult sizes: M, L, XL, XXL
1 lb. **#770 $15.00**
Child sizes: S, M, L
1 lb. **#771 $12.00**

Mars Microphone Lapel Pin
1 lb. **#775 $3.00**

Mars Microphone Magnet
1 lb. **#685 $1.50**

Mars Microphone Mission Patch
1 lb. **#622 $3.00**

Red Rover Goes to Mars Mission Patch
1 lb. **#626 $3.00**

***Winds of Mars* and the Music of Johann Sebastian Bach**
This audio CD features digitally simulated sounds of the winds of Mars between 17 of Bach's finest compositions, played on piano. The wind data were collected by an instrument on the *Mars Pathfinder* lander and were translated into wind sounds through a Musical Instrument Digital Interface (MIDI). CD includes extensive liner notes explaining the production of the Martian sounds and giving a general history of Mars exploration.
1 lb. **#785 $14.99**

Future Martian T-Shirt
Child sizes: S, M, L
1 lb. **#565 $12.00**

Carl Sagan Memorial Station T-Shirt
Adult sizes: M, L, XL, XXL
1 lb. **#581 $15.00**

Search, Discover, Explore T-Shirt
Adult sizes: M, L, XL, XXL
1 lb. **#582 $15.00**

Panoramic View of Mars Poster
10" x 36" 1 lb. **#328 $5.00**

An Explorer's Guide to Mars Poster
24" x 37"
1 lb. **#505 $10.00**

Images of the Planets—Large Prints
These attractive prints are 20" x 16" 1 lb.
#319 Jupiter
#325 Mars (Full Disk)
#332 Saturn
#333 Eight-Planet Montage
#340 Venus
Special Sale—
Any Combination!
1 $7.00 each
2-3 6.00 each
4+ 5.00 each

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Nine 8" x 10" mini-posters.
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Special Value—
Order two binders
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Spacecraft Science Kits
1 lb. **$14.00 each**
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#525 Hubble Space Telescope
#529 Keck Telescope
#530 *Lunar Prospector*
#531 *Mars Global Surveyor*
#538 *Magellan*
#560 *Voyager*

Mars Polar Lander Mini-Model
1 lb. **#778 $3.00**

Attention, Teachers—Submit your order on your school letterhead and receive a 20% discount.

Shop Online at the Planetary Store: http://planetary.org

In *Planetary Disk*, Lynette Cook depicts the birth of a solar system similar to ours. As the plate of dust and gas spins, planetesimals form, glowing orange from the impacts of coalescing debris. These bodies will grow larger over time and eventually form a family of planets. Assorted bright comets orbit, and collide with, the young sun while in the dark background a nebula forms a brood of new stars.

Lynette Cook's lifelong interest in science and art led her to bachelor's degrees in both subjects. She is a member of the International Association of Astronomical Artists, the Guild of Natural Science Illustrators, and the San Francisco Society of Illustrators. Her work has been exhibited at major museums, research centers, and universities across the United States.

THE PLANETARY SOCIETY
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