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COVER:* A Voyager 1 *portrait of Saturn appeared on the cover of the first Planetary Report. Ten years later, we print a recently created computer-mosaic of images captured by* Voyager 2. *These colors were generated by combining images taken through the blue, green and ultraviolet filters on* Voyager's *camera, giving this image a slightly purplish tint. Four satellites appear with their parent planet; from left to right, Mimas and its shadow on Saturn, Tethys and its shadow, Dione and Rhea.

Image enhanced by Alfred S. McEwen and Tammy L. Becker, United States Geological Survey

FROM THE EDITOR

With this issue of *The Planetary Report* we mark the 10th anniversary of The Planetary Society. I've heard it said that nobody cares about organizations' anniversaries, except their staffs and boards. Still, every year, groups around the world celebrate their own existences.

We considered that opinion carefully and agreed that most anniversaries are simply glorifications of the past and can be pointless exercises in self-congratulation. But The Planetary Society is an organization that, in its very being, looks to the future. And that vision is one of the grandest imaginable: We seek to make possible a human future among the planets and to answer an age-old question: Is human civilization alone in the universe?

So to mark our first decade, we have chosen not to parade the Society's accomplishments before you or to recount a history we share. Instead, we will look toward our next 10 years, drawing on our past experiences to set guideposts for 10 more years of achievement.

Page 3—The Next 10 Years—The Planetary Society was born in 1980 from the vision of Carl Sagan, Bruce Murray and Louis Friedman. Here they give us their view of our second decade.

Page 6—A Decade of SETI—In the Search for Extraterrestrial Intelligence the Society has made a truly significant contribution. We sponsor the most powerful continuous program on Earth today.

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Page 28—Q & A—Our most popular column returns with Titan's atmosphere, Io's volcanoes and threatening asteroids.

Page 31—An Invitation to All Members—Help us celebrate our anniversary.—*Charlene M. Anderson*

The Next Ten Years

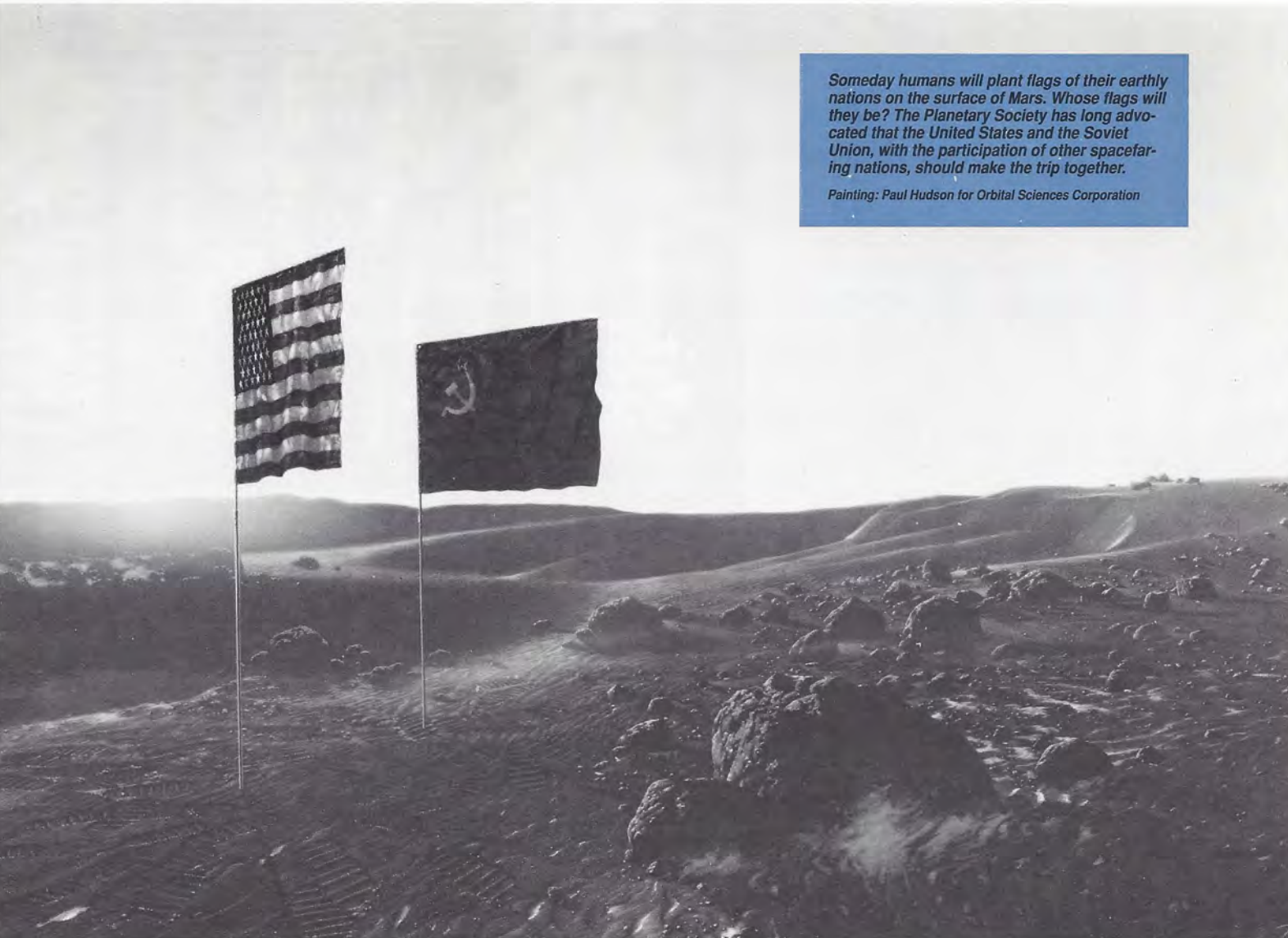
The Planetary Society's Officers Look to its Future

by Carl Sagan, Bruce Murray and Louis D. Friedman

Prophecy is a lost art. We cannot pretend to know the future of our society or the future of the world's space program. Historically, estimates of what we will achieve in technology in the next few years tend to be too optimistic and, in the next few decades, too pessimistic—the latter generally because we cannot foresee major new scientific discoveries or technological innovations. And, it is clear from recent headlines, the world is changing fast—politically, economically and socially. Those changes clearly will affect the human future in space.

At The Planetary Society we are focusing, in this anniversary year, on what the organization can achieve in the *next* 10 years—not so much to predict, but to set guideposts for our activities. We are proud of our first decade. When we founded the Society, we imagined neither our phenomenal growth nor the wide range of our present undertakings.

Our first hope for the next 10 years might be for success in one of our fundamental reasons for being: the search for extraterrestrial life. Whether it were the discovery of a microfossil on Mars (unlikely in the next decade), the signature of proteins or nucleic acids on Jupiter or on a comet or in interstellar space, →



Someday humans will plant flags of their earthly nations on the surface of Mars. Whose flags will they be? The Planetary Society has long advocated that the United States and the Soviet Union, with the participation of other spacefaring nations, should make the trip together.

Painting: Paul Hudson for Orbital Sciences Corporation

or the detection of a radio signal from an alien civilization, that would surely be one of the most important scientific discoveries in human history.

The Planetary Society would be very lucky to play a role in such a discovery, but we are trying to make our own luck. For the foreseeable future, our organization will be conducting the only serious search for extraterrestrial life. With META II soon to come "on-line" in Argentina (see pages 6-7), we will be searching for radio signals from the entire sky, from both celestial hemispheres. We will give the inhabitants of Earth, in this way at least, a view of the whole universe.

Imagine our excitement and sense of accomplishment if the discovery of extraterrestrial life were to come from a Planetary Society program—conducted through the individual efforts of people around the world in the spirit of peaceful cooperation and high adventure.

Mars

If all goes well, in 1994 a spacecraft will land on Mars carrying equipment designed by The Planetary Society (see pages 10-11). We are part of the Soviet-led *Mars '94* mission that will place two orbiters about Mars, two landers on its surface and fly two balloons through its atmosphere. The Centre National d'Études Spatiales, the French space agency, is building the balloon which will carry a guide-rope, called the SNAKE, that we are now designing. The SNAKE will not only enable the balloon to carry out its mission, it will also carry scientific instruments of its own to investigate the martian surface. The Mars Balloon will be the first mobile explorer of the Red Planet.

This project marks the first time that a private organization has been an official member of a planetary mission team. We hope it will be the first of many occasions when private citizens can make significant contributions to the exploration of the solar system.

Mars '94 will follow NASA's *Mars Observer*, scheduled for launch in 1992. This orbiting spacecraft will study the martian atmosphere and map its surface in detail. After these two missions, the time will be ripe for robotic rovers and sample return missions, involving sophisticated robots that could dramatically improve our knowledge of Mars and prepare the way for human missions. Such missions have long been considered in both the United States and the Soviet Union. It's time for the two leading spacefaring nations to pool their efforts and begin these projects.

We hope that the 1990s will continue to bring us the excitement we have come to expect from exploring other worlds. While we will not again see missions with the exploratory scope of *Voyager,* which examined close-up four giant planets and nearly 60 moons, we will see the beginning of a new phase in solar system science with *Galileo*'s in-depth investigation of the jovian system. This spacecraft will orbit among the Galilean satellites (Io, Europa, Ganymede and Callisto), making multiple passes by these intriguing bodies, and it will send a probe deep into

RIGHT: Perhaps never before or since have the American people felt so much pride as when Neil Armstrong and Buzz Aldrin set foot on the Moon. Indeed, all the peoples of Earth shared in their achievement. Such triumphs are still possible; there are other worlds where humans can walk. If the spacefaring nations of Earth work together, we may someday see humans land on asteroids, Mars and perhaps other worlds.

Photograph: Neil Armstrong, courtesy Johnson Space Center, NASA

BELOW: The Soviet people have felt immense pride in their space program, often according heroic status to their cosmonauts. Here a glorified cosmonaut spreads his arms over a church, representing the Russian past, and a crowd of people celebrating their present and future achievements in space.

***Painting: Yuri Tsirkunov, from* In the Stream of Stars**

Jupiter's atmosphere, sampling directly the largest planet in our solar system.

More to Come

Magellan is now orbiting Venus, mapping its cloud-shrouded surface with radar. Japan and the United States are both studying lunar orbiter missions. Soviet and American planners are considering missions to near-Earth asteroids (see pages 14-15). We look forward to the launches this decade of the Comet Rendezvous/Asteroid Flyby and *Cassini*, which will send an orbiter to the saturnian system and a probe into Titan, Saturn's largest moon, rich in organic matter.

Ten years from now the health of the global environment that sustains life on our small world should be systematically and comprehensively monitored from Earth orbit—using instruments and data analysis perfected in the exploration of other worlds. Observing Earth from space as if it were an alien world should provide fundamental insights into global warming, depletion of the ozone layer, and other ways in which we humans are posing a danger to ourselves. In another decade, space science and technology should be playing a much more central role than ever before to enable our species to plan its future wisely.

By the year 2000, the United States, in concert with other spacefaring nations, may well be embarked on a serious effort to build the ships to carry humans to Mars. If so, your Society's pioneering efforts will have been spectacularly rewarded. To carry out such a project, prudent and innovative steps will have to be taken on such difficult issues as heavy-lift launch vehicles, the space station and the future of the shuttle. The Planetary Society expects to continue to play a role in the formulation of national (and international) space policy.

Every time that the *Voyager* spacecraft entered the system of another giant planet, what it found exceeded the most daring guesses of the scientists working on the project. Nature is always more clever, more subtle, more beautiful than our imaginings. It is possible that the most important, the most exciting developments in space, and the role The Planetary Society is destined to play in them, will also far outpace our modest collective estimates.

In the next decade, The Planetary Society should grow significantly, increasing both our membership and the number of countries represented. We should broaden our range of activities, funding new research projects and reaching out to areas we've yet to explore. We pledge to do ourselves what we urge the governments of the spacefaring nations to do: use space exploration to educate and to inspire, as a symbol of excellence and achievement, as a spur to peaceful technological development, as a beacon of a hopeful future for everyone on Earth.

Planetary Society President Carl Sagan is the David Duncan Professor of Planetary Science at Cornell University. Vice President Bruce Murray is Professor of Planetary Science at the California Institute of Technology. Louis Friedman is Executive Director of The Planetary Society. Through their initiative, The Planetary Society came into existence in 1980.

A Decade of SETI

by Thomas R. McDonough

When The Planetary Society was founded, two programs were viewed as the pillars of the organization: planetary exploration and the search for extraterrestrial intelligence (SETI). During our first decade, we not only helped SETI researchers whenever we could, but also sponsored the world's most advanced operational SETI program.

Just a few months after the first issue of *The Planetary Report* appeared, at the start of 1981, we encountered our first SETI crisis. Senator William Proxmire (D-WI) had added an amendment to the US budget, killing the new NASA SETI project. The Society sprang into action with a speed possible only with a private organization. First, we funded Harvard University physicist Paul Horowitz's portable system, called Suitcase SETI. Then, together with NASA, we worked with the Senator's staff to explain the worthiness of the NASA project, and we arranged for Carl Sagan to meet with the Senator personally.

Not long afterward, the Soviet Union hosted a SETI conference in Estonia, inviting scientists from around the world to attend. Because of the Proxmire amendment, American scientists were forbidden to travel on NASA funds. The Society arranged for other funding sources that enabled several American scientists to go.

While Horowitz built Suitcase SETI, with some assistance from our NASA colleagues, the Senator changed his mind about SETI. The next year, the NASA program was back on track.

In 1982, Horowitz tested Suitcase SETI at the world's largest radio telescope, in Arecibo, Puerto Rico. That same year, we helped publicize the SETI Petition, conceived by Carl Sagan and signed by about 70 major international researchers, including seven Nobel Prize winners. This was a landmark document, providing concrete proof to SETI's critics of the program's scientific respectability. And we were also able to provide some support to George Gatewood at Allegheny Observatory in Pennsylvania to help convert an old telescope into a modern one designed to search for planets around other stars.

The next year we enabled two scientists from JPL to perform SETI observations from a NASA antenna in Australia, important in view of the rarity of SETI in the southern hemisphere. And we helped launch *Bioastronomy News*, the SETI newsletter created by Michael Papagiannis of Boston University for the International Astronomical Union.

Back at Harvard, Horowitz found a 26-meter (85-foot) antenna that was about to be mothballed. We reached an agreement with Harvard and the Smithsonian Astrophysical Observatory to take it over, and in 1983 installed Suitcase SETI permanently at the site. We renamed it Project Sentinel.

At this time, Sentinel had 131,000 radio channels, making it the most powerful permanent SETI observatory in the world. But we were not satisfied. There were several scientific arguments for increasing the number of channels to 8 million, but this would require $100,000. Happily, a conversation between Steven Spielberg, Ann Druyan and Carl Sagan resulted in the renowned director of *E.T.* giving us the money with which to search for the real *E.T.* In 1985, Mr. Spielberg threw the switch that turned on our eight-million-channel system, now called META (Megachannel Extraterrestrial Assay).

We also provided some assistance to Ohio State University's SETI program, to the PBS series *NOVA* for its SETI show (starring Lily Tomlin), to the Canadian SETI project of Robert Stephens, and to human-dolphin interspecies research by Diana Reiss at Marine World and San Francisco State University.

In 1988, we organized an international SETI conference in Ontario, Canada, and announced an agreement with Argentine scientists to build a du-

One of these radio-telescope dishes at the Argentine Institute of Radio Astronomy will soon scan the southern skies with the receivers of META II, The Planetary Society's Megachannel Extraterrestrial Assay. With META II, the Society extends its Search for Extraterrestrial Intelligence to the southern hemisphere, giving us full coverage of the sky.
Photo: Argentine Institute of Radio Astronomy

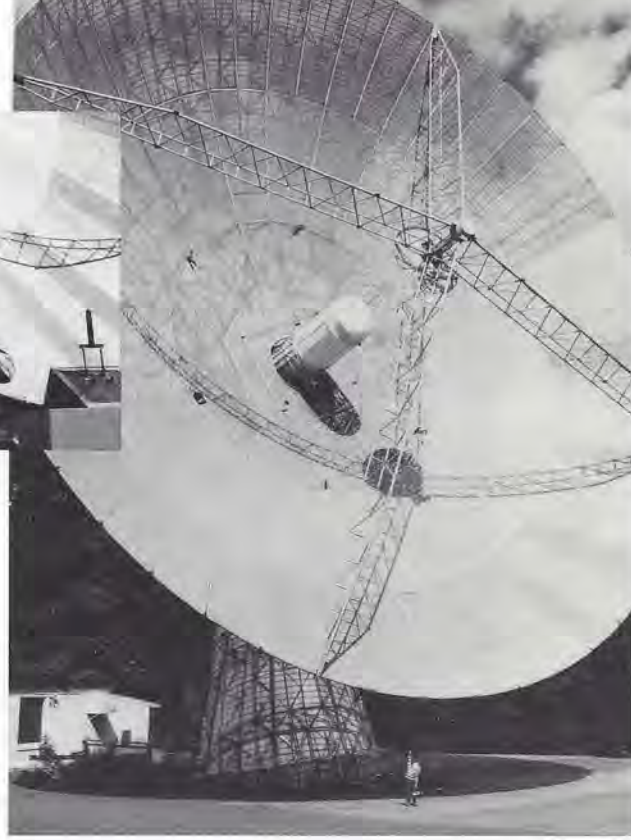
plicate of META. Two Argentine researchers then spent a year at Harvard building META II, which is at this writing being installed in Argentina with a target switch-on date of October 12, 1990. This is a major step, because there have never been long-term SETI observations from the southern hemisphere.

This brings us to the future. We will continue to operate META I and II, providing the world's only SETI program that covers the entire universe. Until 1992, our systems will constitute by far the most powerful SETI apparatus in the world. In October of 1992, NASA hopes to begin observations with its SETI system, which, because of NASA budget problems, will probably then have fewer channels than ours, but will cover a much larger frequency range—the entire microwave region from 1 to 10 gigahertz. The two META's can only listen to small segments of this spectrum at any one time, but Horowitz is studying the possibility of adapting NASA hardware to build a new system that would have an astonishing 100 million channels, and could cover large parts of the microwave realm quickly.

The Soviets will be launching a radio telescope into orbit called *Radioastron*. It will primarily eavesdrop on galaxies, quasars and other astronomical objects. But when a suspicious object is found by an astronomer, *Radioastron* will examine it carefully to see whether it has the characteristics of a radio signal from another civilization. Other SETI projects are under way in the USSR, Canada, France, Australia and the US. Because the cost of the needed electronics keeps falling, we may expect more countries to enter the race to make one of the greatest discoveries in the history of humanity.

ABOVE: In 1985 The Planetary Society's Megachannel Extraterrestrial Assay went "on-line" as Steven Spielberg and his son, Max, turned on the power to the META I supercomputer.

Photograph: James J. Aulenback



RIGHT: META I uses the radio telescope at Harvard University's Oak Ridge Observatory. From this site it scans the northern skies searching for radio signals that might be broadcast from other technological civilizations in our galaxy.

Photograph: Paul Horowitz

In the long run, as our civilization becomes electronically noisier with satellites, cellular phones, TV and telephone microwave links creating more and more electromagnetic "smog," SETI may have to be moved to the far side of the Moon. Despite that, I am optimistic about SETI success in the next decade. There is, of course, no guarantee that E.T. is out there, or that he, she or it is making a loud enough galactic noise to be detectable with our equipment. But there are going to be more SETI programs operating around the Earth than ever before, using electronic components far more powerful than those available just a decade ago.

Furthermore, there are many astronomical satellites in orbit or soon to be, launched by the US, the USSR, the European Space Agency, Japan and other nations, as well as many Earth-based telescopes. While not intended specifically to search for other beings, it's possible that one of these instruments might detect some unusual phenomenon that turns out to be the first conclusive evidence of another civilization.

One way or another, if E.T. is phoning, there is a good chance we'll hear the bell ringing sometime in the 1990s.

Tom McDonough is The Planetary Society's SETI coordinator and the author of The Search for Extraterrestrial Intelligence, Space: The Next 25 Years *and* The Architects of Hyperspace.

The State of the Search

The third IAU Commission for Bioastronomy Conference was held in June, in Val Cenis, France near the Swiss and Italian borders. About 100 scientists from all over Europe, the USSR, Japan, Canada and the US converged among the summer-idled ski lifts that glistened in the Alpine sunshine to discuss the state of the search for extraterrestrial intelligence (SETI). The highlight of this search has been The Planetary Society's META (Megachannel Extraterrestrial Assay) I project at Harvard University's Oak Ridge Observatory. Several new SETI systems were described, including our META II in Argentina. NASA is continuing to build its impressive system, with a target date of October, 1992 for observations to begin, although funding problems will probably force them to start with a less powerful system than originally planned.

The major surprise was the number of SETI projects now active or soon to be: in addition to the Society's META I at Harvard and META II in Argentina, there is the Ohio State University project; a pulsar-aided search at Nancay, France; Robert Stephen's Algonquin System in Canada; the Soviet Aelita and Zodiac projects; Project Telescope at CSIRO in Australia, and Serendip II of the University of California at Berkeley. Nonetheless, our two META's are still the most powerful SETI systems now operating. —*TMcD*

The 1990s

A NEW DECADE OF DISCOVERY?

Whither The Planetary Society as we head towards the year 2000? Some of the many distinguished members of our Board of Directors and Advisory Board share their visions of what goals the Society should set its sights on during the next decade.

The 1990s are presenting us with a unique set of opportunities. We find ourselves in the midst of historic change throughout the world. Any such period presents great challenges, because change itself eliminates historic barriers and encourages new ideas and the reexamination of old assumptions.

The most prominent change in the world order today is the ending of the Cold War. At the same time, the world is also witnessing dynamic economic growth in Japan and Asia, a reawakening of the industrial might of the United States and the certainty of a new colossus in the form of the European Economic Community led by a reunited Germany. That kind of economic activity, coupled with the freedom afforded by a reduction of the threat of nuclear war, will encourage a greater willingness to experiment and allow suppressed or dormant desires for discovery to resurface.

Every generation has thrilled to discovery. Although everyone gets excited about new developments in science and medicine, most people are thoroughly captivated by the discoveries of new lands, new peoples and new planets. The search for extraterrestrial life captures imaginations because it holds the promise that someday we may discover new life forms on these new planets.

Always, it is reaching out to the unknown that generates the greatest excitement. That excitement has been present throughout the ages, but, from time to time, has been depressed because of economic concerns, cold wars, hot wars, or struggles within nations. We now have a special opportunity: We have entered a decade likely to be free of such energy-draining diversions. That climate, nourished by tremendous economic opportunity, should encourage a reawakening of our love of discovery. Let's seize the moment!

I encourage my fellow Directors, members of the Society, our staff and all people interested in discovery to focus our energies on a discreet series of worthy projects. Let's not be distracted by any of the myriad worthwhile causes being proposed by honorable groups and individuals. Instead, let's rededicate ourselves to two of the grandest ideas of all time—adventure and discovery. We must take advantage of this opportunity to proceed with the multinational exploration of space—both human and robotic—remaining fixed upon our ultimate goal: missions to Mars and beyond.
—Joseph Ryan, O'Melveny and Myers

I wish The Planetary Society continued success in its next decade, which, at least as far as the US space program is concerned, may be a very difficult one. A great deal of agonizing reappraisal, if not restructuring, may be necessary in connection with the space shuttle, the space station and NASA itself.

In this connection, I strongly advise everyone to read Freeman Dyson's comments on the US space program in *Infinite in All Directions*, particularly his remarks on the Hubble Space Telescope, which turned out to be highly prophetic. (Has anyone yet misquoted Macbeth: "Hubble, Hubble, toil and trouble?")

However, I'll make a prediction: In the long run, the Space Telescope will do everything we'd hoped for—and more. Its initial problems will be forgotten, except by those who caused them—and had to rectify them.

The end of the Society's *next* decade will see the approach of a date of some interest to me—January 1, 2001, the dawn of the new century and the new millennium. I hope by then we will have set our feet firmly on the road to Mars—where all the action is going to be for the next few generations.

Before we move on to the moons of Jupiter. . .
—Arthur C. Clarke, CBE, Chancellor, International Space University, Chancellor, University of Moratuwa, Sri Lanka

The Planetary Society has rendered an invaluable service to the cause of space exploration. By focusing attention on the exploration of the solar system, The Planetary Society has helped build a base of public support for the initiative that President Bush has proposed for a return to the Moon and putting people on the surface of Mars by the early years of the next century. I am very grateful to the Society for the opportunity that I have been given to participate in this great enterprise.
—Hans Mark, Chancellor, University of Texas at Austin

Humankind has puzzled over the planets for centuries, but only during the past 35 years—the era of planetary exploration—have we learned enough to begin to put together a coherent picture of the nature of the solar system. To continue the exploration so recently begun is the reason for The Planetary Society's existence.

In the next decade we can expect to understand broadly the evolution of planets and their smaller companions, the satellites, comets and asteroids. Many lines of inquiry are moving toward a consensus based on the planetesimal hypothesis, in which dust grains orbiting about the infant Sun collided, stuck together and gradually grew into the planetary system we see today.

We see conspicuous evidence for the planetesimal hypothesis in the heavily cratered lunar highlands and on the battered face of Mercury. Another crucial clue lies in the tilt of the planets relative to the ecliptic (a plane defined by Earth's orbit about the Sun), a fact difficult to explain without giant collisions. We see this most dramatically at Uranus, which is lying on its side, with its rings and satellites orbiting perpendicular to the ecliptic.

Perhaps the most evocative testimony to our origin is the presence of the Moon. Earth's seemingly eternal companion was most likely produced about 4,450 million years ago by the glancing impact of a Mars-sized body on the early Earth. We thus possess the beautiful and poetically inspiring Moon as the result of a chance event.

Since the time of Newton, humankind's thinking about our planetary system has been dominated by the concept of clockwork solar systems proceeding through an orderly evolution. What we've learned during the age of planetary exploration has changed this type of thinking.

The philosophical implications are profound: Our solar system has been shaped by chance events. Other planetary systems are probably common around small, single stars. Even so, our chances of finding a replica of our own system seem remote.

But in this age of ever-more-capable space technology, we now have the means to look for other planetary systems. We have the ability to explore our own system in ever-increasing depth. The Planetary Society's mission over the next 10 years is to make sure that the momentum of the last 35 years continues.

—S. Ross Taylor, Australian National University, Canberra

During the remaining few years of the 20th century the Society should continue as an informed advocate of space exploration. The Society has a distinguished international Board of Advisors uniquely qualified to guide the directors and officers on policy issues. Because of its private, non-profit charter, the Society can react quickly to developing space issues and then speak frankly, unfettered by national or international political biases.

Education, used in the broadest sense, should remain the Society's primary goal. *The Planetary Report* should continue to feature accessible, technically proficient articles written by scientists and engineers who are leaders in planetary exploration. The Society's programs of providing educational materials on the space sciences to teachers and students should be augmented. Clearly without a scientifically literate public, there can be no informed system of checks and balances when budgeting scarce resources.

The Society is not and should not become a politically active organization. The laws of science are immune to international borders. Most scientists share a global perspective dedicated to the good of humankind. Encouraging cooperative space ventures which may lead to closer harmony among nations is a worthy objective for the Society. Also, pooling resources is only common sense. As an example, the Society's leadership with Soviet (and other) colleagues in planning cooperative ventures to Mars may expedite future

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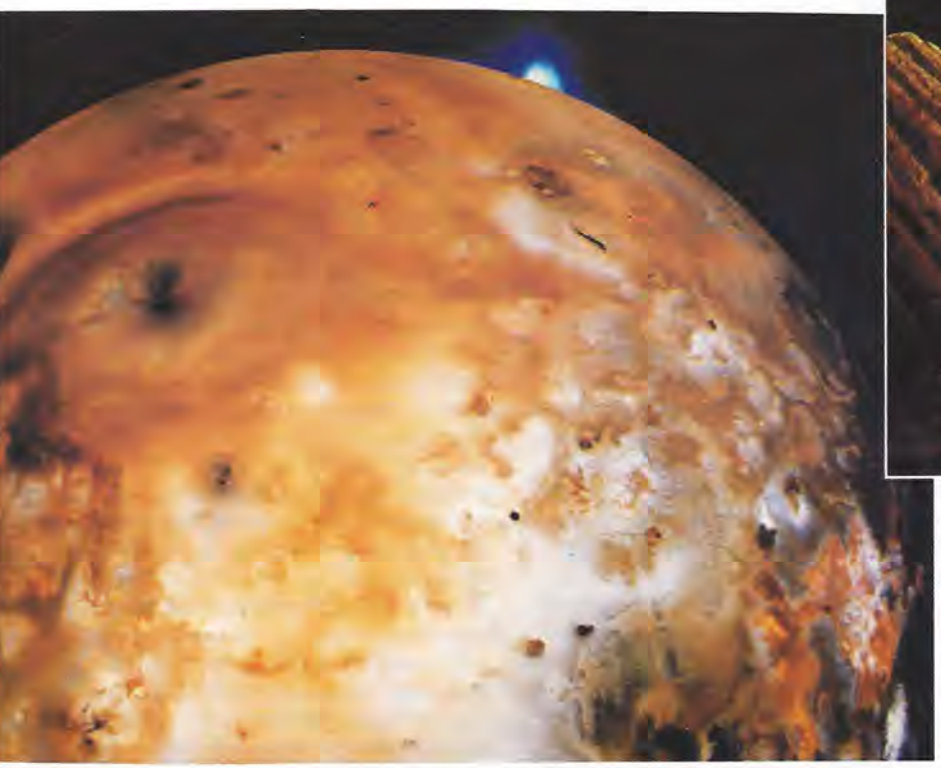


LEFT: Erupting volcanoes on Io were among the earliest surprises of the Voyager missions. This tiny moon of Jupiter seems to be the most volcanically active world in our solar system. In this newly enhanced Voyager image, the volcano named Pele shoots a sulfuric plume above the moon's limb.

Image enhancement: Alfred McEwen, United States Geological Survey

ABOVE: No painters have yet planted an easel on the surface of Io, but they can still travel there with the help of imagination. Leading Soviet space artist Andrei Sokolov renders his vision of an Io landscape, complete with erupting volcano.

Painting: Andrei Sokolov, from In the Stream of Stars

FLYING SNAKES ON MARS

The Planetary Society Mars Balloon Project

by Harris (Bud) Schurmeier

Since the Montgolfier Brothers figured out in 1782 how to harness hot air to fly across Earth, balloons have been a handy means of scientific research, as well as a way to have fun. At The Planetary Society, with our Mars Balloon Project, we've found a way to do both.

Jacques Blamont, Planetary Society advisor and visionary scientist, is renowned for his imaginative and highly practical ideas for exploring the planets. His most successful idea—so far—is to use balloons to carry scientific instruments across alien worlds. In 1986, the *Vega* mission to Venus and Halley's Comet launched two balloons into Venus' infernal atmosphere (see the January/February 1987 *Planetary Report*).

A portion of the Mars Balloon team, 1990 vintage, poses for their portrait with the SNAKE guide-rope. This is the fourth year that our team of students, professionals and enthusiasts braved the heat of the California desert to test equipment designs intended for Mars. *Photograph: George Powell*

Following that triumph, it was natural to consider using balloons on another Earth-like planet—Mars. Jacques proposed using montgolfiere balloons (containing gases that could be heated by the Sun so they became lighter than the surrounding air) to carry instrument packages across Mars. The balloons would be designed to fly during the day and land at night, when their captured gases cooled, lowering them to the ground.

This idea captured the interest of James D. Burke of the Jet Propulsion Laboratory (and Technical Editor of *The Planetary Report*). In 1986 he organized a small group at JPL to examine Jacques' proposal. They determined that ballooning on Mars was eminently possible, and excitement about the enormous potential and novel opportunity spread rapidly to JPL's parent institution, the California Institute of Technology (Caltech), and to The Planetary Society.

Through engineering analyses and field tests, the growing Mars Balloon team determined that a balloon flying through the martian atmosphere and landing on the surface would need to carry a guide-rope for stability. The resourceful team members quickly realized that this guide-rope could serve a dual purpose: It could carry scientific instruments to study the martian surface as well as providing stabilizing ballast. Such a device could become the first mobile explorer on Mars.

Assembling a Team

At Caltech, Professor Bruce Murray, The Planetary Society's Vice President, assembled an enthusiastic team of students to analyze and test the physics of montgolfiere balloons on Mars. Tom Heinsheimer of Titan Systems, an experienced balloon system designer and pilot, began developing a computer model for the design and operation of balloons in the martian atmosphere.

With the success of the *Vega* balloons on Venus, Soviet and French mission planners began to think about including balloon probes on the *Mars '94* mission. Unfortunately, NASA discontinued funding for the balloon work by JPL employees, who nevertheless continued on in their spare time. Through the Universities Space Research Association, NASA did, however, provide some funding for student help.

Fearing that a very promising and innovative idea was about to wither on the vine, The Planetary Society stepped in and increased its financial support for the balloon studies. With close connections to the Soviet/French *Mars '94* team and a commitment to international cooperation in planetary exploration, The Planetary Society became coordinator of the US Mars Balloon development by the end of the summer of 1987.

That summer also saw the beginning of desert testing of balloon and guide-rope concepts. At two sites chosen for their resemblance to martian terrain—Lavic Lake and the Pisgah lava flows—hot air balloons dragged strange devices representing guide-rope payloads across the dry lake bed and lava crevasses. (Close inspection of the varied experimental devices would have revealed them to be a palm log, a rubber roller, a plastic box and a heavy rope threaded through a polyvinyl-chloride irrigation pipe.)

The team soon discovered that, if the guide-rope snagged, even a slight wind would blow the balloon to the ground and most likely destroy it. The rope-and-pipe configuration proved the most snag-resistant. Work immediately began to discover the best possible design.

A Snake is Born

Jim Burke developed a structural concept that could work on Mars. To make it slippery yet hardy, it would need a metal skin. To cross depressions without snagging and pass over obstacles without wrapping around them, a guide-rope must not be too flexible, yet it must yield gently as a balloon sets it down. It must also be able to coil up inside a Mars descent module.

Burke made his first model out of index cards rolled into truncated cones that were nested together and taped to a one-half-millimeter steel cable. The first field test model, made of aluminum cones attached to a light chain, performed excellently in tests on the Pisgah lava. A Planetary Society-Soviet Space Research Institute team successfully flew this model from hot-air balloons in Lithuania.

Anyone who watched these models slither along as the balloon dragged them across the California desert knew there was only one possible name for this design: Snake. The team members, with their technical backgrounds, couldn't resist trying to construct an acronym for the name. Tom Heinsheimer suggested "Surface Navigation and Kontact Experiment."

In 1988, stainless steel models, carrying instruments to measure forces and accelerations on the guide-rope, took over. They passed their test flights with flying colors at the Pisgah and Amboy lava fields. We knew we had a concept that would work on Mars.

By late 1988, The Planetary Society proposed something that had never been done before: A citizen-sponsored organization would have a formal role on a flight project. The Soviet and French space agencies recognized that the Mars Balloon Team had gained great expertise in the design, development and testing of our SNAKE guide-rope. The Centre National d'Études Spatiales (CNES) accepted the Society's proposal. The Mars Balloon team became an official entity in the world of space exploration.

To Preserve and Study

The guide-rope's primary purpose is to ensure the safety of the balloon and gondola that will fly on the *Mars '94* mission. The gondola will carry a variety of scientific instruments, including a high-resolution camera system. As the balloon descends to the surface at night, the guide-rope must slowly and gently "unload" to stabilize the balloon in such a fashion that neither the balloon nor the gondola touches the ground.

Its secondary purpose is to carry out scientific investigations of the martian surface.

In 1989, The Planetary Society Mars Balloon team continued design, development and testing of SNAKE concepts. In tests and analyses we watched it perform under different conditions. We sought out its weaknesses. We had to discover ways the guide-rope could fulfill its purposes.

ABOVE: The SNAKE successfully traverses a lava crevasse in this 1987 drag-test. The balloon team sought out the harshest and most Mars-like sites to test the SNAKE's ability to avoid snagging on obstacles. ***Photograph: Ed Hauptmann***

RIGHT: Over soft sands, cracked lavas, parched lake beds and whatever forbidding terrain they can find, the balloon team tows their obliging SNAKE. It has so far passed all of its drag tests with flying colors. ***Photograph: James Willett***

A group from Utah State University became integral members of the Mars Balloon team. Students from USU, the University of Arizona, Harvard and Caltech worked with the volunteers from JPL. Tom Heinsheimer refined his balloon-system performance model. [And Harris "Bud" Schurmeier became Project Manager and coordinated Planetary Society design and testing with the CNES *Aerostat Martien* project.]

The 1989 test model was a major change in configuration. The SNAKE became shorter but sprouted a cable tail to help it lie down on landing. The tail also prevented the SNAKE's hind end from lashing about as the balloon dragged it along. Tests at the Amboy lava fields in the Mojave Desert showed that, as long as the SNAKE's head is kept off the ground, it is very unlikely to snag.

We developed a design that eliminated the internal cable that had been used in previous test models. This freed up more room for scientific instruments. We proved that our design could provide the needed ballast for the Mars Balloon as well as carry a scientific payload.

Meeting Our Goals

This year the Planetary Society Mars Balloon team is working under an official contract from CNES. Despite the heat of a long, dry summer, our enthusiastic team is continuing desert tests. We have four goals for this year:

1. To complete the design of the flight model SNAKE. Jim Cantrell of USU, who joined the team as a graduate student and is now working for CNES in Toulouse, France, is responsible for this task. He is also helping the *Aerostat Martien* team integrate the scientific payload.
2. To analyze and test elements of the SNAKE design, including alternative materials for the various components.
3. To study the behavior of the SNAKE in drag tests across different types of terrain, and to determine the effects of the terrains on the SNAKE.
4. To support and assist the CNES tests of the balloon system.

The team from CNES is arriving in September, bringing their test balloon and gondola. So as you read this, the Mars Balloon team could be out in the sweltering Mojave Desert, chasing the French balloon as it drags our SNAKE across sand dunes and lava beds.

We have a lot of work to do, but the fun and our sense of accomplishment make every small setback or discomfort worthwhile. Planetary Society members have steadfastly and generously supported our work, and we won't let them down. We have every confidence that when the *Mars '94* mission is launched, it will be carrying our SNAKE to Mars.

Bud Schurmeier is one of the most distinguished project managers in the history of the space program. In the 1960s he ran the Ranger *project that sent the first US spacecraft to the Moon. In the 1970s, he served as* Voyager*'s first Project Manager. And in 1989, he agreed to manage The Planetary Society's Mars Balloon project.*

Our Members Remember:

Ten Years With The Planetary Society (and on to the Next Ten)

Sunrise from Earth orbit—an impossible sight until humanity dreamed it possible and made the journey to see it. With the Space Age just over three decades old, and The Planetary Society only 10 years old, our members already foresee a future that will take us far beyond Earth.

Photograph: Johnson Space Center, NASA

Membership has its privileges, and one of them is being asked your opinion. We asked a few of our members, including some charter members who joined us way back in 1980 and 1981, to tell us their impressions of The Planetary Society's last decade, and what they would like to see happen during the next one.

I'd like to see more about a prospective mission to Mars. I would also like to see speculation about ordinary citizens taking trips into space. How far into the future will it be before we will be able to take *Concorde*-like regular flights to the Moon and Mars? I would someday like to go to Mars.

In the political arena, I would like to see more attention paid to possible cooperation between the US and the USSR, linking their space programs and sharing non-military knowledge to avoid duplication of effort.
—Betty Kahn, Topeka, KS

I'm completely against SETI (the Search for Extraterrestrial Life). I think the possibility of a productive result is so negligible that it is a waste of resources—the Society would be in a much better position to fund projects that are much less speculative, like more scholarships.

The idea of a human mission to Mars has enthralled me ever since I was a kid. I was 11 years old when *Sputnik* went up, 23 when Neil Armstrong set foot on the Moon, so the idea of humans on Mars has great appeal for me. But I have some misgivings. If the spacefaring nations had a limitless budget for space exploration, then perhaps they should do it. But the US, for instance, hasn't had a government that's been willing to make that kind of a commitment—and I don't think that's going to change anytime soon.

The Society might do best to retrench a bit and promote something that would look better to the budget-cutters in Congress—robotic exploration of the solar system, including orbiters around all the planets and their major satellites, particularly the jovian and saturnian moons. Non-human exploration brings in a lot more knowledge per dollar.
—Dr. Sam Karayusef, St. Paul, MN

I'd like the Society to continue to promote human spaceflight. I don't object to international cooperation in space, but I think this will prove to be too difficult to coordinate. If the point of a mission to Mars is to deploy instruments, collect samples and make observations, then you could design a very elaborate robotic mission to accomplish that. But I agree that a human mission would generate more enthusiasm and support. Just look at the *Ranger* missions that crash-landed on the Moon. How much enthusiasm did they generate, as opposed to the *Apollo* missions?
—Kenneth Goodwin, Acton, MA

As a member of a local astronomical group, I've been proud and happy about the The Planetary Society's encouragement of planetary exploration. I think the Society is well-advised to do whatever it can monetarily in that regard. Admittedly, in the billion-dollar arena of space travel, that sort of participation has to be small, but any effort should be applauded.

As for the Society's interest in SETI, I have qualms about how much of our resources we should devote to it, although I'd love to see it succeed. I think the contributions we've made so far were well-advised, but I don't think our participation ought to be expanded.
—R. Shirriff, Birmingham, AL

Back in 1980 when I joined, I was working with McDonnell Douglas. I was a project leader, and we had just finished working on the *Galileo* Jupiter probe [the contract was awarded to Hughes]. I'm retired now, and I don't think about those things a whole lot anymore, although I do enjoy reading *The Planetary Report*.

The Mars goal seems a little far-reaching to me. We need to make sure the groundwork is properly done before we attempt anything like a Mars mission. A good, solid base beginning with an Earth-orbital station and later, Moon colonization seems better, in the near-term, than focusing on a human mission to Mars. I think we have a tendency to reach out too far, too soon. I am in favor of more international cooperation in space, but I also realize the political realities involved. I'd like to see a bit more emphasis on robotic missions. I support SETI, but at its current funding level—we shouldn't increase it.
—Hans Vetter, Creve Coeur, MO

Earthrise from lunar orbit—if we could send humans to the Moon, why can't we. . . ? The Apollo *Moon landings are seen by some as the apex of human achievement. Planetary Society members believe that we are capable of much more, and that if we work together, we can look back on our home world from Mars or the asteroids, and maybe even detect extraterrestrial life.*

Photograph: Johnson Space Center, NASA

I'm all in favor of the space station and a joint mission to Mars. If humans are going to go to Mars, we've got to get there that way. On our way to Mars, I think we've got to take small steps. I'd also like to see more exploration of the Moon, leading to a possible settlement there—if it wouldn't take too much money away from a Mars mission. A lot of the technology we use every day now came about as a result of trying to go to the Moon.
—Michael Taylor, Peoria, IL

I'm not a fan of the Mars mission, the shuttle or the space station, and would much prefer to see more robotic missions as opposed to human ones. They have historically been the most scientifically successful missions. I am in favor of building a lunar observatory, not necessarily human-operated.

I enjoy *The Planetary Report* a great deal, and read it from cover to cover, although I'm not sure that I agree with all of the Society's stances on certain issues.

I like the SETI program because it shows imagination and flair. Innovative research of the kind that often can't be funded by national funding agencies, NASA in particular, should fall right into the lap of The Planetary Society. It's excellent that we're promoting that with gusto.
—Edward Bowell, Flagstaff, AZ

It does get frustrating to constantly read about plans the US and the USSR have in space. As we read, we think, "that's fine for the US, that's fine for the Soviet Union—but what about Britain? What's our role in this?" Unfortunately, the United Kingdom doesn't have a space policy. That makes an organization like The Planetary Society all the more important, because it's the only way those of us who live in a non-spacefaring nation can participate. I contributed money for SETI. This project is going to become more and more important. Apart from the benefits of radio telescopes constantly monitoring the skies, side benefits will be new discoveries. You can't really lose with that sort of a project.
—Andrew Lound, Birmingham, England

The Society has done an excellent job so far. The Mars adventure is long overdue. In the 1960s, I expected it in the 1980s. In the 1970s, they promised it for the 1990s. I get very annoyed when Society members like Bruce Woollatt (in the March-April issue's Members' Dialog) describe a Mars mission and caring for the Earth as mutually exclusive goals. We have got to accomplish both. What if our ancestors decided to solve all their internal problems before inventing the wheel or crossing the oceans?

The Moon is a nice place to go if you want to mine, but Mars has much more emotional appeal, since it is the planet in our solar system that is most Earthlike. If you want to spread interest in space to anyone besides engineers and scientists, then Mars is it.
—Hans Starlife, Stockholm, Sweden

We need to focus on our scholarship program. While we've done a good job encouraging young people to go into the sciences, we should do more, because it's projected that the shortage of personnel is going to become critical if we don't encourage people in science education.

We should also educate people on the mission of The Planetary Society, telling people why we think planetary exploration is a good idea, especially now that there is so much weeping and gnashing about the problems in the US space program. We need to maintain our focus on why it's important to go into space. We should be saying to people "Space is not a friendly place. It is, and will be, a difficult place, and there will be problems—but it's still worth going to." There are wonderful things to be learned out there, and the technological spinoffs, not the least of which are medical, directly affect the quality of all of our lives here on Earth.

We cannot afford to let up on the goal of planetary exploration. We should continue to support SETI, especially in the light of all the US government cutbacks.
—David Brown, Houston, TX

From what other worlds might we someday watch a dawn or dusk? If we listen to Planetary Society members, then humanity is bound only by the laws of physics, the limitations of biology and our own imagination and will.

Painting: Pokhadayev, from In the Stream of Stars

Asteroids in Your Future—

The Next Decade of The Asteroid Project

by Eleanor Francis Helin

To foretell what will be done with near-Earth asteroids over the next 10 years, you have to have faith that humans are interested in exploring space. They should be very interested! We occupy an extremely small piece of space. There is so much waiting for us to discover, if only we want to.

The Planet-Crossing Asteroid Survey (PCAS) is a continuing program to search for the small solar system objects that pass near Earth. Our program is funded primarily by NASA, but over the years we've received much-needed support from private individuals as well as Planetary Society members. With the help of the World Space Foundation, which administers our Planetary Society grant, my team and I have been able to discover new worlds just waiting to be explored.

To date (August 1990), we have documented 144 near-Earth asteroids, ranging from a few hundred meters across to a few exceeding 15 to 20 kilometers. Most are in the one- to three- kilometer range. In terms of orbits and compositions, these objects make up a very diverse population. About a dozen are easier to reach, in terms of energy, than the Moon. We could prospect these asteroids robotically. They are perhaps the best candidates for missions using solar sails powered by the most efficient energy source known—sunlight. And, if humans are serious about exploring the solar system themselves, missions to asteroids would be excellent tests for more ambitious voyages to Mars and perhaps beyond.

The Planetary Society agreed to fund Eleanor Helin's asteroid project in the hope of finding good candidates for spacecraft missions. Our investment paid off almost immediately with the discovery of 1982DB, which is still one of the easiest known asteroids to reach from Earth.

Photograph: Eleanor F. Helin

With all this potential, why aren't asteroids given more attention? They should be!

We began the Planet-Crossing Asteroid Survey some 20 years ago with the goal of increasing our knowledge of the bodies that populate near-Earth space and might eventually collide with terrestrial planets. The cratered surface of the nearby Moon records a history of bombardment that has been mostly erased from the changing surface of Earth.

Are They Important? Ask a Dinosaur

It is through the study of meteorites (asteroids that survive the trip through Earth's atmosphere) that scientists may have discovered what happened to the dinosaurs. (See the January/February 1985 *Planetary Report*.) Most scientists now believe that an asteroid or comet crashed into Earth some 65 million years ago, causing the extinction of the dinosaurs. It seems only prudent to patrol our skies for objects on a collision course with us.

The great promise as well as peril offered by the asteroids should motivate us to do constructive things with them. The first step is to find them. It is doubtful that we have located to date more than about 10 percent of the total population larger than a kilometer in diameter.

As we have become more effective, more efficient and worked still harder, the PCAS discovery rate has increased. Since January 1989, our program has found 15 near-Earth asteroids and 5 comets. The Schmidt telescopes that are used on Palomar Mountain have been responsible for the greatest number found in the world. This record is the result of the systematic searches, hard work and the diligence of the asteroid teams.

Even with these excellent results, we still strive to do an even better job, although we work with 19th-century techniques using old equipment looking at a tiny part of the sky on a very thinly stretched budget. If we can find the funds, we can make improvements and step up our program to increase our discovery rate and get significantly better results.

We are also ever vigilant for technical breakthroughs. One possibility would be to mate charge-coupled devices (CCDs) to the focal plane of a wide-field Schmidt telescope. This combination would provide large sky coverage and allow us to detect fainter objects deeper in space. With this type of improvement we could begin discovering perhaps 10 times as many near-Earth asteroids as we now do.

Our present equipment has so far limited our discoveries; we know virtually nothing about the population 10 to 50 meters in diameter. If one of these should collide with

our planet, it could cause devastation out of proportion with its small size. Meteor Crater in Arizona, over 200 meters deep and one kilometer wide, is an example of what a 50-meter object can do.

The present level of NASA funding, along with help from adventuresome individuals, including Planetary Society members, will allow us to continue our critical work and improve our techniques. But upgrading our instruments to enable us to pick up smaller objects would require much more money than is now available.

Too Close for Comfort

Perhaps if a modestly sized asteroid were to pass extremely close to Earth, the unsettling experience would raise the level of interest in asteroid searches. Over the last year, a few asteroids (that we know of) made very close approaches to Earth. The closest, 1989FC came within 750,000 kilometers of our planet. Our team discovered three others that came uncomfortably close by astronomical standards: 1989PB came within 4 million kilometers, 1990MF came less than 5 million kilometers, and just last month, on August 9, 1990OC passed within 6 million kilometers. I hope that it takes something less than an asteroid impact to jolt us out of our complacency!

Our search program has found some of the most accessible of near-Earth asteroids. These bodies travel in orbits that bring them close to Earth's orbit, so a spacecraft could reach one with a minimal amount of fuel. The three most accessible known are 1989ML (according to recent analysis by Alan Friedlander), 1982DB (described in the May/June 1982 *Planetary Report*) and 1982XB (described in the January/February 1982 *Planetary Report*). Our PCAS team recently discovered two more likely candidates for missions, 1990MF and 1990OS.

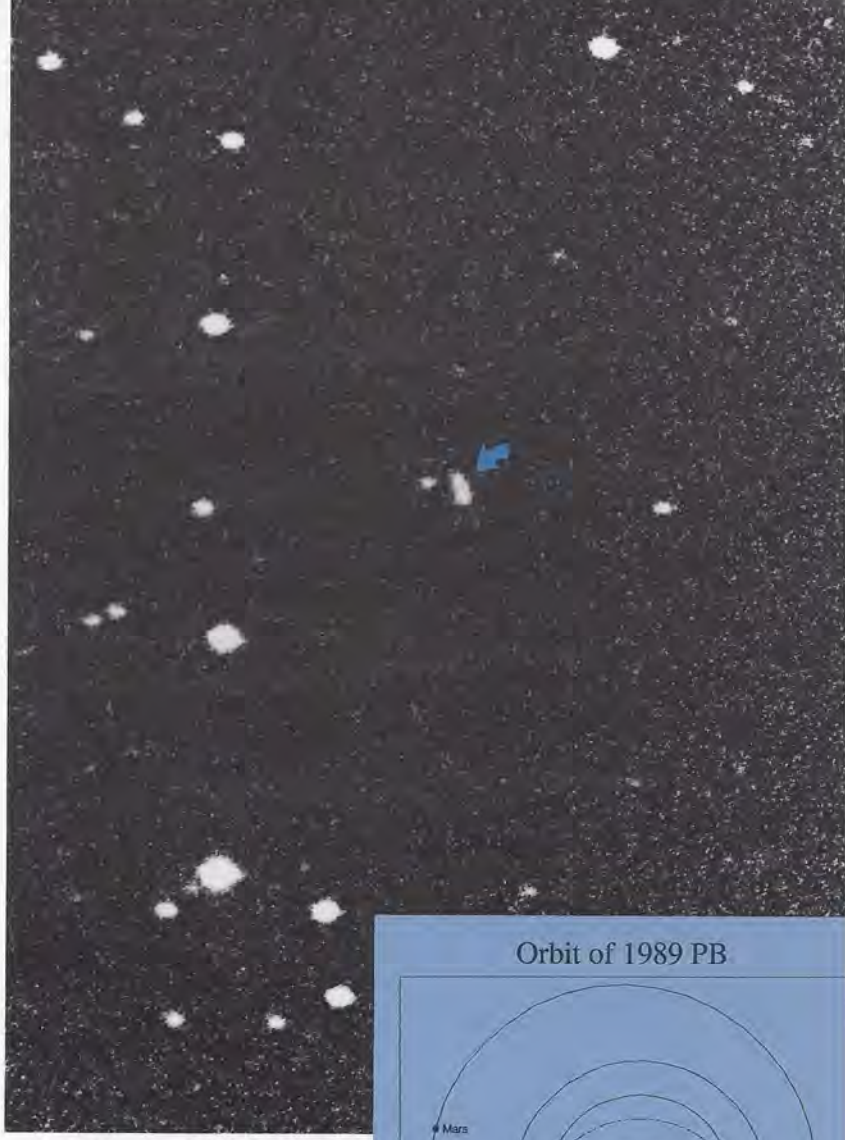
The United States and the Soviet Union both have plans to visit asteroids in the Main Belt that circles the Sun between the orbits of Mars and Jupiter. This is where most of our solar system's asteroids are found, and the Main Belt is a major source of near-Earth asteroids. The *Galileo* spacecraft will pass by asteroids Ida and Gaspra on its way to Jupiter. The Comet Rendezvous/Asteroid Flyby mission now planned by NASA would take a close-up look at another of these small bodies. The Soviets are considering sending a spacecraft to Vesta, one of the largest known asteroids.

Many people have proposed that hardware left over from earlier space probes could be used for a cost-effective first look at a near-Earth asteroid. We might even accomplish a sample-return mission before the end of the century.

When I consider the progress I've witnessed over the 30 plus years since *Sputnik*, I'm pleased to have been around during this fantastic time. Since the basic work has been done, there are no reasons other than mandate and money that we can't now produce similar seemingly amazing accomplishments. We need only to springboard into space, using many of the resources we can find there to meet the challenges of the 21st century.

This next decade will witness discoveries of more unusual bodies in our solar system. Perhaps we'll find the theoretically predicted Earth Trojan asteroids, traveling along our planet's orbit 60 degrees ahead of and behind us. We may catch an object in the act of changing from an active comet to an inactive asteroid. There may be distant small bodies orbiting beyond Pluto and Charon. Maybe we'll find members of the now-theoretical Kuiper Disk of comets in the vicinity of Uranus and Neptune. Or perhaps we'll even detect a denizen of the inner Oort Cloud. These refugees from that hypothetical reservoir of comets surrounding our solar system will probably only be seen after they have broken loose from the outer cloud and begun their journey toward our neighborhood. There are many surprises still left for us as we explore our solar system with renewed vigor.

Discoveries are waiting for the diligent and daring!



A large population of asteroids orbits the Sun in the vicinity of Earth—and occasionally they cross our path. Shortly after Helin and her team discovered 1989PB last year, the asteroid passed within only 4 million kilometers (2.5 million miles) of Earth. By astronomical standards, that was a close call.

Photograph: Eleanor F. Helin

Eleanor Francis Helin, known to her friends as "Glo," is one of Earth's premier asteroid hunters. As the Principal Investigator for the Asteroid Project supported by The Planetary Society, she leads an industrious team, including Brian Roman, Ken Lawrence and others, that has substantially added to our knowledge of objects that travel through Earth's neighborhood in space.

Glimpses of a Goddess—

Captions by Donald B. Campbell

To the Babylonians she was Ishtar, queen of supernatural beings. To the Greeks she was Aphrodite, the divine manifestation of love. The Romans appropriated the Greek ideas about the brightest point of light in the sky, and called her Venus after the local love goddess.

We denizens of the Space Age retain the Roman name for the second planet from the Sun, and value her now for what she can tell us about the history of our solar system and about our own home planet. To this end, we've sent three *Mariners*, sixteen *Veneras*, a *Pioneer* orbiter and probe mission, two *Vegas* and now *Magellan* to investigate our closest planetary neighbor. Even now, 28 years after our first spacecraft reached her, Venus continues to hold our attention.

Venus is permanently shrouded in thick, yellow clouds, her face forever hidden from eyes that see in the visible portion of the electromagnetic spectrum. Yet instruments that use radio waves, such as radar, can see through the clouds. *Veneras 15* and *16* mapped the planet and picked out features as small as one kilometer across. *Magellan*'s radar will reveal details as small as a football field. This will be our most detailed look yet at Venus, and this mission should teach us much.

Yet there is still much we have learned from instruments based on Earth. The great radar dish at Arecibo, Puerto Rico, over 300 meters across, can beam a powerful signal at Venus and catch its reflection. By processing the radar data, scientists produce pictures like the ones you see on these pages.

Each new fact seems to raise another question. Is Venus' surface shaped by tectonic forces, as Earth's face changes as continents drift across crustal plates? Do volcanoes erupt from its surface, creating craters and spewing toxic gases into an already noxious atmosphere? Is Venus pocked by impacts with asteroids and comets, as are all the other terrestrial planets?

Scientists using the detailed *Magellan* data will soon be answering these questions for us. But the more Venus teaches us, the more our fascination for her increases. One thing is certain: We will never tire of learning about her hidden charms, and through her, the secrets of our own planet, her sister, Earth.

—Charlene M. Anderson

FIGURE 1
Lat. 45°S to 10°N
Long. 250° to 40°
Resolution Approx. 2 km

The Arecibo Radar Looks at Venus

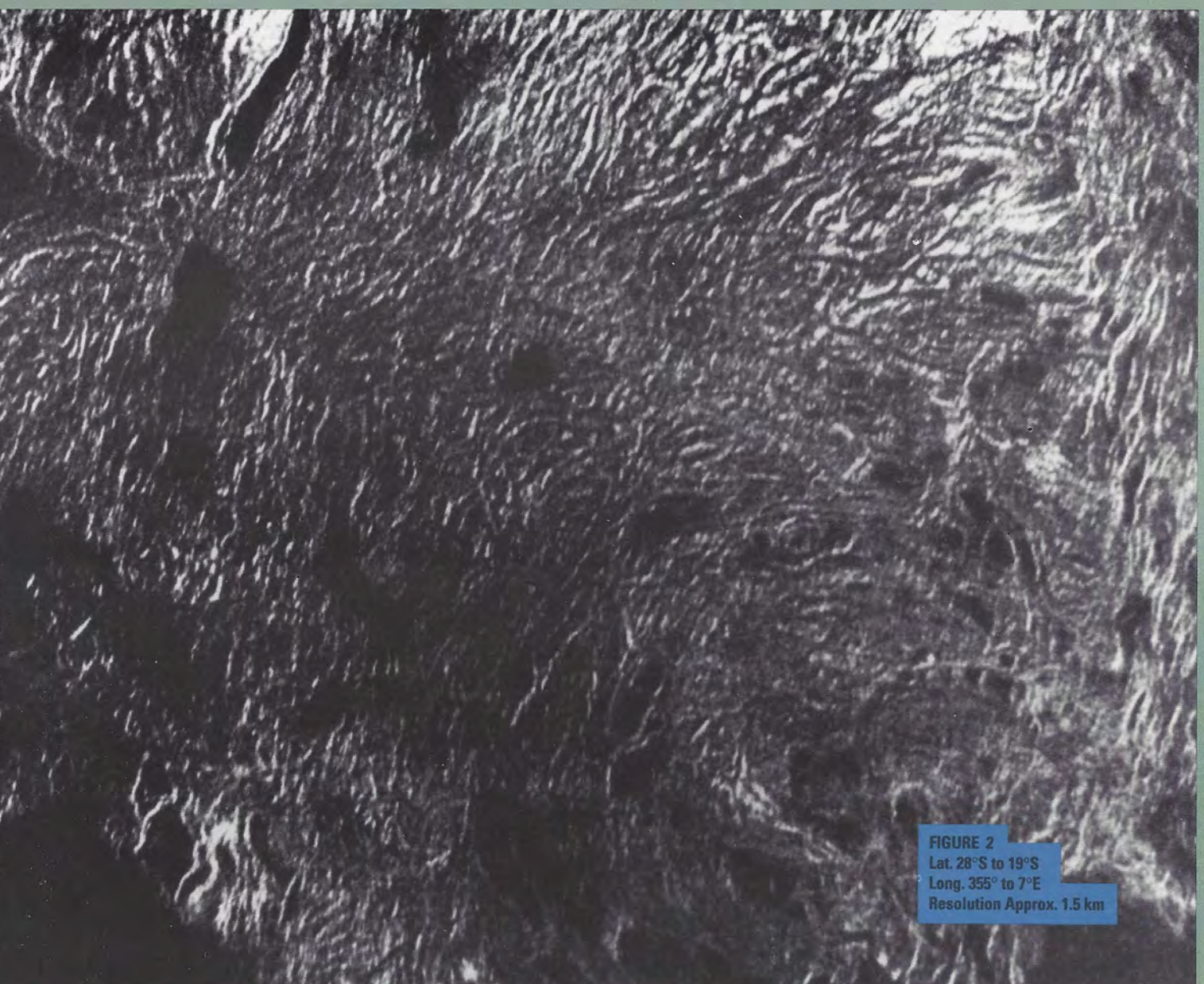


FIGURE 2
Lat. 28°S to 19°S
Long. 355° to 7°E
Resolution Approx. 1.5 km

Figure 1— Alpha Regio and Environs

In the early 1960s, scientists probing with radar beneath Venus' clouds discovered a spot that strongly reflected their radio beams. They named this first-identified surface feature Alpha Regio. In this picture it is the bright region to the right of center. The ridged and grooved face of Alpha Regio is similar to a type of terrain called "tessera." On the far left side of the picture there are three large shield volcanoes, Ushas, Innini and Hathor Montes. Near Ushas Mons, radar has detected numerous small, probably volcanic, domes. Many possible impact craters can also been seen in the radar data. Just to the left of center are three prominent craters, whose origin—either volcanic or impact—is as yet unknown.

Figure 2 — Alpha Regio

Two Soviet radar-mapping spacecraft, *Veneras 15* and *16*, investigated Venus in the 1980s. They discovered a type of terrain marked by cross-cutting systems of ridges and valleys. The appearance of the terrain suggested tiling, so it was called "tessera" after the Greek word for tiles. Scientists are still debating the nature of the processes that deformed the surface in this fashion. Tesserae cover about 14 percent of the planet imaged by the *Veneras* at high northern latitudes. The Arecibo radar has examined 56 million square kilometers of Venus, and found only one large area of tesserae—the highlands of Alpha Regio. This picture is a close-up of the bright region in Figure 1.

FIGURE 3
Lat. 37°S to 17°S
Long. 327° to 353°E
Resolution Approx. 2 km

Figure 3—
West of Alpha Regio

Just to the west of Alpha Regio is an area informally referred to as the "Crater Farm" because of the high density—for Venus—of craters. The three large craters in the center of this picture (a detail from Figure 1) have interior diameters of 50, 40 and 30 kilometers. Around them are several other smaller craters and numerous, possibly volcanic, domes. Scientists are debating whether the craters are of volcanic or impact origin, but the question should be settled by results from the *Magellan* mission.

FIGURE 4
Lat. 78°S to 50°S
Long. 250° to 40°E
Resolution Approx. 2 km

Figure 4—
Helen Planitia and Lada Terra

This Arecibo image is the first look we've had at the high southern latitudes of Venus. (*Veneras 15* and *16* imaged northern latitudes only.) We see here an upland area named Lada Terra, which was identified in the *Pioneer Venus* altimetry data at the southern edge of its coverage. Lada Terra fills most of the right side of this image, with its northern boundary outlined by three ovoid features 300 to 400 kilometers in diameter. Similar features called coronae appear in the *Venera* data. Scientists believe these features are surface expressions of convective processes, where molten material from the planet's interior wells up to the surface. The giant corona in the lower right is almost 1,000 kilometers across and is one of the largest so far discovered on Venus.

The smooth plains of Helen Planitia fills most of the left side of this picture. The circular structure at top center is probably a double-ringed impact basin; it is named after the great physicist, Lise Meitner.

Donald B. Campbell is a Professor of Astronomy at Cornell University. From 1981 to 1987 he served as Director of Operations at the Arecibo Observatory in Puerto Rico.

Sister Worlds: Earth and Venus

by Susan Lendroth

You can't pick up a newspaper today without reading about threats to Earth's environment—ozone depletion, deforestation, global warming. Despite extensive press coverage, few people know the role planetary exploration plays in helping to provide a better understanding of these problems.

The Planetary Society's new program, "Sister Worlds: Earth and Venus," explores this field of comparative planetology, examining how planetary research has given us insights into the workings of Earth's environment. And we still have much to learn. "Sister Worlds" is part of the Society's broader "Earth as a Planet" program.

"Earth as a Planet" involves The Planetary Society working cooperatively with individuals, organizations and institutions around the world to help find solutions to the environmental problems facing Earth today.

Funding for "Sister Worlds" comes from member donations to the "Earth as a Planet" program and from a grant by the Norris Foundation, which also provided funding for such Planetary Society programs as Mars Watch and *Voyager* Watch.

Earth, above, and Venus, below, are often called sister worlds. They are nearly the same size, orbit in the same solar system neighborhood and are made of nearly identical materials. But they have evolved into very different places. *Images: Earth, Johnson Space Center; Venus, Ames Research Center, NASA*

Venus has often been called Earth's twin or "sister world." It's our closest planetary neighbor, and is roughly equal to Earth in size and mass, yet the two planets have evolved along widely divergent paths.

For millennia, humanity devised countless tales about this mysterious, cloud-shrouded planet, including the idea that Venus was a steaming jungle world of swamps warmed by its proximity to the Sun. The truth is even more bizarre—we now know Venus to be a scorched wasteland with a surface temperature hot enough to melt lead.

How did two planets that are so similar end up so differently? And, knowing that, what can Venus teach us about our own world? These are some of the questions "Sister Worlds: Earth and Venus" helps answer.

As we have with all Society programs, we are offering free "Sister Worlds" material to both the general public and educators. Available on request is a special information packet that includes fact sheets on Venus and the *Magellan* mission, a reprint of a *Planetary Report* article by Carl Sagan, guidelines for planning events and a request form for borrowing a custom-made slide set. Teachers should also request the set of accompanying lesson plans.

The "Sister Worlds" slide set will be available in October, in time for organizations to coordinate events around new data that will be coming in from *Magellan*'s mapping mission of Venus, the *Galileo* flyby of Earth in December and the beginning of the school year. Our collection of 40 slides with narration on cassette tape, "Sister Worlds" will take viewers on a journey from the blistering surface of Venus to the cool blue atmosphere of Earth.

A series of special events is being planned for fall and on into 1992 as part of both the "Sister Worlds" and the broader "Earth as a Planet" program. These include a lecture by Carl Sagan on October 22 in Charlottesville, Virginia, entitled "A Pale Blue Dot: Exploring Other Worlds and Protecting This One;" a January, 1991, "Sister Worlds" presentation at the Smithsonian Air and Space Museum in Washington, D.C. in conjunction with the opening of the new IMAX film *The Blue Planet* and special programs for the 1992 International Space Year. Additional activities will be scheduled throughout the coming months in partnership with science museums, astronomy groups and other institutions worldwide.

The Planetary Society hopes that these programs will illuminate how studying the other worlds of our solar system helps us better understand and appreciate our own fragile piece of the universe.

For a copy of the "Sister Worlds" packet, write to "Sister Worlds," c/o The Planetary Society.

Susan Lendroth is Manager of Events and Communications for The Planetary Society.

SEEDING THE FUTURE

Ten Years of Planetary Society Support for Small but Significant Projects

by Charlene M. Anderson

How can an organization like The Planetary Society measure its success?

In just our first few years we grew to be the largest space-interest group in the world. In the US Congress and administration, and with Soviet space leaders, we've built a reputation as effective advocates of planetary exploration and the search for extraterrestrial life. Whenever a big space story breaks, our telephones start ringing off the hook with press calling for thoughtful comments and good quotes. In 10 short years, The Planetary Society's voice has been heard around the world.

In these many ways we might measure our success.

But as an organization that by its very nature seeks to shape the future, The Planetary Society may prove to have been most effective in the way we've supported small projects with great potential—potential far out of proportion to their costs. META I and II, the Asteroid Project and the SNAKE for the Mars Balloon are our largest and most visible projects, but over the years we have undertaken or sponsored many smaller projects that may someday bear extremely valuable fruit.

Our philosophy for choosing what projects to fund was laid down early in our history: As a medium-sized membership organization (as compared to a group like the National Geographic Society with 10,500,000 members), The Planetary Society can't fund extremely expensive research, nor can we afford to support numerous small programs. But we can seek out projects where a small amount of "seed" money may enable a program to grow that will have great impact on the future.

Such small programs often slip through the cracks of foundations and governments. We can tide over a valuable research program until it finds a continuous source of funding. When governments and their agencies aren't talking to each other, we can bring together people who can significantly contribute to each other's programs. We can tackle questions that official agencies are not yet ready to ask.

In our first 10 years, The Planetary Society has taken on many programs like these, programs that have made a difference. Here we have room only to mention a few, but their breadth, diversity and even ambition will stand for what we feel are some of our greatest successes. In the next 10 years, we hope to see some of these seeds bear fruit of their own. We will keep looking for fertile projects to nurture. And we may then measure our success by achievements we have not yet even imagined.

As commissioned by The Planetary Society, Science Applications International Corporation envisioned the type of spacecraft that might someday take humans to Mars.

Painting: Michael Carroll

Mars Oxygen Production System Design

The scope of human Mars exploration can be limited by many things, but one of the most important handicaps is the mass to be launched from Earth, landed on Mars and launched back to Earth. For missions using propulsion systems available in the near future, most of that mass will have to be propellant. If we can decrease the necessary amount of propellant, we can increase the mission's scope.

A solution to this problem is to manufacture propellant on Mars. This project at Old Dominion University in Virginia built a test system that manufactured liquid oxygen for propellant from a simulated martian atmosphere. The Planetary

Society provided a grant to buy the needed equipment.

The Very Cheap, Quick Mission Study

In 1987 The Planetary Society began a study of what we called the "Very Cheap, Quick Mission" to the Moon. The goal was to find a way—using inexpensive technology—to find water ice that may be trapped in permanently shaded areas of the lunar poles. The question of whether or not the Moon holds water is crucial to planning future exploration. Despite intensive effort, the study participants could not find a quick and cheap way to make unambiguous measurements that can answer that question.

The Graz Meeting

In 1984, when relations among nations discouraged official cooperation in research and on missions, The Planetary Society brought together in Graz, Austria some of the leaders in space science and engineering. Soviets, Europeans and Americans exchanged data gathered from missions to and research on Mars and Venus. The Soviets announced their *Phobos* mission to Mars and its largest satellite. Soviet scientists invited American scientists to work on the mission with them.

American scientists were on the *Phobos* team when the mission launched on schedule in 1988.

Together to Mars Spacebridge

The Planetary Society used the technology of communications satellites to hold a "spacebridge" conference between scientists and engineers in the Soviet Union and the United States. Through the satellite link, they freely exchanged ideas about the robotic and human exploration of Mars—and whether the two spacefaring nations could undertake it together.

The Public Broadcasting Service (PBS) used our spacebridge as the basis for a one-hour special on Mars exploration; other programs were shown in the USSR and Japan.

Mexico City Educators' Workshop

Educators outside of the spacefaring nations do not always have access to information and materials about planetary science. The Planetary Society believes that the excitement children feel about exploring the planets can be harnessed to foster their interest in science in general. During this 1987 workshop, planetary scientists shared their knowledge with teachers and others involved with curriculum development. The lectures were videotaped and will eventually be made into teaching aids for Spanish-speaking audiences worldwide.

We are considering trying to repeat the success of this workshop with another to be held in Argentina.

Linked by satellite with their Soviet colleagues, American planetary scientists discussed the possibilities for exploring Mars during the Spacebridge sponsored by The Planetary Society. This landmark meeting formed the basis for a television show broadcast by the Public Broadcasting Service, and in the USSR and Japan.
Photograph: Rhoda Pollack

A Search for Substellar and Planetary Mass Objects Orbiting Nearby Stars

We do not yet possess the technology to actually "see" planets around other stars (that may change when the Hubble Space Telescope is fixed), but by being clever it may be possible to detect them. One of the most intriguing projects is this search by astronomers at the University of Victoria, British Columbia. They can precisely measure velocity shifts in stars that may indicate the presence of unseen planetary companions.

The Planetary Society contributed a small amount of seed money to this project, enabling it to continue until it successfully found other sponsors.

Planetfests '81 and '89

The two grandest parties ever thrown for planetary exploration were the Planetfests organized by The Planetary Society to celebrate the triumphs of the *Voyager* project. For *Voyager 2*'s 1981 encounter with Saturn, over 15,000 people came to watch images transmitted live from the spacecraft as it passed the planet. In 1989, for the Neptune encounter, we again held symposia, set up displays and showed live images, but this time we topped it all off with a party at JPL featuring entertainment by Chuck Berry. The bash was broadcast live on the Turner Broadcasting System, and, in Japan, over the Asahi Broadcasting System. □

Television audiences in the US and Japan shared in our huge closing party for Planetfest '89, celebrating the people who helped Voyager 2 on its grand tour of the outer solar system.
Photograph: Ken Wong

Students: Help Send Us "TOGETHER TO MARS"

by Barbara Bruning-La Belle

"Where were you when humans first landed on the Moon?" That question has been asked countless times since July 20, 1969. On that day, people around the globe joined together to witness the unimaginable: humans stepping on to the lunar surface. For those too young to remember, it may be hard to imagine the thrill that surged throughout the entire human community, regardless of nationality, religious or cultural differences.

Many years later Geneva, Switzerland was the site of the 1988 Wright Colloquium, "Voyage to Mars." In attendance were several prominent scientists: Among those meeting with the Colloquium's sponsor, H. Dudley Wright, were Bruce Murray and Tom Paine of the United States, Roald Sagdeev and Sergei Kapitsa of the Soviet Union, and Jacques Blamont of France. All could attest to the enormous effect the lunar landing had upon their lives. Now, they gathered to envision the next step: the exploration of Mars.

H. Dudley Wright International Student Contest

To accomplish this goal, a daunting number of physiological, technical and environmental problems must first be resolved. But the scientists who gathered that day may not be the ones to solve them. Who will be called upon to answer these challenges? The citizens of the 21st century, today's high-school students.

The discussions at the Colloquium inspired an exciting new science competition, the H. Dudley Wright International Student Contest, entitled "Together to Mars." This contest is administered and promoted by The Planetary Society with support from the H. Dudley Wright Foundation. The contest was established to encourage young people's creativity and achievement in international peaceful space exploration, with exploration of Mars as the next objective.

Who Is Eligible?

All students born during or after 1973 are invited to submit 3,000- to 10,000-word essays on topics related to life-support for a Mars mission. All who enter will receive recognition.

Three national finalists will be chosen from each participating country to enter the international competition to be held in the summer of 1991. Final selection of the 20 international winners (no more than three from any one nation) will be made by a distinguished international panel of scientists and educators.

A maximum of 20 prizes of $2,500 (US) will be awarded to each international winner. In addition, the winners and their teacher/mentors will be flown to Washington, D.C. to attend the Space Congress that will be held during the International Space Year 1992.

"TOGETHER TO MARS" Contest

As of this writing, 27 nations are officially participating in the "Together to Mars" competition. Representatives of the H. Dudley Wright International Student Contest can be found in the following countries:

Argentina
Australia
Belgium
Canada
Colombia
Costa Rica
Denmark
Finland
Great Britain
Hungary
India
Iran
Ireland
Israel
Italy
Japan
Malaysia
Mexico
Norway
Pakistan
Portugal
Spain
Switzerland
Thailand
The Netherlands
The US
The USSR

Opportunities still exist for institutions and qualified individuals to coordinate the contest in countries not yet represented. Where the contest is already established, there is still a need for student mentors. If you would like to participate in the "Together to Mars" competition, either as a coordinator or as an entrant, write to:

The Planetary Society
"Together to Mars,"
65 No. Catalina Avenue,
Pasadena, CA 91106.

Be sure to include your complete name and address, including your Zip or postal code and your country. State that you would like information on the H. Dudley Wright International Student Contest and give the name of your local coordinator.

Barbara Bruning-La Belle is Program Coordinator for the H. Dudley Wright International Student Contest.

The Volunteer Network—A Vital Link

by Carlos J. Populus

From the very beginning of The Planetary Society, our members have asked about ways they could become even more involved in supporting the Society and the future of space exploration. As our membership increased all over the world, these inquiries also shot up dramatically. It became clear that a large percentage of our membership is not content with simply sitting back and watching events unfold. Our members want to be directly involved in making things happen.

Here at our Pasadena headquarters, we have had from the beginning a small but very dedicated group of people—Lu Coffing, Carol Buck and David Hagie, to name three who are still with us—who generously donated much time and effort in helping the Society through its infancy. Because of this help, The Society's management felt that a volunteer effort on a worldwide scale might prove even more successful.

Thus, in September of 1986, the Volunteer Network was born, making possible our members' greater participation in furthering The Planetary Society's goals. Volunteers were encouraged to take the initiative in setting up displays, collecting signatures on the Mars Declaration, passing out brochures, recruiting new members, and organizing lectures in their local areas.

Just four months after the announcement of its formation in the September/October 1986 issue of *The Planetary Report*, the Volunteer Network could boast 337 members. Today, four years later, the number of dedicated volunteers on our roster has grown to more than 1,500 worldwide. Of these, 109 serve as regional coordinators.

With the Volunteer Network's assistance, The Planetary Society has been able to conduct some very successful programs. Mars Watch in 1988 and *Voyager* Watch in 1989 each engendered many co-sponsored events (lectures, demonstrations, visual presentations and so forth) all over the globe, due almost entirely to the efforts of our volunteers.

Some of these projects were especially exciting and fun—such as Planetfest '89, held in August 1989 in Pasadena. (See the November/December 1989 *Planetary Report*.) Volunteers gave up both time and sleep to sell T-shirts, run projectors and even work as security guards. We couldn't have pulled it off without them.

HOW YOU CAN HELP

If you would like to join this group of enthusiastic volunteers and help support the goals of The Planetary Society, please write to Carlos J. Populus, Volunteer Network Coordinator, 65 No. Catalina Avenue, Pasadena, CA 91106.

And then there was the "Big Dublin Star Party." This event, orchestrated by Irish Volunteer Coordinator Paul Bracken, was held as the big finish to the *Voyager* exhibition, presented in conjunction with the Irish Astronomical Society.

Bracken expected that the bash, held in Dublin's Phoenix Park, would draw a few hundred people. Instead, over 2,000 people waited patiently in line (some of them even holding infants!) in order to take a peek at Neptune and Saturn through one of six borrowed telescopes. Society volunteers circulated through the crowd to explain what was happening in the skies. Many of those who attended were not Planetary Society members—not *yet*, anyway. These are just two examples of the dedication shown by Volunteer Network members all over the world.

Scheduled for this year are 39 events (lectures and displays) conceived, organized and carried out entirely by members of the Volunteer Network, in locations as diverse as Brisbane, Australia; Willowdale, Ontario, Canada; Berkeley, California; Birmingham, England; Isfahan, Iran; Kepong, Malaysia; Boston, Massachusetts; Nordhorn, Germany; and many other locations. Volunteers are also serving as support staff for an additional 29 Planetary Society events. That's a total of 68 events scheduled so far, and we will probably add an additional 20 to 30 events before year's end.

In celebrating our tenth anniversary, The Planetary Society would like to thank all who contributed to our growth as Volunteer Network members. In addition, we would like to single out the following individuals for a special thank you for their outstanding contributions on behalf of The Society. Alphabetically, they are: Barbara Bowman in Berkeley, California; Carol Buck in Rancho Palos Verdes, California; Regina Forbes in Holbrook, Massachusetts; David Hagie in Pasadena California; Tom Hanna in Milwaukie, Oregon; Kerry Johnson in Santa Paula, California; K.K. Kooi in Petaling Jaya, Malaysia; Andrew Lound in Birmingham, England; Hema Murty in Toronto, Canada; and Michael Slage in Fountain Valley, California. These individuals have distinguished themselves by their unusual initiative and hard work on behalf of The Society.

As to the future, we hope that the Volunteer Network will grow to have one active regional coordinator in every state in the US and in each country in the world. Through the initiative of our coordinators we hope to be able to hold events in every corner of the planet. We are counting on the Network to be instrumental in the success of our "Sister Worlds" program, in circulating the Mars Declaration, and in continuing to spread our message of peaceful, cooperative space exploration to all the inhabitants of Earth.

Carlos J. Populus is Volunteer Network Coordinator of The Planetary Society.

by Louis D. Friedman

WASHINGTON, DC—NASA's troubles with the Hubble Space Telescope and the grounding of the space shuttle fleet have provided rich grist for the Washington political mills. Coming right in the midst of debate over the federal budget, these problems led to debate and discussion in the White House and Congress about what NASA should have done and should do in the future.

As we go to press, it appears that the fault in Hubble's primary mirror could have been detected by testing on the ground. The hydrogen leaks in two separate shuttles' fuel systems were unrelated to each other, and we hope the shuttle will soon be flying again.

Even if NASA can fix all the technical problems, it still faces a crisis of confidence. Critics within and without Washington are questioning the agency's ability to carry out large scientific and technical projects.

Pressure from the huge and growing federal deficit is also squeezing the agency. Facing fierce competition for shrinking federal funds, NASA programs already underway are being pinched and future programs have become questionable.

Before the Hubble and shuttle problems surfaced, the Appropriations Committee in the House of Representatives had already emphatically refused to appropriate money to study the Moon and Mars missions President Bush has proposed. Planetary Society members sent thousands of letters to their Representatives and Senators urging that they support the initial studies for human exploratory missions. In their responses, the politicians frequently stated that while they supported space exploration, such new programs would have to wait. Continuing programs, such as the shuttle and space station, needed their funding increased and would receive priority.

The political and budgetary ramifications of the Hubble and shuttle problems are severe. When a shuttle launch is delayed, it can cost millions of dollars per month just to store the payload. To fix the space telescope will require NASA scientists and engineers to implement new and costly procedures, and ultimately new instruments must be launched and installed.

Many of these problems are results of NASA's dependence on the shuttle to launch almost all scientific payloads. The shuttle fleet was supposed to be

The Illogic Is Irrefutable

The NASA Search for Extraterrestrial Intelligence program is designed only to "listen" for radio signals that another civilization might be broadcasting to other advanced civilizations. It is not a program that actively attempts to contact other possible life forms. In his fiscal year 1991 budget, President Bush had asked $12 million for NASA's SETI program. The House Committee on Appropriations cut that to $6.1 million. When the committee's proposal reached the floor of the House, Representative Ronald K Machtley [D-RI] introduced an amendment to eliminate SETI funding from the federal budget. We excerpt here portions of the discussion on the House floor.

Silvio Conte (R-MA): "We don't need to spend $6 million this year to find evidence of these rascally creatures. We only need 75 cents to buy a tabloid at the local supermarket. Conclusive evidence of these crafty critters can be found at checkout counters from coast to coast. [Mr. Conte then entered into the Congressional Record five articles on UFOs from tabloid publications.] If we continue to fund this dog [NASA's SETI program]—a Golden Fleece award winner in 1978—then we should seriously consider funding an even more ambitious program—SCI: Search for Congressional Intelligence."

Ronald K. Machtley (D-RI): "We cannot spend money on curiosity today when we have a deficit. I might suggest that, in fact, if there is such a superintelligence [sic] form of life out there, might it be easier just to listen and let them call us?"

Bob Traxler (D-MI): "The logic of the distinguished gentleman from Massachusetts [Mr. Conte] and the maker of the amendment [Mr. Machtley] is irrefutable."

capable of more than 30 launches per year. Then the frequency lowered to 15, then 10 and now may be even less. Routine and regular American access to space has proved an illusion.

Since plans for space station *Freedom* depend on routine and frequent shuttle launches, this program now also faces serious questions.

To simply assemble the space station will require some 30 shuttle launches over 4 years. The Congressional Office of Technology Assessment (OTA) estimates that, even with 98 percent reliability in the shuttle program (a figure not yet achieved), there is an 8-in-9 chance that a shuttle will fail while building the space station. Even a single shuttle failure would be catastrophic to the space station program.

Another problem was addressed in an internal NASA study, which estimated that astronauts will have to perform over 3,000 hours per year of extravehicular activity (EVA) to build and then service the space station. A normal, full-time work year is 2,080 person-hours. This excessive need for EVA would be a threat to the astronauts' safety.

Both NASA and the White House National Space Council (chaired by Vice President Quayle) are considering these problems and their possible solutions while debate continues in Congress.

These problems came at possibly the worst moment for the American space program. For the first time since the Kennedy/Johnson administration, the White House has shown an active and positive interest in space exploration. Under White House pressure, NASA appointed an external commission to consider the agency's organization and ability to carry out future programs. Congress held hearings on the shuttle and Hubble problems, and on NASA itself.

The current troubles, coupled with Congress' lack of enthusiasm for Bush's human exploration initiative, focus our attention on the need to define and disseminate the rationale for the human exploration of space. To address this, The Planetary Society considered—for the first time—accepting government money to examine the reasons for space exploration and ways to build public support for it.

We planned a series of four conferences to study and discuss why humans should explore the solar system. The Planetary Society asked the National Space Society to organize public sessions for these conferences. We hoped to bring space professionals, influential thinkers and the public together to build a rationale that can carry the American space program forward. However, the lack of funds for the Space Exploration Initiative have put this plan on hold.

WASHINGTON, DC—NASA's Search for Extraterrestrial Intelligence (SETI) again encountered opposition in the United States Congress. From the floor of the House, Representative after Representative took turns commenting on the program. An amendment to the federal budget offered by Representative Silvio Conte (R-MA) deleted all 1991 funding for NASA's SETI program. As I write this, the Senate still has to act upon this amendment.

By NASA standards, SETI is a small program, requiring only a few million dollars a year; the House Appropriations Committee had voted it $6 million for 1991. Although it has widespread scientific support and is popular with the general public, for those unfamiliar with the strategy of listening for extraterrestrial radio signals, SETI is an easy target for those looking for programs to attack. (See box for excerpts of congressional statements on SETI.)

With the future of NASA's SETI program uncertain, The Planetary Society's META (Megachannel Extraterrestrial Assay) project becomes more crucial to humanity's efforts to determine if there are other advanced lifeforms in the universe. Our program remains the only continuous search for extraterrestrial radio signals in the world. (See pages 6-7.)

The Society's Board of Directors is now deliberating how we should react to this unfortunate development. We are considering both the US government's program and our own. We welcome your letters on this subject.

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

Fix The Planning First

Editorial by Louis D. Friedman

Space is a difficult place. The false claims of cheap, easy and routine operations in space are now haunting us. In the past two years we've seen failures in the Soviet *Phobos* mission to Mars, the European *Hipparcos* astronomical satellite, the Japanese *Hagomoro* lunar mission and the United States' Hubble Space Telescope. They remind us that space is indifferent to human-built devices, difficult to deal with, and even dangerous.

Fixing the problems will be the easier job. For example, redundant systems that can take over when one system fails will be built into the next *Phobos* spacecraft. New and well-tested instruments can "repair" Hubble. But, it will be harder —and more important—to learn from our errors and to fix the management and planning systems that failed in all these missions.

In the Soviet program, we have already noted the deficiencies in the system design. (See the May/June and July/August 1989 *Planetary Reports*.) In the American program, we must learn that we can't base our plans on frequent shuttle launches.

Perhaps, before NASA proceeds with space station construction, the agency should build a heavy-lift launch vehicle that would be more powerful and (because it would not carry humans) simpler to operate. In the long run, this approach might even speed up the space station building process.

Another option to consider is moving microgravity processing to a robotic platform removed from the hubbub of human activities. This would simplify the requirements NASA is now forcing on the station design.

These and other alternatives need to be considered now. We hope that the new commission appointed by NASA will do just that. ❑

News & Reviews

by Clark R. Chapman

For the past 10 years I have been writing this column, reporting on current events that are of interest to The Planetary Society. Now, the time has come to reflect on where we've been, where we are, and where we're going in planetary exploration.

The singular accomplishment of the 1980s was *Voyager.* This final mission of the "Golden Age of Planetary Exploration" showed us the marvels of the outer solar system. In a decade of mounting woes for NASA, *Voyager* was the shining example of how to do it right: On cost, on schedule, and with results far beyond expectations.

Throughout the 1980s, NASA had chiefly the planetary program to point to with pride. Yet, these planetary successes were the fruits of ideas born in the 1970s. The 1980s became a time of retrenchment. Missions intended for the early 1980s, *Galileo* and *Magellan*, were not even launched until 1989.

The year 1990 opened with an air of optimism missing since long before the *Challenger* disaster. The Hubble Space Telescope (HST) was sent into orbit, promising to unlock the mysteries of the universe. *Galileo* encountered Venus. *Ulysses* was being prepared for launch. President Bush set a goal for NASA: the Space Exploration Initiative (SEI) that would send people to the Moon and Mars. The long-delayed *Lunar Observer* mission was finally on track. The end of the Cold War seemed to be nurturing international cooperation in space. For the first time in years, Congress approved two major new planetary missions: the Comet Rendezvous/Asteroid Flyby (CRAF) and *Cassini* to study the Saturn system.

Hubble—Through a Glass Half Full?

Many of the promises I've just listed could still come true. As I write, *Magellan*'s first pictures of Venus' surface have been released, and engineers are hoping that its mapping activities can begin soon. *Galileo* is doing fine, as it nears its December encounter with Earth. Astronomers who see glasses "half full" rather than "half empty" are sincere when they claim that many of Hubble's observations can still be made. Its optical defects can be largely removed from data by computer massaging. Eventually, instrument replacements can achieve nearly all of HST's original goals.

Despite Congress' intent to zero-out SEI, President Bush still supported it. Although budget cuts have taken their toll (NASA abandoned a vital instrument for the international *Mars '94* mission and is offloading instruments from CRAF), at least work is still proceeding on CRAF/*Cassini*. The same budget cuts have stopped all advanced planning work by engineers on such projects as the *Discovery* series of small missions to objects like near-Earth asteroids and Pluto, but hopes are that planning can be restarted in the new fiscal year.

But just as the post-Cold War euphoria was undercut by Iraq's invasion of Kuwait (and the attendant US military response and skyrocketing costs of oil), so it now looks gloomy for NASA and even for international space programs. While *Magellan* might map Venus, contact with that spacecraft was periodically lost just as it began sending back pictures of our sister planet. (As you read this, you will know if *Magellan* went on to glorious achievements as *Voyager* did after its shaky start.) And the Senate mark-up of NASA's appropriations bill would cancel CRAF and threaten *Cassini*.

Worst of all, from my perspective as a planetary scientist, is the ever-lowering morale of my colleagues. Let's not mince words: Hubble truly is crippled, and years of planning for HST operations had to be thrown out. In late August, planetary astronomers were shocked to learn that 40 percent of the research groups with programs up for renewal by NASA will be terminated. They will get 50 percent funding for one final year, then go out of business. Many of those not terminated were also cut up to 50 percent because of budget shortages.

Simple Sixties Lessons

I'll conclude my list of woes. I hope things will be looking better by the time you read this. Still, I think the last 10 years held some simple lessons for us. The higher funding levels of the 1960s and 1970s contributed to the successful approaches to science and project management seen during those two decades. More recent attempts to run full planetary programs with ever-eroding budgets have not worked.

The world is wealthy enough and united enough to afford the long-term commitments to education, research and advanced planning that make state-of-the-art technological endeavors like spacecraft missions possible. Yet the future of space exploration, at least by the US, is threatened by continuing budgetary instability, the ascendancy of financial speculation and the worship of short-term goals in the United States' psyche—and by the paralysis of politicians who can't take decisive and committed action.

We live in an age of compromise. So often, the budget-cutters think you can live with a 10 percent cut, and after that, a 15 percent cut. But some things need to be done right, or not at all. It is a worse thing to waste money building half a bridge than to not build one at all. We need to build bridges to other worlds. So, we must await farsighted political leaders who, like John F. Kennedy, can proclaim a goal, garner the necessary resources and persevere.

Clark R. Chapman has reviewed books and articles, and occasionally commented on the space exploration scene since Volume 1, Number 1 of The Planetary Report.

SOCIETY Notes

ASTEROID TRACKERS RECEIVE GRANT

The Planetary Society has awarded a grant to David Balam and Jeremy B. Tatum at the University of Victoria, British Columbia, Canada for their studies of Comet Levy and 1990MF, an Earth-approaching asteroid. (For details of this project, see the May/June 1988 *Planetary Report*.)

The pair have been able to track the fast-moving 1990MF as it came very close to the celestial pole, and have gathered enough information on Comet Levy to enable the Minor Planet Center at the Harvard/ Smithsonian Astrophysical Observatory to compute a preliminary orbit for it.

AND THE WINNERS ARE. . .

The Planetary Society's Scholarship program has entered its fifth year of awarding fellowships and scholarships to students planning to enter the fields of planetary science or engineering. The Society strives to encourage the engineers and scientists of tomorrow who will someday take us to Mars and beyond or will help us rediscover our home planet.

College Fellowship Awards:
These are awarded to undergraduates majoring in science or engineering. Applicants must be members of The Planetary Society or be nominated by a member. Fellowships are awarded based upon academic achievement, commitment to a career in planetary-related science or engineering, and a 2,500-word essay on a relevant topic. The 1990 winners include:
Shawn M. Diamond from the University of Wisconsin, Robert Andrew Morgan from Purdue University, David Holmes Reilly from Princeton University, Stefan A. Serbicki from Florida Atlantic University, and Adam Peter Showman from Stanford University.

New Millenium Committee High School Scholarships:
Every year the New Millennium Committee of The Planetary Society gives scholarships to high school students who show promise in fields related to planetary exploration. This year's applicants were asked to consider how studies of other planets have helped us better understand our own world. This year we divided the award among:
Douglas Acton of Burke, Virginia; Christine Hopper of Austin, Texas; Andrew Jordan of Austin, Texas; Kevin Siedentopf of Polson, Montana; Robert Uglesich of Mayaguez, Puerto Rico; and Cory Welt of Las Vegas, Nevada.

National Merit Scholarship
The Planetary Society sponsors a scholarship in this prestigious program. Each year, from the several thousand National Merit Finalists, we select one student who we feel can make significant contributions to planetary exploration. This year our winner is Jennifer L. Hoffman who is attending Stanford University where she plans to major in astronomy.

CABLE TELEVISION, THE NEW FRONTIER

Members of The Society's Portland, Oregon Volunteer Network (Tom Hanna, Coordinator) have been producing "Space, the Future Frontier," a half-hour cable television news program on current issues in space exploration.

A representative of a local cable network met Tom and other Planetary Society volunteers at an event and was so impressed with our organization that he got his station to provide all the production costs and training in exchange for 13 months' worth of programs.

A new program is featured every month, each airing six times on the Paragon Cable Network on three different channels: 11, 27 and 33. (Times vary, so check your cable guide.) So far, guests on the program have included Stan Seeberg, an authority on meteorites, and a group of school children discussing their "space seed" experiments.

OUR MAN IN WASHINGTON: ROBERT S. KRAEMER

The Planetary Society is pleased to announce that Robert S. Kraemer, formerly of the Goddard Space Flight Center, has joined us as a Special Consultant to The Society.

Mr. Kraemer retired in March 1990 from his position as Assistant Director of Engineering at Goddard. His long and distinguished career in space engineering includes a stint as Director of Lunar and Planetary Exploration at NASA during the 1970s—the "Golden Age of Planetary Exploration," as Mr. Kraemer puts it.

He will be based in Washington, DC, and will report to us on meetings, hearings or other political events that are of interest to The Planetary Society, its mission or its programs. Mr. Kraemer is not a lobbyist—rather, he is a knowledgeable reporter who will be The Society's eyes and ears in the United States' capitol.

KEEP IN TOUCH

Our mailing address:
The Planetary Society
65 N. Catalina Avenue
Pasadena, CA 91106

Call for an updated events calendar:
(818) 793-4328
east of the Mississippi
(818) 793-4294
west of the Mississippi

General calls:
(818) 793-5100

Sales calls ONLY:
(818) 793-1675

Questions & Answers

What makes Io's volcanoes erupt? Scientists believe that tidal tugs from Jupiter and Europa heat the small moon's interior. This heat provides the energy to shoot out plumes of sulfur and its compounds in frequent eruptions. Painting: Bob Eggleton

What is the cause of the volcanic activity on Io?
—Tony E. Yaghamaie, Seattle, Washington

The active volcanoes on Io, Jupiter's innermost satellite, came as a complete surprise to most of the planetary science community, although a few investigators had speculated on their possibility before they were discovered by Linda Morabito of the *Voyager* Navigation Team.

The original speculations on potential causes of Io's volcanism are still the most plausible 10 years later. The basic idea is that Io is slightly deformed due to strong tidal interaction primarily with Jupiter and Europa, the next satellite out. Such tidal pulling makes Io more oblate, but then allows it to relax as its position relative to Europa changes. This repeated flexing of Io's outer shell has generated considerable internal heat that, over time, has mobilized most volatile materials near the surface including water, with sulfur and its compounds remaining behind.

Today this strong tidal heating is probably generating various kinds of volcanism simultaneously on Io: surface flows and ponds of quickly cooling liquid sulfur; surface flows of much hotter silicates, such as basalt; and the spectacular, primarily sulfur dioxide driven umbrella-shaped plumes so familiar from the *Voyager* flyby pictures.

Between the two *Voyager* flybys, the shapes of some of the active features changed, implying that Io's surface is highly dynamic. Nevertheless, the placement of the surface markings as seen from Earth, and the pattern of volcanism, appears to have been fixed over the last 50 years. This, in turn, implies a stable internal heat source consistent with the periodic tidal interactions among Jupiter, Europa and Io.
—DAVID PIERI, *Jet Propulsion Laboratory*

How can Saturn's moon, Titan, with less than half the diameter of Earth, hold an atmosphere about one and a half times the pressure of our own?
—Charley Levinson, Smyrna, Georgia

The ability of a planet or satellite to generate an atmosphere and then to maintain it for 4.5 billion years depends on several factors. Other things being equal, the basic parameters are the mass of the object and the temperature of its exosphere: a massive, cold planet is the best candidate.

A large mass means a strong gravitational field, which holds the atmospheric gases around the object. The lower the temperature, the more slowly the atmospheric molecules move, and the more difficult it is for them to escape into space. Thus a cold satellite like Titan can maintain an atmosphere almost as effectively as a warm planet like Earth despite Titan's smaller mass.

If a planet or satellite is *too* cold, most of the gases will freeze out on its surface, which is why Neptune's moon, Triton, and Pluto have such tenuous atmospheres. If it is too hot, it will have no atmosphere at all. For example, inner solar system bodies, such as Mercury and our Moon, are simply surrounded by ultra-thin halos of atoms.

Two major processes work to re-

move atmospheric gases: escape and deposition. Gas molecules are always in motion, the more massive ones moving more slowly than the lighter ones. Atoms, molecules and rockets can leave a planet or satellite and fly off into space if their velocities are large enough. This so-called "escape velocity" depends on the body's mass and radius: it will be larger for more massive bodies. If the velocities imparted by the gas molecules' temperatures at the outer fringes of the atmosphere exceed the escape velocity, they will fly off into space.

A small body like Titan has a lower escape velocity than Earth. Thus to retain an atmosphere, its exosphere must be colder than Earth so the molecules move more slowly, as indeed it is. At the average temperature of Titan's upper atmosphere, molecules like methane (CH_4) and nitrogen (N_2) have great difficulty escaping into space. But these molecules are constantly being broken apart by bombarding electrons from Saturn's magnetosphere and by cosmic rays and solar ultraviolet photons. Most of the fragments of these collisions recombine to form more complex molecules that create the ubiquitous smog layer in Titan's atmosphere and rain down on the surface.

This deposition process has greatly depleted the atmospheric methane. Some nitrogen atoms escape directly when the molecular nitrogen is broken apart with sufficient energy to allow one or both of the constituent atoms to achieve escape velocity. The hydrogen atoms produced by the breakup of methane will also escape. We expect to find evidence of both of these loss processes—deposition on the surface and escape into space—with the *Cassini-Huygens* instruments when we study the composition of Titan's surface and measure the relative abundances of the nitrogen and hydrogen isotopes in 2002 AD.

—TOBIAS OWEN, *University of Hawaii*

If Earth were faced with an impending asteroid or comet impact, what sized body could be deflected to a new trajectory with today's resources? How could it be done? What sized body would be life threatening?
—J. W. Wright, San Clemente, California

The object responsible for Meteor Crater in Arizona was approximately 50 meters (about 160 feet) across. Such an asteroid could be deadly if it struck near a populated place. Unfortunately, ground-based telescopic patrols cannot detect objects that small until they are bearing down on us. (Futuristic Moon-based patrol systems have been suggested, however.)

The most threatening asteroids are those larger than about a mile. Civilization as we know it could be destroyed by such an object; we've discovered only a few dozen so far. But it is estimated that several hundred such potential impactors are there to be found. An expanded search program, using telescopes like the Schmidts currently employed on Mt. Palomar or the proposed Spacewatch Telescope, could catalog most of these objects. If one were found on a path that could strike Earth in the next few years or decades, a space mission could be launched to deflect it. We would need some lead time, and the mission would be expensive, but the future of civilization might be hanging in the balance. (See article on page 14.)

It is entirely within our technological capacity to rendezvous with the intruder, plant a modest bomb—it has been calculated that a few kilograms of chemical explosive might do—and nudge the object onto a slightly different path. Recent radar observations of the double nature of 1989PB caution us that asteroids may be rubble piles rather than solid rock, and we would not wish to fragment the object. A blizzard of dozens of 300-meter "mountains" might be even more deadly than the impact of a single mile-wide asteroid.

—CLARK R. CHAPMAN, *Planetary Science Institute*

FACTINOS

A tiny new saturnian moon has been discovered by Mark Showalter, a scientist at NASA's Ames Research Center. Showalter found the small, bright object while analyzing images taken by *Voyager 2*.

The new moon, temporarily called 1981S13, is only about 20 kilometers in diameter, (about the size of Manhattan) making it the smallest yet found around Saturn. It orbits in the major gap of Saturn's outermost ring, known as Encke's gap. Because the moon pushes material away from its orbit, it is believed to cause this 300 kilometer-wide gap.

—from NASA Ames Research Center

In late May, scientists at Pennsylvania State University reported that they'd found more evidence to support a controversial theory that Earth is being bombarded by about 20 house-sized comets every minute. John J. Olivero, a professor of meteorology at the university, said his microwave observations of the normally dry upper atmosphere detected brief water vapor "puffs" that appear to be the tracks of the comets as they enter the atmosphere.

Olivero said the comets are small and are composed of "fairly fluffy ice" like very dry snowballs. The ice vaporizes as it enters the atmosphere, but each one, on average, adds enough water to the environment to fill a swimming pool. Some scientists think that, over the eons, the comets filled the world's oceans, formed its polar caps and played a critical role in the evolution of life on Earth.

Olivero's study seems to add credence to the "small, icy comet theory," that caused a major stir in the scientific community when it was put forth in 1986 by physicist Louis Frank of the University of Iowa.

—from Frank D. Roylance
in the *Detroit News*

If history repeats itself, Jupiter's Great Red Spot may soon lose some of its color, report NASA astronomers. About 13 months after it turned white, a cloud belt just north of the spot is reverting to its typical dark brown color. When this happens, eddies in the jovian winds feed ammonia ice crystals into the Spot, washing out some of the red color. The belt turns brown when violent storms mix Jupiter's atmospheric gases. Sunlight then triggers reactions by the ammonia and methane, creating a brown smog. When the cloud belt turns white, the eddies diminish, reducing the amount of ice entering the Great Red Spot, allowing it to turn a darker red.

—from the *Los Angeles Times*

missions while reducing international tensions.

With financial support from its members and friends, the Society should continue to provide seed funding for exciting adventures such as the Search for Extraterrestrial Intelligence (SETI). While large-scale SETI research is the province of governments, the Society has shown leadership now, while governments debate the issue. Success in the SETI searches sponsored by the Society would be the ultimate achievement of the foreseeable future.

—Henry J. Tanner, Financial Consultant

The US civil space program has, after thirty years of experience, reached a level of maturity that cries out for a critical appraisal of the merits of its various components.

Robotic commandable spacecraft in both Earth orbit and deep space have made immense and pervasive contributions to scientific understanding of the Sun, the Earth, and the other planets with their systems of satellites and rings, comets, and the distant astronomical universe. The planetary program, in particular, has yielded results far transcending its initial promises. Robotic spacecraft have also provided many utilitarian applications of space technology for the direct benefit of the Earth's population.

On the other hand, the flight of human crews in space has, despite its use of the dominant part of our national resources in space exploration, defaulted repeatedly on its promises and, since *Apollo*, has yielded very meager results, either scientific or utilitarian.

These facts demand a drastic revision of our national priorities in space in order to emphasize and enhance support for the things that work and to diminish support for things that do not. My hope for the next decade is that such a revision of priorities will occur.

—James Van Allen, Professor of Physics, University of Iowa

As a newcomer to The Planetary Society, I am still learning about the Society's objectives and how those objectives are implemented. So far, I've become familiar with *The Planetary Report* (which is excellent) and I was very impressed with the events organized during the *Voyager 2* fly-by of Neptune last summer. However, I'm still learning! My hopes for the Society are therefore fairly general at this point. They are:

a) That you will continue to advocate international dialogue and cooperation in space exploration (despite the political climate) and that you will point out the humanistic, scientific and financial reasons for doing so;

b) That you will stir the imagination of young people by conveying the excitement of exploration and discovery and that you will offer a vision which is too compelling to ignore; and

c) That you not give human spaceflight the cold shoulder despite the competition between human and robotic missions for limited financial resources (I guess I'm biased a little on this point, but I think it *is* part of the total picture and will continue to be).

—Marc Garneau, Canadian astronaut

I cannot say very much about what I would like to see in the space program for the next 10 years because that has been predetermined already in the USSR and by NASA, especially the exploration of other planets. There is, however, some room for the study of Earth toward the end of the decade. This time should be spent monitoring our planet, its atmospheric composition, radiation budget, clouds, oceans and surface in relation to seasons and geography. The planet is in the process of changing very quickly and we must monitor it.

In our age, science is over-organized with many reports, papers, proposals and documents to be written and considered and accepted before one gets any funds. The Planetary Society has proven its usefulness to science with such projects as working for the continuation of planetary missions in the 1980s, or testing balloons of new design for the USSR *Mars '94* mission. Such activities should continue.

There is another kind of activity the Society could organize which would be inexpensive and useful. Much of the material obtained by previous planetary missions is still not analyzed in full depth simply because investigators have no time to do it. Most of this work would only require the use of personal computers and some guidance from the investigators. I am sure that many Planetary Society members would be able and very willing to do such potentially fruitful work. The Society could be an organizing link between its members and the scientists.

I can give examples of such potential work from my personal experience. In 1968, after being involved in the treatment of *Venera 4* data, I thought it would be useful to analyze *Mariner 4* radio signal data. Over the course of seven years I talked to several US scientists and NASA officials and wrote many letters. The result: one slide, from Dr. Ichtiaque Rasool [now with NASA]. Using this slide, Dr. A.S. Gurvich and I wrote a note published in 1971 by the *Journal of Atmospheric Sciences* on turbulence in the Venus atmosphere. Another attempt, not so insistent and with no result whatsoever, was in relation to *Pioneer Venus* descent data on pressure and temperature which could be used to test the internal consistency of the measured values and to estimate atmospheric vertical velocities. Both subjects remain of considerable interest. I believe most planetary scientists could name many subjects from their own experience that are worthwhile to pursue.

—G. S. Golitsyn, Institute of Atmospheric Physics, Academy of Sciences of the USSR

Congratulations to The Planetary Society on its 10th anniversary. We can now truly say: "What is past is prelude."

Prelude to what? At the very least, a continuation of our hopes and dreams as we look out into space. All the physical frontiers of Earth have been reached, from the heights of Everest to the depths of the oceans.

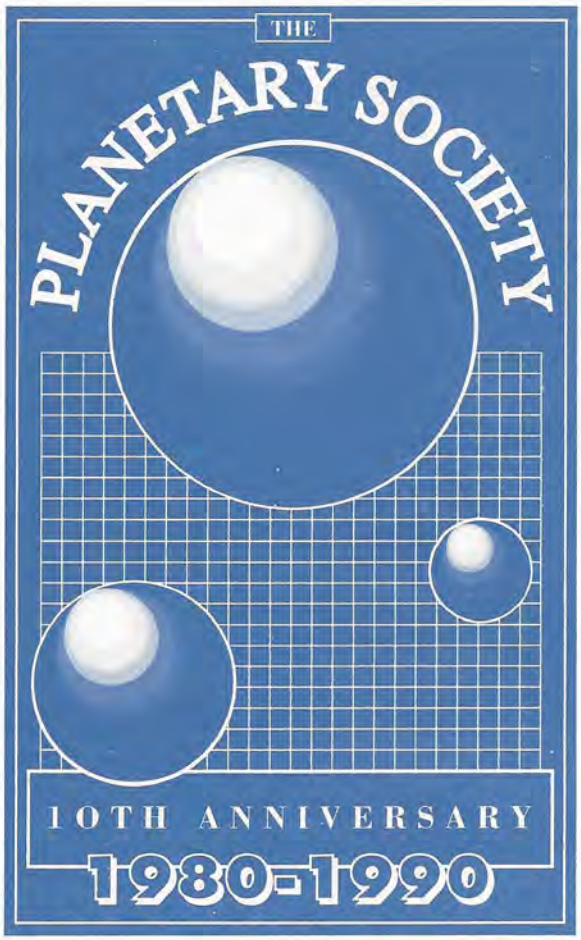
But humans are, deep within their essence, explorers. Space is humankind's last frontier, and it contains so much territory we may never run out of new areas to investigate. I expect that Mars will be the next immediate object of exploration because it is the one planet in our solar system that is most like Earth. The moons of Jupiter may well be next after Mars. I suspect we will begin by sending automated machines, but inevitably, humans will not be far behind. I hope our visits to these worlds will be part of an international effort that will highlight the unity of humanity on our planet Earth.

We will inevitably be drawn as well to the search for extraterrestrial intelligence. I see this as a further search for God, since all creation mirrors Him and nothing mirrors Him more than Intelligence.

—Rev. Theodore M. Hesburgh, C.S.C., President Emeritus, University of Notre Dame

An Invitation To All Members:

Help Us Celebrate The Planetary Society's 10th Anniversary



Come and celebrate with us! We are marking The Planetary Society's 10th anniversary with an exciting series of events this December.

Saturday, December 8th, *Galileo* will encounter Earth, marking the first time a spacecraft traveling from interplanetary space will visit our world. We've chosen to celebrate our anniversary during encounter week. After all, the Society exists to insure that, with missions such as *Galileo*, the exploration of the solar system continues.

The festivities will commence on Wednesday, December 5, with a black-tie dinner hosted by Society President Carl Sagan at the Biltmore Hotel in Los Angeles. The theme will be "One Earth, Many Worlds." Our members will mingle with the Society's celebrity friends and the scientists working on *Galileo* and other planetary missions.

On Saturday we will move the festivities to the California Institute of Technology in Pasadena (and close by The Planetary Society's headquarters). There we will hold three separate panel discussions.

On this encounter day, *Galileo* will aim at its home planet instruments developed to study the jovian system. En route to Jupiter, *Galileo* flew once by Venus and will fly twice by Earth. The spacecraft team will describe for us not only what they learned at Venus and hope to learn at Earth, but also *Galileo*'s ultimate mission at Jupiter.

By December, *Magellan* should be well into its mission to map Venus by radar. A panel of mission members will report on the spacecraft's condition, show us their exciting new data and tell us what they've learned so far about Earth's sister world.

To top off our celebration, Society President Carl Sagan will moderate a panel of special guests who will speculate on why humanity journeys into space. We expect to have a lively discussion.

We hope you'll be able to join us. If you'd like more information, please return the RSVP form below.

Anniversary Celebration RSVP Form

Mail to "10th Anniversary," The Planetary Society, 65 N. Catalina Avenue, Pasadena, CA 91106 U.S.A.

Name_____

Address_____

City_____ State or Province_____ Postal Code_____ Country_____

I would like additional information on the Anniversary Dinner, "One Earth, Many Worlds" ❑

I would like additional information on "Exploring Our Sister Worlds" ❑

INHABITANTS OF MARS *Sweet-faced Martians gaze out upon their highly civilized world in this illustration done for an article by H. G. Wells about the possibilities of life on Mars, published in* Cosmopolitan *in 1908.*

William R. Leigh was primarily known as an illustrator of western scenes. This is one of his rare forays into the world of fantasy. ***Illustration from the collection of Ron Miller***

This illustration, and most of the artwork in this issue of The Planetary Report, *is drawn from the soon-to-be-published book,* In the Stream of Stars, *by William K. Hartmann, Andrei Sokolov, Ron Miller and Vitaly Myagkov. The book grew out of a series of artists' exchanges sponsored by The Planetary Society.*

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