# The PLANETARY REPORT

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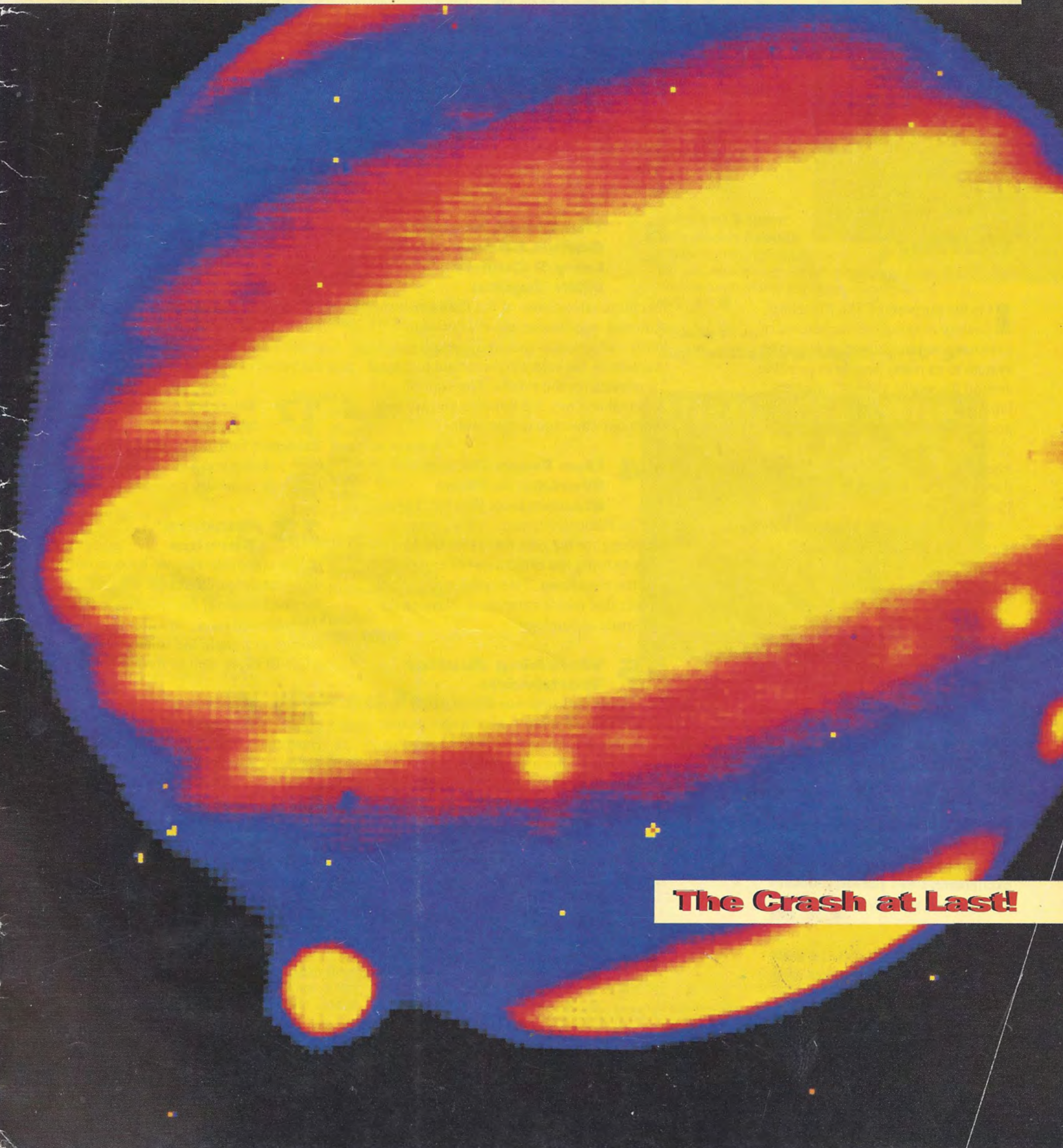

The Crash at Last!

**On the Cover:**

This infrared image of Jupiter was captured on July 18, 1994, with the 10-meter Keck telescope at the summit of Mauna Kea on the island of Hawaii. At lower left, the bright plume from the impact of comet Shoemaker-Levy 9's fragment G rises above the planet's eastern limb. This picture was taken about 10 minutes after the predicted time of the impact. In this false-color image, yellow represents the hottest areas, and blue, the coolest. In subsequent shots, this plume brightened to outshine the planet and render it invisible next to the extreme glare of the plume.

Image: W.M. Keck Observatory/Imke de Pater, James Graham and Garrett Jernigan; University of California, Berkeley

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## From The Editor

It is the purpose of The Planetary Society to bring the excitement of exploring and investigating our solar system to as many people as possible around the world. One of the problems we face in carrying out our purpose is the indifference many people claim the public has toward happenings off our own planet. Who cares, they ask, what happens on a planet like, say, Jupiter?

Well, the events on Jupiter in July should prove to even the dourest skeptic that the public's imagination can still be captured by planetary happenings, both by the sheer spectacle of interplanetary collisions and by their lessons for us on Earth.

Comet Shoemaker-Levy 9 focused the public's attention on the planets, and it is now our job to make the most of that interest. Our Jupiter Watch program will continue through *Galileo*'s exploration of the jovian system and, with our members' help and support, we can keep the public interest high. Watch these pages for coming events and ways you can participate in the planetary excitement.

*—Charlene M. Anderson*

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# Members' Dialogue

## Earthly Microorganisms

Two items in recent issues of *The Planetary Report* (H. Jay Melosh's article in July/August and W.F. Mellberg's letter in Members' Dialogue, September/October) state that viable terrestrial microorganisms were recovered from parts of the *Surveyor 3* camera after three years' exposure to the lunar environment. It is true that the camera parts had been exposed to the lunar environment for three years, but it is less clear that the microorganisms had been.

I was *Surveyor* project scientist and custodian of the *Surveyor 3* parts returned from the Moon. A person on my staff witnessed the biological test that led to the finding of terrestrial microorganisms on the camera. He reported that a breach of sterile procedure had occurred: an implement used in the test was put down on a nonsterile laboratory bench and then, without re-sterilization, touched to the camera. It is, therefore, quite possible that the microorganisms were transferred to the camera after its return to Earth, and that they had never been to the Moon.
—LEONARD D. JAFFE,
*Pasadena, California*

## Questionable Questions?

One of the questions in your Planetary Exploration Survey in the July/August 1994 issue of *The Planetary Report* is vague, if not confusing. You ask the readers how they feel about the benefits of planetary exploration, then give three choices: low, moderate or high. This question can be interpreted many different ways. Are you asking what the benefits could be, what they should be or what they will be?

Because of the ambiguity, this question cannot be used to draw any final conclusions. I understand the limitations of a short survey, but asking someone "how you feel" about a particular issue is asking for a lot of information—more than can be provided by just one of three choices on a questionnaire.
—STEPHEN PERRIER,
*Fort Worth, Texas*

## Which Way to Pluto?

Rob Staehle and his coauthors have written an excellent summary of the proposed Pluto Fast Flyby mission. However, they have failed to address the rationale for avoiding the use of a Jupiter gravity-assist (JGA) to reach Pluto. (This subject was hotly debated by a panel of space scientists and engineers at the International Academy of Astronautics Conference on Low-Cost Planetary Missions last April.) The advantages of the JGA technique are readily apparent—either a much larger payload mass capability or a smaller launch vehicle requirement could be achieved with flight times under 10 years.

For example, an *Atlas* launch vehicle could deliver a 380-kilogram (835-pound) spacecraft to Pluto in 9.5 years, or a *Proton* launch vehicle could transfer a 500-kilogram (1,100-pound) payload in 8 years. The respective passage distances at Jupiter would be 12.7 and 8.6 Jupiter radii, which should not require excessive radiation shielding. Science payloads would be in the 50-to-70-kilogram (110-to-154-pound) range, which would be a great improvement over the current 10-kilogram (22-pound) baseline in the Staehle proposal.

Without the need to miniaturize the science instruments, it's likely that costs could be reduced while increasing capability. Use of the JGA technique would require a launch in 2004, with the spacecraft reaching Pluto as early as 2012. This arrival date compares quite favorably with Staehle's direct-trajectory proposal, which currently is scheduled to launch no earlier than 2001 and arrive at Pluto around 2010.

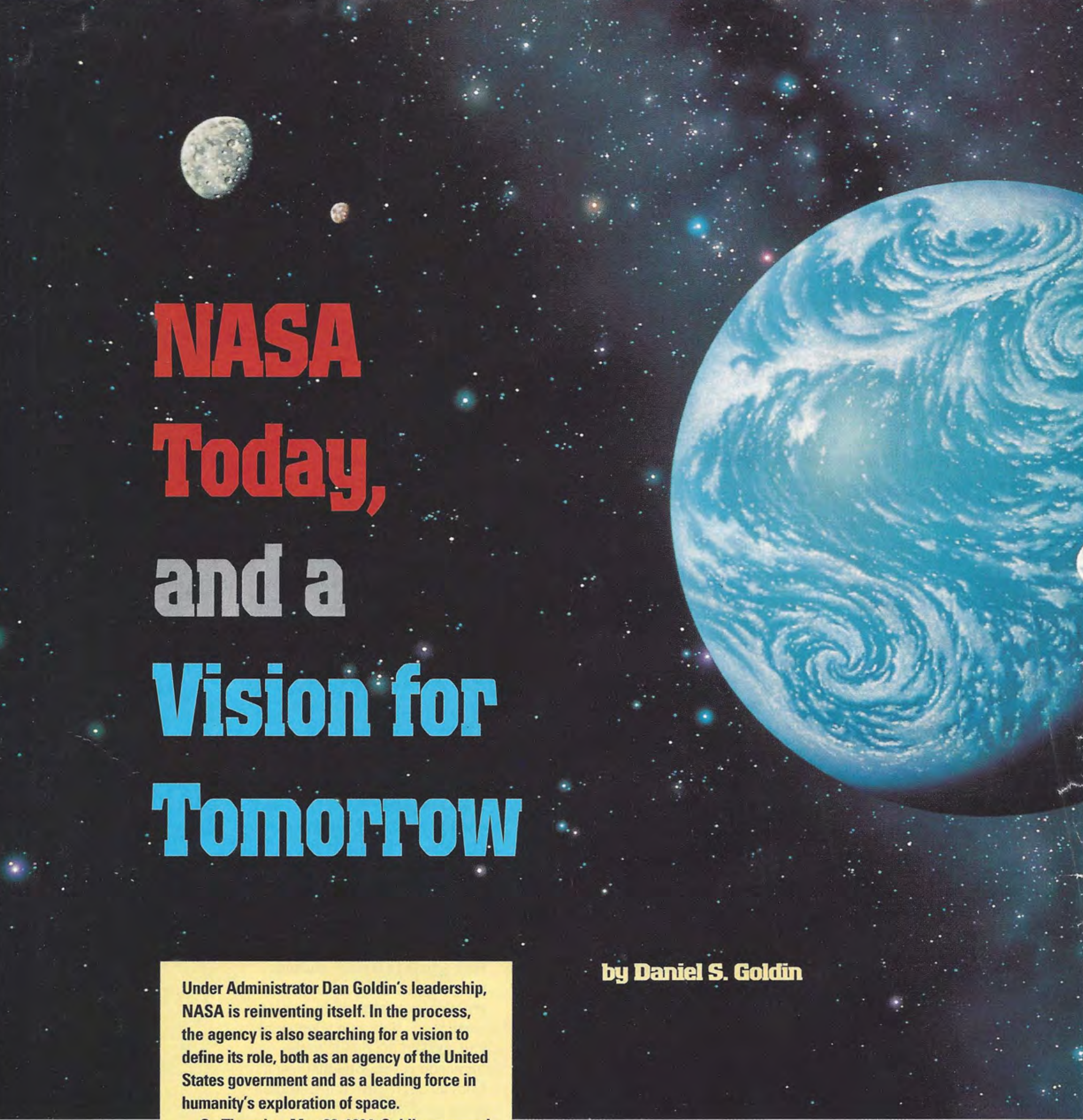
It appears that the scientific goals of the Pluto Fast Flyby mission could be achieved at lower cost and with greater effectiveness by using a JGA maneuver. The primary motivation for employing the direct-trajectory concept seems to be a justification for using a high-tech, microspacecraft design even when it is not required.
—ROBERT W. FARQUHAR,
*Columbia, Maryland*

I must applaud everyone who is involved in the Pluto Fast Flyby mission: the engineers and students who are creating the tiny, advanced science components, the team that is putting the mission together and making sure it fits within weight and price restrictions, the Society for its detailed account of the mission and even the bureaucratic pressures that have resulted in the restrictions on today's spacecraft.

Microspacecraft like the Pluto mission will bring humanity closer to space than ever before, as politicians become more willing to fund more missions in the face of increased success for less money. What's more, the advanced instruments mentioned at one point in your article (a science package weighing much less than a modern planetary camera, high-gain antennas as light as a telephone) will awaken the public to the tremendous spin-offs that result from an aggressive but restricted space program.

Thank you for another information-packed issue. I always look forward to receiving *The Planetary Report*, especially when it contains as much good news as this issue.
—GEORGE BUCKINGHAM,
*Brandon, Manitoba, Canada*

Please send your letters to Members' Dialogue, The Planetary Society, 65 North Catalina Ave., Pasadena, CA 91106-2301.



# NASA Today, and a Vision for Tomorrow

by Daniel S. Goldin

**Under Administrator Dan Goldin's leadership, NASA is reinventing itself. In the process, the agency is also searching for a vision to define its role, both as an agency of the United States government and as a leading force in humanity's exploration of space.**

**On Thursday, May 26, 1994, Goldin proposed one possible unifying vision to members of the American Geophysical Union, gathered to celebrate the organization's 75th anniversary. What follows is an adaptation of that speech.**

**We invite Planetary Society members to share their views of Goldin's suggested overarching goal for NASA: the search for life-sustaining worlds beyond our own.**
***—Charlene M. Anderson***

When my daughters were very young, I gave a talk at their elementary school. I started to describe Earth and how it spins about its axis, and why we have day and night. I talked about the various planets, about Mars and Venus. And I tried to tell them about the outermost planet of the solar system, Pluto. I even described to them that there might be something beyond that planet. And there were very, very happy faces in the room.

Then, I told them about the Sun and how it provides

***Left:* This Earth-like planet, sheathed in water and clouds, rotates at the center of a system of rocky moons. Do any worlds like this exist around nearby stars? Answers to questions such as this could provide a focus for NASA.** Painting: Joe Tucciarone

energy to the planet. And I made a mistake. I told them the Sun was going to burn out in about 5 billion years. They were absolutely appalled; they were frightened. And their main worry was, what's going to happen to me?

This anxiety, this fear, is not a bad thing; it reflects our urge to survive. In the past, it has led us to explore new continents, to find new places where people might live and prosper, to find new methods of producing food and fuel, to create new ideas and new technologies.

Today, we fear global economic competition, ethnic strife, environmental degradation and an ever-increasing population on this very small planet. We are becoming a global society, and we realize we need a transformation—human, social and technological. All three are required in order to survive.

NASA has an especially important role to play in protecting our planet. People are worried about global warming, changes in the ozone layer, deforestation, loss of biodiversity, and air and water quality. This is the reason for NASA's "Mission to Planet Earth," which is one way NASA will help accomplish the larger transformation.

Another way NASA may play a role in achieving this transformation is by helping to answer a new question we now face: "How can we *all* live together on our small planet?"

The space station, first conceived as a symbol of dominance, now is a symbol of our new yearning to live in harmony with other nations. It may turn out to be not only a testbed for technology, but for learning how we can work together with other nations on an incredibly complex technological venture.

Relevance must be at the heart of what we do—using the resources of space, and the technologies we develop to get there and operate—to better the lives of all people in our nation and the world.

In the ancient past, one of the reasons astronomers sought to map out the heavens and learn about the seasons was to improve agricultural production and planning. What they did was relevant to their people's needs, and those people understood that. There was a direct connection.

In the recent past, there was also a direct connection between the space program and the American people's needs. For decades, the space program perfectly filled America's need to beat the Soviet Union, to demonstrate technological superiority over the "Evil Empire." The space program had a purpose. It had a mission. And throughout the Cold War, it had tremendous support from the American people. They were able to make that direct connection.

Then the Berlin Wall came down, and before our eyes an old era crumbled. What is this new era that is emerging? We don't know yet. We are struggling to define ourselves and redefine our science and space policies as we head into an uncertain new age. And we are struggling to make a transformation from a space program that for 35 years was a projection of power to one that is relevant to human needs in the 21st century.

**NASA is getting its house in order, and we will soon be ready to look outward once again.**

There is uncertainty today over how to do that. That's okay. It really couldn't be any other way. Those who cry for clarity in the midst of chaos are asking for a formula for disaster. It will take time to think this through. We cannot expect this instant clarity as we leave the Cold War behind and we turn slowly toward the new millennium.

But we need to begin working toward a unifying vision for the space program—an integrating goal that will define our purpose. And a purpose that will strike a chord in the hearts and minds of Americans. It won't happen overnight. It will take time, thought and imagination.

NASA is getting its house in order, and we will soon be ready to look outward once again. We are reinventing ourselves. We are doing what we said we'd do.

We absorbed a 30 percent budget cut in the last 18 months because the president and Congress asked us to step up to the challenge of today's tough times. Even though our budget has come down, we have started new programs—Mars Surveyor, Mars Pathfinder, Small Sat (the Small Satellite Technology Initiative), the Relativity Mission (a gravity mission to empirically test Einstein's theory) and NEAR (the Near Earth Asteroid Rendezvous). Most of these programs will take two or three years to develop, not two or three decades, and will cost tens or hundreds of millions of dollars, not billions.

And we have firmly started a number of large missions that were in the planning stages: the Advanced X-ray Astrophysics Facility (AXAF), *Cassini* and the Earth Observing System (EOS). We have made difficult decisions about how to spend our precious resources. We've brought a new accountability to NASA, instituted contract reforms and created a Program Management Council to keep our programs on track, hold them to cost and detect problems early. When they overrun, we cancel them. The American public expects no less.

We redesigned the space station at the request of President Clinton. We will have a safer, cheaper station that does more robust science, and does it sooner. We brought the Russians aboard as partners, also at the request of the president. We committed a year beforehand to repair the Hubble Space Telescope in December of 1993, and we did it. The spacecraft is now producing spectacular results. Shortly after I arrived at NASA, we committed to a launch date for GOES-8 of April 1994, and we did that too. GOES (for Geostationary Operational Environmental Satellite) is now in final checkout in orbit. If all goes well, we intend to turn it over to NOAA (the National Oceanic and Atmospheric Administration) as a fully operational system. America will no longer have to rent spacecraft from the Europeans, but will work together with them on joint systems to benefit people from each of our countries.

We are a leaner, more efficient NASA. We have reduced the cost of the Earth Observing System by more than a factor of 2. We are proposing to fly five missions to Mars for about the cost of one *Mars Observer*. We plan to accomplish the objectives of the SIRTF (Space Infrared Telescope) mission for about one-quarter of the cost projected just a few years ago. And we have brought down the cost of SOFIA (the Stratospheric Observatory for Infrared Astronomy) by a factor of 2. We hope that we'll be able to start that in the not too distant future.

We are planning the Fire and Ice mission with the Russians to go to the Sun and to Pluto. We propose to do it for about one-third of the price projected only two years ago. All quality science. We have just released an announcement of opportunity for small science missions that go from design through operations and launch for $8 million to $12 million or less.

We are reshaping the agency. If we hold steady on our course for the next 10 years or so, we will be in a position to embark on a new direction for our space activities. It is not too soon to begin thinking about what that direction might be.

We might send humans to Mars to search for signs of ancient life or to establish if there is subsurface water. We might go back to the Moon, or visit a nearby asteroid. We might develop space commercially through industry–government partnerships. We might do all those things and more.

But today, I want to sketch out a different possibility. I want to begin a dialogue between NASA and the science community that will forge a new vision that connects NASA and the American people—a shared vision that all Americans can understand, and one that responds to their hopes and dreams. Even if we can't get started on it for a decade or two, it could chart a path to the future.

So here goes. What if, while protecting the precious resources on our own planet, and exploring our own solar system, we also commit to studying the universe with powerful observatories to do something extraordinary? I'm not sure whether these observatories should go on the Moon or in Earth orbit or in some near solar orbit, but what if we used them to seek and discover planets around nearby stars?

Wouldn't that very knowledge of their existence transform our understanding of our place in life, of our place in the universe? Provide hope? Shouldn't we set our sights on finding out whether there is a nurturing environment beyond our solar system?

There is a host of stars within tens of light-years from Earth. Many planetary scientists now believe that planetary systems may be common, and we know life did start in the hostile environment of early Earth. So it is not out of the question that nearby stars might have planets capable of sustaining life.

In the future, we will have the technology needed to image planets that might orbit nearby stars. It may be possible to infer through spectroscopic analysis of their atmospheres or the colors of their oceans whether or not they are life-bearing, whether or not there is carbon dioxide, water and ozone. What a revelation that would be! That would change everything—no human endeavor or human thought would be untouched by that discovery.

Every society leaves behind a legacy. The ancient Greeks produced art, philosophy and the beginnings of theoretical science. The Egyptians built the pyramids of Giza. The Romans laid 50,000 miles of highway. And the Mayans built observatories to map the stars.

Perhaps, just perhaps, the next generation's legacy will be an image of a planet 30 light-years from Earth and the tools of technology it took to capture that image. Or perhaps it will be something else, something we haven't even dreamed of yet. We have to get ready scientifically fairly soon. We would have to establish a technological foundation for imaging other solar systems—developing the needed telescopes and interferometers and other instrumentation.

The remote sensing observations made by our planetary missions and by the Earth Observing System would help us design the instruments needed to observe the planets around other stars—make a ground truth, if you will, for interpreting results.

In fact, we need to focus all of our space sciences on the problem, starting with understanding how stars are formed and how protoplanetary disks of dust and gas are formed around young stars. We would need to understand how planets are formed from this dust and gas, what they would be like and how they would evolve. And we need to understand how a habitable planetary environment can evolve and be sustained, and be shielded from injurious stellar radiation and plasma particles around such planets.

The search for life-sustaining worlds could be a new, unifying goal for space research. It's one possibility—by no means the only one or necessarily the right one. What is clear is that we need goals like this that can integrate the space sciences into a simple statement that the American public can understand and give us a path to go down. We went to the Moon, and we had *Apollo*. We did unbelievable planetary science. We did unbelievable space physics. And we got started on space astrophysics. The American public understood. All I'm saying is there needs to be an integrating theme. Not a set of disciplines that perform a set of entitlements, but an integrated theme that asks basic questions.

I have asked the newly formed NASA Science Council to start articulating a vision for the role of space science in America. And I mean all the sciences—Earth, life, microgravity, planetary, fundamental physics and astrophysics. I've asked it to address the changing role of space science in America, its priorities and how it reaches

**I invite you to join us as we turn to the future. For any vision to be worthwhile, it must be a shared one.**

out to the nation, how well it communicates with the American public. I've asked it to set goals not only for cutting-edge science and exploration, but for the human values of leadership, teamwork, productivity and integrity.

I invite you to join us as we turn to the future. For any vision to be worthwhile, it must be a shared one.

Some of the things NASA hopes to do in the near future will contribute to our hypothetical goal of discovering life-sustaining planets. The Solar-Terrestrial Probe series will study the plasma and magnetic environment that couples the Sun and Earth. We hope SOFIA and SIRTF will make new observations—observations of stellar and planetary formation processes. We hope to go to the edge of the solar system, to Pluto, and go back to Mars, and get clues from asteroids, comets and other planetary bodies about the origin and evolution of the solar system. However, these will not be billion-dollar missions. They have to be small, fast, and we have to get them off in two to three years, not two to three decades. We can do it because the technology is here.

And a decade from now, we hope to have gone through the whole of the solar system, defined the Sun–Earth connection and completed the survey of the universe across most of the electromagnetic spectrum. We would indeed, at that point in time, be ready for the next step.

Let us begin. We need you to be part of something that's just beginning at NASA. We've got a new team in place, and a funny thing is starting to happen. We're not just talking about budgets and fiscal cycles and contract reform. We're talking about the future again. We're talking about working toward a vision that will integrate the space program, and give it the power and resonance to unify America once again, as we step out into the first light of a dawning age.

*Daniel S. Goldin is the administrator of NASA and an enthusiastic advocate of a strong, unifying vision for America's space program.*

# The Crash at Last:
## Comet Shoemaker-Levy 9 Collides With Jupiter

**by Keith Noll**

*Twelve minutes after fragment G's impact, Peter McGregor took this infrared image of its radiant plume with the Australian National University's 2.3-meter telescope at Siding Spring. On Jupiter's right side, the bright puff of impact A has rotated into view.*

*Image: Peter McGregor, Siding Spring Observatory*

*Top left: The impact sites of fragments D and G resulted in this smeared bull's-eye on Jupiter. NASA's Hubble Space Telescope took this picture on July 18, 1994, an hour and 45 minutes after G hit the planet, creating the dark spot surrounded by a thin, dark ring. This fragment entered Jupiter's atmosphere from the south at a 45-degree angle, and it appears that the impact debris forming the large crescent shape flew back in that direction. The small, dark spot to the left of G's impact site is where fragment D hit on July 17, 1994.*

*Right: In this Hubble Space Telescope image, eight impact sites are visible. From left to right, they are: the E/F complex (barely visible on the planet's edge), the star-shaped H site, then tiny N and Q1, small Q2 and R, and on the far right limb, the D/G complex. This picture is a composite of separate images taken through different color filters to create "true color" renditions of Jupiter's multicolored clouds.*

*Images: Hubble Space Telescope Comet Team and NASA*

It was better, bigger, more spectacular than anyone had dared hope. With most of Earth's telescopic power trained on Jupiter, with the mighty Hubble Space Telescope in orbit and with the spacecraft *Galileo* approaching Jupiter, wave after wave of data flowed to scientists, taxing their powers to understand what was happening.

The public and press were more excited than anyone had hoped, also overwhelming the researchers but this time with demands for "instant science" and encapsulated explanations of what they were seeing on Jupiter. As *Planetary Report* readers know, this sort of on-the-spot theorizing is often erroneous; the true scientific story may not emerge for months to come. By then most of the popular press will have lost interest in Shoemaker-Levy 9 and the real story will only be told in the pages of technical journals.

With this article by one of the scientists working on the SL9 impacts, we begin our coverage of this once-in-a-millennium event. Here are some of the early images from around the world and interplanetary space. As scientists slowly work through the data and enhance the images, we will continue our coverage, and Planetary Society members will get a full report.
—*Charlene M. Anderson*

**July 16, 1994:** A single fragment—a small chunk of solar system debris torn to shreds by the slight difference in gravitational pull across it during a grazing pass by Jupiter two years before—plunges through 60 kilometers (about 35 miles) of Jupiter's atmosphere every second. In less than a minute, the density of the atmosphere becomes too high for the fragment to push through. The tremendous kinetic energy is dissipated in a brief flash, an explosion of enormous energy.

We knew this much about what would happen during the collision of SL9—officially named comet Shoemaker-Levy 9 (1993e)—with Jupiter well in advance of the actual event. On almost any clear night, a careful observer can see a miniature version of this enacted in Earth's starry sky as dust-sized grains achieve a moment of brilliance as they streak overhead. But size can be important, and nothing on the scale of SL9 had ever been witnessed by human beings.

What would we be able to see? Giant flashes and plumes, or nothing at all? How large were the fragments hidden in the cocoons of dust? How massive? Were there single objects or many fragments in each condensation? How much energy would they deliver into Jupiter's atmosphere? What were the fragments made of? Would they contain a high fraction of condensed ices, in which case the designation "comet" would be correct, or would they be relatively poor in these volatiles and high in silicate minerals and therefore deserving of the name "asteroid"? What would be the effects of dumping so much energy into a small part of Jupiter's atmosphere? Would we see waves moving away like ripples in a pond? Would the clouds be altered, and new circulation patterns formed?

The experiments on the Hubble Space Telescope (HST), and at most observatories on Earth, focused on these very basic questions. Some projects proposed to look for specific effects; others were looking for anything that might turn up. Images would be used to search for clouds, and plumes, and flashes, and to follow the evolution of any changes in the atmosphere. Spectra would be used to analyze the composition of the fragments both before and after they hit, and also to look for changes in the chemical composition of Jupiter's atmosphere caused by the mixing and heating that the giant explosions would produce.

## Waiting for the First Impact

By 8:00 p.m. EDT (eastern time) on Saturday, July 16, the Operations room at the Space Telescope Science Institute in

*Above: Only* Galileo's *instruments, out of untold numbers, had a direct view of Shoemaker-Levy 9's fiery death. The Jupiter-bound spacecraft took these four images of fragment W's nightside impact on July 22, 1994, at a distance of 238 million kilometers (about 150 million miles) from the planet. These pictures were taken two and a third seconds apart.*

*The first frame shows no impact, but in the next three a point of light appears, brightens and then fades. No one is sure yet*

*Left: This sequence of Hubble Space Telescope images chronicles the rise and fall of fragment G's plume after G smashed into Jupiter. The time elapsed from the first appearance of the small, bright feature in the top frame to its full-blown intensity and subsequent flattening and dissipation was 18 minutes. The plume is visible primarily by reflected sunlight, and the apparent gap between it and Jupiter's surface is the planet's shadow.* *Images: Hubble Space Telescope Comet Team and NASA*

Baltimore was sweltering. Inside were 30 to 50 people—as many as could get in the door—far more than the usual one or two operators plus the half-dozen scientists on the official list. The first fragment of SL9 had hit Jupiter four hours earlier. Rumors that something had been seen from the ground were flying, and the excitement was uncontainable.

Real information about what had been seen was traveling more slowly. The HST's brand new Wide Field/Planetary Camera 2 had taken two orbits' worth of images of Jupiter hours before, but because of the geometry of communications satellites the precious data had been written to one of the tape recorders on board, waiting to be relayed to Earth. Observatories in Europe, Africa and South America—at just the right longitudes to observe the crash of the first of more than 20 pieces of the comet—were also at work.

About three hours earlier, Melissa McGrath, my colleague at the Space Telescope Science Institute and a member of the science team, had come running excitedly down the hallway, telling all of us to read the latest e-mail. Scientists observing Jupiter from Calar Alto in Spain had reported seeing a plume from impact A! This was not something we had expected to see from the impact of the first fragment, one of the least bright "pearls" in the string. In fact, we were already prepared to remind the hordes of reporters waiting in the auditorium that the brightest (and presumably largest) piece, fragment G, was not going to strike Jupiter until Monday morning. We did not want the expected disappointing results from impact A to lead to a repeat of the misinformation following comet Kohoutek. We were ready to emphasize that science begins with observation and that even the observation that nothing happened is a valid, and interesting, scientific result.

At about 5:30 p.m., half a dozen of us had huddled around a radio and listened to a live report from South Africa. The telephone link was cut off in the middle of the interview but lasted long enough for us to learn that astronomers there had not seen anything unusual. This was in line with our more pessimistic and conservative expectations. A primary lesson that every scientist must learn is not to let expectations prejudice an experiment. The data are the only source of truth in the end. However, it is literally impossible not to include some guesses about what might be observed when designing an experiment or an observation sequence.

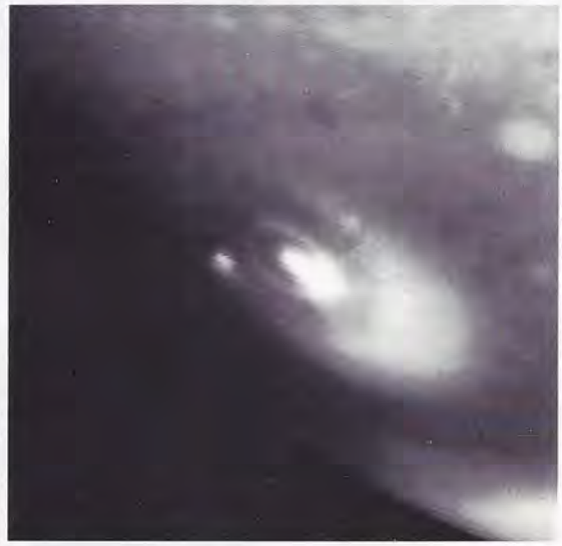
The comet fragments were estimated to be anywhere from a few kilometers across down to boulder- or even sand-sized particles traveling in clusters. The range of possible effects of the collisions was equally broad, and while we all secretly hoped for spectacular phenomena our skepticism told us that the effects, if any, were more likely to be small.

Other reports came over the e-mail. One South American observatory reported seeing a spot at the impact site. Another reported no detection. Getting two positive reports was encouraging, but the negative reports were puzzling. We did not know what to expect.

As the time for the Hubble's tape playback drew closer,

***whether these flashes depict the object's entry into Jupiter's atmosphere or the subsequent explosion and fireball. Fragment W was the last piece of the comet seen to hit the planet.***

**Galileo *will continue to return data and images of the event through January 1995. Once scientists integrate all the* Galileo, *Hubble Space Telescope and ground-based data, they will have an excellent account, from start to finish, of the Shoemaker-Levy 9 story.*** *Images: JPL/NASA*



***Right: These are two close-up views of fragment G's impact zone. The image on the top was made in green (visible) light with the Hubble Space Telescope's Wide Field/Planetary Camera 2 (WFPC2). On the bottom is the same field taken through the WFPC2's methane filter.***

***The thin, dark ring surrounding the G impact in the visible image is about 80 percent the size of Earth. The methane filter view suggests that the explosion may have occurred within Jupiter's atmosphere, because the rays of the ejected material do not point precisely to the center of the ring.***

*Images: Hubble Space Telescope Comet Team and NASA*

the room quieted. It would take a couple of minutes for each image to be transferred to the computer, and we would see each image in sequence. The first image had been taken at about 4:10 p.m. EDT, or about 10 minutes after the predicted impact time. Each following image would be about three minutes later.

Just after 8:00 p.m., the first image flashed on the screen in a hushed room. Nothing but Jupiter was there. I bit my lip and thought about the last year of work I and the others in this room had done to prepare for this observation. If something was going to be there, it should have been in this image. The next image was similarly blank. I felt my hopes deflate.

Then the third image was displayed. A faint speck appeared over the limb—just a few pixels, but in the right place. This is the kind of signature a cosmic ray can make when it hits the detector array, and even though the exposure was short it was a possibility. Then came the fourth image. The speck was there again, this time more than a few pixels—definitely something real.

The room came alive. Could this really be it? This image was taken almost 18 minutes after the predicted impact, seemingly too late for what we were seeing to be from that impact. Someone asked if the speck could be one of Jupiter's satellites by chance in the way, and ran to get the astronomical almanac.

When the next image was displayed on the screen, a collective gasp filled the room, then an eruption of cheers and exclamations. We could hardly believe what we were seeing. The spine-tingling sensation of that moment is something I will not forget. Superposed on Jupiter's normal clouds was a tremendous and beautifully symmetrical pattern of dark clouds. Like a bull's-eye, a perfectly circular ring surrounded a dark streak where the comet chunk had entered Jupiter's atmosphere. Farther out was a spray of material shot back out of the bull's-eye by the enormous energy of the explosion. This was an image taken almost an hour after the previous one in the HST's next 96-minute orbit around Earth, and by this time the impact plume had settled and the impact site had rotated well into view. Fragment A had been late, but there could be no more doubt: The week and month and year to come would be very interesting.

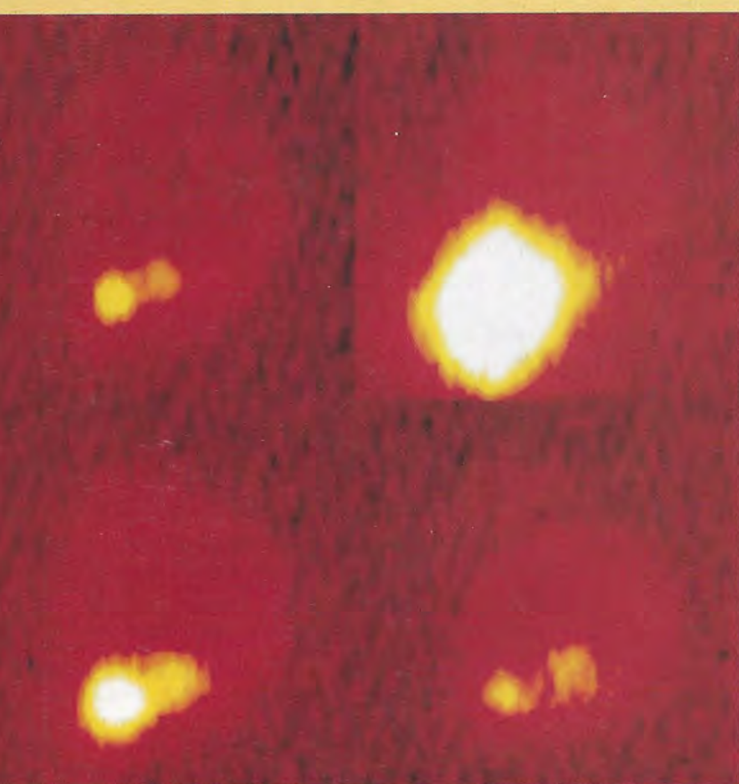
The rest of the week is hard for me to remember in detail. Every day brought exciting new discoveries. The spectroscopy team that I lead was waiting for impact G, when we would get our first chance to see what kind of material was being spewed out of the crash sites. The spectrum showed dramatic changes, and in ways that we did not fully expect. We stayed up till early in the morning with stacks of books and papers, puzzling over the identification of the new lines in Jupiter's spectrum. Roger Yelle, a science team member from the University of Arizona, identified sulfur, $S_2$, the next morning over breakfast, and then the following day Sushil Atreya, of the University of Michigan, and Paul Feldman, from Johns Hopkins Univer-

***This mosaic of four images shows the aftermath of fragment R's collision with Jupiter on July 21, 1994. The upper images were taken with the ROKAM infrared camera on the McDonald Observatory's 2.7-meter telescope. The two lower images were taken at the same times as the upper ones, but they are CCD (charge-coupled device) frames taken with the 0.8-meter telescope. Brightening due to R's impact is visible in the upper right frame. Previous impact sites are still visible in the infrared.***

*Images: ROKAM—Yongha Kim, University of Maryland; Beth Clark and William Cochran, University of Texas. CCD—Wayne Pryor, University of Colorado; Chan Na, Southwest Research Institute; and Anita Cochran, University of Texas*

***Using the 3.5-meter telescope at Spain's Calar Alto Observatory, scientists caught the first view of fragment Q's impacts at Jupiter's lower left limb on July 20, 1994.***

*Image: Calar Alto Observatory*



***Scientists at the South Pole had the unique advantage of being able to view the comet impacts nonstop, because from that vantage point Jupiter did not set but remained in view 24 hours a day. Using the 24-inch South Pole Infrared Explorer telescope, they were able to record the crash of fragment L.***

***This time sequence (from upper left to lower right) starts with the still glowing remnant of the older K impact. In the next four frames, the L fragment hits, brightens and begins to fade. At lower right, L's remnants are to the left of K's.***

***Image: Hien Nguyen, University of Chicago, South Pole Infrared Explorer***

sity, identified carbon disulfide, $CS_2$. The oxygen-containing molecules we had expected to find were not there, but there seemed to be plenty of sulfur molecules. Sulfur molecules are especially interesting because they are one of the possible colorants in Jupiter's clouds, but no sulfur molecule had ever been observed before in Jupiter.

Exuberant astronomers from observatories around the world flooded the Internet with so many images and so much information that it soon became difficult even to read every new message. My normally circumspect colleague Roger Knacke, observing at the United Kingdom Infrared Telescope on Mauna Kea, Hawaii, left an excited message on my answering machine during one of my four-hour sleep breaks, saying his group had "looked into the maw of the explosion" of the R fragment and retrieved some very interesting data on the composition of the hot plume. There was so much to observe that nearly every investigation will have something to say about this complex phenomenon.

## Taking Stock

Only the earliest results are in at this time, just a month after the crash. As is evident on these pages, there was a lot to be seen in the images. There are plumes and clouds and waves in the atmosphere. The spectra have yielded a bounty of information on the composition of the impactor and also on Jupiter. Surprisingly, the clouds of debris were darker than Jupiter's clouds, maybe because of the sulfur compounds that were seen after the impacts.

Now that the excitement and the news coverage have died down, the more difficult tasks of carefully looking at each bit of data, of comparing it against theoretical calculations and then transforming results into scientific talks and figures and papers, begin. Eventually, we may be able to say what the comet was made of, or even whether it was a comet at all. We may learn whether the material we see is from the comet, or from Jupiter itself.

The answers to our questions will require a time-consuming quantitative analysis of the data, something that will take months. Already there are sessions and symposia planned for the October meeting of the American Astronomical Society's Division for Planetary Sciences, and for next May at the Space Telescope Science Institute. Undoubtedly there will be papers published for many years about the data gathered over the last weeks of July 1994. And astronomers of following generations as well may want to study the papers we will write and the data we will archive because it may be longer than the time from the invention of the telescope to now before anything similar to the great crash of SL9 will happen again.

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*Keith Noll is an astronomer at the Space Telescope Science Institute in Baltimore, Maryland. He is especially interested in the atmospheres and surfaces of the many exotic worlds in our solar system.*

# Live From Other Worlds: A Pilot Electronic Field Trip

by Geoff Haines-Stiles

*Given The Planetary Society's commitment to education and interest in the use of robotics and virtual reality in planetary exploration, we were happy to get involved in an innovative endeavor that combines the two. Developed and produced for public television by longtime Society members Geoff Haines-Stiles and Erna Akuginow, the project described here is designed to stimulate students' interest in science and the exploration of other worlds. It is a multimedia project that incorporates new technology into the classroom. Our contribution was a grant to help create a teacher's guide, and we are making videotapes available to the public. With your support, The Planetary Society will continue to be there, blazing a path down the information superhighway on behalf of the exploration of space.—Charlene M. Anderson*

Using live, interactive television, Internet connections and innovative classroom tools, students and teachers have begun to go on electronic field trips to the frontiers of scientific discovery. As part of a new public television project called *Passport to Knowledge*, they are becoming active partners with research teams exploring remote places.

The pilot program, *Live From Other Worlds,* aired in December of 1993 as a miniseries of three 40-minute television programs. It linked students in the United States to NASA scientists working near McMurdo Station in Antarctica. Students participating live on camera in schools in Hawaii and Virginia, and in California at NASA's Ames Research Center, were able to communicate with researchers over—and under—the Antarctic sea ice more than 10,000 kilometers (6,000 miles) away.

The explicit focus of *Live From Other Worlds* was a NASA telepresence project researching robotic control techniques in preparation for future planetary missions and, as part of the NASA/National Science Foundation Antarctic Space Analog Program, surveying the underwater environment of McMurdo Sound at depths never before explored by humans. The implicit message was the excitement of cutting-edge research and the personal satisfaction felt by young scientists like robotics team leader Carol Stoker and diver Dale Andersen, both Planetary Society members.

On-line, teachers and students were able to use computers and modems to connect more personally with scientists by reading two field journals, "The Telepresence Project Research Log," kept by Carol, and "Dale's Dive Diary." In these regularly updated reports, the scientists described what they saw, felt, thought and learned as they worked under difficult conditions in one of the most remote areas of the world. They gave students intriguing details about doing science in Antarctica, including such things as safety precautions researchers needed to take to survive on the sea ice, as well as personal anecdotes about life at McMurdo Station, such as what was on the menu for Thanksgiving dinner.

Through another innovative on-line feature, "Researcher Q&A," managed by NASA's K-12 Internet project, scientists in Antarctica and elsewhere were available to respond via computer to questions from youngsters and teachers. Students could read researchers' responses to questions sent by other students, and they could then follow up with their own inquiries or comments. One volunteer expert (dragooned into this by Chris McKay, Planetary Society advisor) even worked on the project from his home in England and provided great information about future Mars missions.

Students were eager to participate when the opportunity arose to join Dale, via satellite and telecommunications, during one of his dives. Using regular school computers and modems, they were even able to drive *Mars One,* the underwater robot, as well as a prototype surface rover in a test environment at NASA Ames, from thousands of miles away.

For *Live From Other Worlds,* a comprehensive teacher's guide was researched, developed and printed by the project team, with the assistance of the NASA Mission From Planet Earth Study Office. The hands-on activities were developed by a team of science educators, with the (much appreciated) collaboration of the SETI Institute and The Planetary Society. Classroom teachers reviewed these activities for practicality and for intelligibility.

The next phase of this ongoing project extends the eyes and ears of its student audience to the entire continent of Antarctica, from McMurdo Station to the South Pole, and from the Dry Valleys to the central west Antarctic ice sheet. It looks at the coevolution of the continent and its life-forms, ancient and modern—at the geology, climate, biology, history and future of one of the most fascinating places on Earth—as well as at the ongoing enterprise of scientific discovery and at the researchers who are unlocking Antarctica's secrets. The four-part *Live From Antarctica* will air on December 13 and 15, 1994, and January 10 and 19, 1995. If all goes well, the January 10 program will include the first-ever live video broadcast from the South Pole. Like the pilot project, the upcoming miniseries will be supported by carefully coordinated print and computer materials for students and teachers.

Future field trips will involve NASA's Kuiper Airborne Observatory, the Hubble Space Telescope, the 1997 landing of *Pathfinder* on Mars and—if a current Discovery-class mission is approved—perhaps even *Live From the Moon*!

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*Geoff Haines-Stiles is a longtime producer and director of science television, including "The Creation of the Universe," "Together to Mars?," Carl Sagan's* Cosmos *and many* Nova *programs on space themes.*

# Watching Jupiter Worldwide

**by Susan Lendroth and Carlos Populus**

Comet Shoemaker-Levy 9 has come and gone, and the first leg of Jupiter Watch is over. The comet impacts were as spectacular as we had hoped, and our events around the world were successful as well. We've already begun work on the next focus of our program, *Galileo*'s December 1995 arrival at Jupiter.

Although we planned and cosponsored an array of activities in other places, we centered our main events during the predicted impact period, July 16 through 22, in Washington, DC—the political heart of the United States space program. The Washington area was not only the focal point of our Jupiter Watch activities but also the unofficial comet-news headquarters for scientists and reporters alike, with NASA Goddard Space Center and the Space Telescope Science Institute, both nearby in Maryland, hosting numerous press conferences. The Society invited Gene and Carolyn Shoemaker and David Levy, the comet's discoverers, to the area to participate in our activities.

Observing the results of the comet impact firsthand was the high point of the week for the 800 people who came to the US Naval Observatory (USNO) on Thursday, July 21. When we announced our plans for this in June, the free passes were immediately snapped up, and the event quickly became one of the hottest tickets in Washington. The program and open house were jointly sponsored by the observatory and by the Society.

July 21 did not begin auspiciously for an outdoor event. In midafternoon the first raindrops spattered the pavement, and weather forecasts warned of a tropical depression moving into the region. By 6:00 p.m. it was pouring at the Naval Observatory, but the sky did clear long enough for everyone there to catch a glimpse of Jupiter. The observatory's 12-inch and 26-inch telescopes were opened to the public, and local amateur astronomy groups provided a few dozen additional telescopes for the evening. These telescopes were scattered across the sloping lawn of Vice President Gore's helicopter pad (his residence is located on USNO grounds). Fortunately, for the sake of continued amateur astronomy in the region, only fireflies flew over the helipad that night.

David Levy, one of our speakers, got his first chance to actually see the comet impact sites that night. Once he peered through the observatory's 12-inch telescope and began to sketch Jupiter, no one could tear him away until the clouds returned.

Other speakers included Christopher Chyba, who talked about the Tunguska explosion in 1908, and Ken Johnston, scientific director of USNO.

On July 22, we wrapped up a spectacular week of comet impacts with a presentation by Planetary Society President Carl Sagan, David Levy and the Shoemakers to a thousand people at the Stouffer Mayflower Hotel. Tired but ecstatic, Levy and the Shoemakers traced the story of the comet's discovery through its fiery demise, while Sagan discussed the comet impacts in the larger context of how the solar system continues to evolve. The evening concluded with a chance for the audience to ask questions, and one woman delighted the speakers with a report about how her amateur astronomy group had observed a brightening of Io during one of the impacts. Gene Shoemaker asked her to send him the details, so the science continued even during our public events.

Our Jupiter Watch tour group, 38 people representing seven nations and several languages, was on hand for the week's festivities. Their itinerary included many activities geared to Society interests, including a visit to the National Air and Space Museum's Paul E. Garber Restoration Facility and a private tour and lecture at Goddard, in addition to our special Jupiter Watch events.

## More Jupiter Watch Highlights

Beginning in April, and right up to the second week of July, The Planetary Society sponsored or cosponsored more than 35 events all across the US and around the world—in Canada, Spain, Ireland and Malaysia. David Morrison of NASA Ames Research Center, Donald Yeomans of the Jet Propulsion Laboratory and David Levy were among our lecturers.

In Los Angeles on July 16, the first night of the impacts, Mount Wilson's 100-inch telescope was connected to several television monitors so that the 300 event-goers could watch as the comet fragments struck Jupiter. About 40 amateur astronomers brought their telescopes and trained them on the planet. The fragments that hit the first night were among the smaller ones, and a light cloud cover moved in just after dusk, so, unfortunately, those attending the event were not able to see any sign of the impacts.

One night during the impact period, at the Museum of Science in Boston, approximately 500 people "lasted all night long," according to Planetary Society Regional Coordinator Regina Forbes-Schraut, to see the dark marks left by the impacts. Interest was so high in Galway City, Ireland, that about 300 people crowded into a theater built to seat 100 to hear a lecture on the comet by physicist/astronomer Kevin Nolan. Ireland Regional Coordinator Paul Bracken reports that the lecture was so well received the audience wanted more, and he got numerous requests for a second lecture to present post-impact data and analysis.

All in all, this part of Jupiter Watch has been a great success. We now look forward to keeping the public interest in planets and comets high. Our next target date is December 7, 1995, when the *Galileo* probe will enter Jupiter's atmosphere and the spacecraft will go into orbit about the planet. More Jupiter Watch events and programs are coming, and we'll let you know what's going on when our plans are set.

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*Susan Lendroth is Manager of Events, and Carlos J. Populus is Volunteer Coordinator, for The Planetary Society.*

# News and Reviews

**by Clark R. Chapman**

If the energy of the excited state of carbon 12 were just a *little* higher, the processes that create heavy elements in stellar interiors would fail to form carbon. The universe would then be made of just hydrogen and helium, without the ingredients for life. So writes physicist Steven Weinberg in the October issue of *Scientific American.*

The prevalence of mammals (and the neurologically complex species *Homo sapiens*) on Earth is but the quirky outcome of a bewildering sequence of chancy events during the past billion years. Otherwise, dinosaurs might still reign—or evolved algal mats might be the most complex life-form on our planet. So argues Stephen Jay Gould, also in the October *Scientific American*.

Indeed, were it not for the wild temperature oscillations of recent ice ages, our brains might not have been stimulated to develop language and intelligence, according to William Calvin. More recent ups and downs in the success of different societies around the world, discussed by Robert Kates, have put me (and *you,* my readers) in an advantaged culture where we can read *Scientific American* or *The Planetary Report.* Otherwise, we wouldn't now be contemplating these questions.

## The Anthropic Principle

Perhaps the contingencies that led me to write these words, and you to read them, just manifest the *anthropic principle:* If things had happened differently (as in a trillion parallel universes), we wouldn't be here to witness, or ask about, our universe. Maybe there are as-yet-unknown laws of physics that will explain the seeming coincidences. Perhaps a Gaia-like process operates, in which life modifies and stabilizes its environment to foster evolutionary progress. But maybe not.

Each autumn, *Scientific American* devotes an issue to a single topic. This year's issue is on life in the universe; predictably, it contains articles like Leslie Orgel's essay on the origin of life. But the table of contents ranges from the Big Bang (and the eventual "Big Crunch" or "Big Chill"), through the creation of the elements and the development of Earth's atmosphere, to the nature of intelligence itself. In short, this topic embraces physics, chemistry, geology and biology—with a fair amount of philosophy tossed in, too.

On one level, the October *Scientific American* is a primer on modern thinking about how stars formed and how life evolved, illustrated by recent pictures from the Hubble Space Telescope. On another level, it serves as a launching pad for the reader's own personal exploration of what his or her mind can learn about itself and its origins.

## Certainties and Uncertainties

The astrophysicists who wrote the introductory articles in this collection seem confident about what happened during the first minute (indeed the first millionth of a millionth of a second!) of the universe's existence. And they are sure about how the heavens came to look the way they do and how the chemical elements came to be.

Later articles carry a much less certain tone (or ought to). Claude Allègre and Stephen Schneider describe the conflicting theories about how Earth's atmosphere evolved. Calvin's article on how intelligence emerged sounds convincing, but Marvin Minsky's very different perspective on intelligence makes one wonder if we really know enough about our brains to know why we are intelligent.

Best of all is Stephen Jay Gould's article on evolution. He integrates all the threads he has woven in his writings for *Natural History* magazine and his numerous books, and argues that many of our cherished beliefs about ourselves are, at best, distorted. Far from living in the "age of man," human beings are a marginal evolutionary accident within an interminable "age of bacteria." Gould shows that life has evolved episodically, that it has hardly "progressed" in diversity and complexity, and that we are a special product of evolution only in a chauvinistic sense that we ourselves appreciate.

## Planets as Abodes of Life

Missing from the October *Scientific American* is an article about planets. (Carl Sagan's piece concerns planets, but he rarely strays from his topic of searching for life.) Another odd thing about the universe is that it naturally creates the local concentrations of heavy elements we call planets, and places some of them in propitious locations (in swarms of carbonaceous projectiles near stars), where their surfaces can reach room temperature, so that water is liquid and can mediate chemical reactions involving the organic materials that rain from the skies. That is a recipe for an abode for the origin and sustenance of life.

Yet one must piece together scattered paragraphs from several articles to learn the rudiments of planetary formation, the life cycle of planets, and the modulation of environments caused by planetary processes. The articles leap too quickly from stars to the evolution of life on Earth. But that is a small criticism of an otherwise excellent source of after-dinner reading material.

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*Clark R. Chapman has been named a member of the imaging/spectroscopy team of NASA's first Discovery mission, the Near Earth Asteroid Rendezvous (NEAR).*

# World Watch

**by Louis D. Friedman**

*Planetary Society Vice President Bruce Murray recently completed a three-month stint at the Institute of Space and Astronautical Science (ISAS) in Japan. There he provided input to ISAS and others on possible future missions and space opportunities.*

*ISAS is Japan's principal organization responsible for space science and planetary exploration. The larger National Space Development Agency (NASDA) is that nation's main space agency, responsible for developing its space infrastructure, human spaceflight program and Earth applications. Japan has absolutely no military space program, consistent with its constitution and pacifist political views.*

*Overseeing the entire Japanese space program is the Space Activities Commission (SAC). It has just produced a new government policy document, "Toward Creation of a Space Age in the New Century," outlining Japan's vision for space over the next three decades. This coherent plan displays a strong international focus.*

*Japan has set a course to become a major player in Earth's exploration of the solar system. We print here a few excerpts from the SAC document.*
*—Louis D. Friedman*

Japan is now in a position to make effective use of its capabilities to progress further in worldwide space activities. Growing expectations from Asia-Pacific countries in recent years of Japan's role in the field of Earth observation are closely related to the progress of Japan's space technologies.

In Japan, space development must be promoted as an important national policy. Holding strictly to the principle of limiting space development to peaceful purposes, while deepening mutual understanding and cooperation with the world, we will strengthen our efforts in space development as follows.

**1.** Actively address such tasks as exploring the unknown universe and further deepening understanding about the Earth as the foundation for the future of mankind.

**2.** Try to positively develop creative and innovative space technologies that may be inherited by the next generation, for the purpose of enlarging the sphere of human activities in space.

**3.** Make efforts to ensure that the philosophy and significance of space development can be shared internationally in order to promote international cooperation.

Solar system science using medium-sized observation satellites in Earth orbit and space probes will be enhanced to increase our understanding of the Earth's atmosphere and plasma environment which will be extended to the research of the atmospheres of Venus and Mars. [Planet-B, a Mars aeronomy orbiter, will launch in 1998.] Studies of the Moon's internal structure will also be conducted and their results will be used primarily as the basis for studying the internal structure of other planets such as Mars. [Seismometers will be carried on the surface penetrators of Lunar-A, an orbiter mission scheduled for launch in 1997.] In addition, samples will be returned from asteroids and comets. [A sample-return mission to the asteroid Nereus is under study for 2003.] Through these research activities, Japan will accumulate the knowledge to solve the mystery of the structure of the solar system, its evolution and the origin of life.

In addition to medium-sized satellite programs, Japan will initiate programs utilizing larger launch vehicles to study Mercury, the Sun, and the outer planets and their satellites in the first decade of the 21st century. Japan may also participate in the international projects for geological surveys of the Moon and other planets using multipoint observation and rovers.

In the third decade of the 21st century, targets of observation will be expanded to the outer edge of the solar system. The medium-sized satellite programs will be continued, and a new lunar and planetary program using large launch vehicles may be pursued within the framework of international cooperation.

Japan will continuously promote unmanned lunar exploration in order to investigate the possibilities of conducting space activities on the Moon.

For two purposes, lunar scientific exploration and possible lunar usage, NASDA, ISAS and other space science research institutes will promote unmanned programs: First phase: Lunar observation by satellites in lunar orbit. Second phase: Lunar surface observation using landers and rovers. Third phase: Returning samples from the lunar surface.

In and after 2010, it is conceivable that lunar activities will be conducted through international cooperation. These activities may include such as the construction of an unmanned observation and experiment system on the Moon (an astronomical observatory, etc.) to realize continuous unmanned scientific observation from the lunar surface and Moon utilization experiments.

Also in the third decade of the 21st century, assuming the development and operation of the space infrastructures enabling highly reliable low-cost manned transportation, it might be possible to construct a manned astronomical observatory on the Moon through international cooperation after determining that manned activities are sufficiently justified. □

# Readers' Service

Our Readers' Service is an easy way for Society members to obtain newly published books about the science and adventure of voyages to other worlds.

We make these books available at the lowest possible prices. Each title is offered for six months, or three issues of *The Planetary Report*. We keep rotating our stock so that the titles we offer are always fresh.

### *Space Adventure II*

(CD-ROM),
Knowledge Adventure, 1994.
Retail price: $79.95
Member price: $49.95

### *Comets, Meteors, and Asteroids*

by Seymour Simon;
Morrow Junior Books, New York, 1994.
Retail price: $15.00
Member price: $12.00

### *Space Vehicles*

by Anne Rockwell and David Brion;
Dutton Children's Books, New York, 1994.
Retail price: $13.99
Member price: $11.00

Computers are already ubiquitous. Whether a child rushes to log on to the computer or heads for the bookcase depends on what that child needs for intellectual and emotional fuel, and on what he or she finds in both places.

It is too soon to know if CD-ROM will steal customers from booksellers. But if you fear for the future of literacy, relax. Not only do kids have to read to get to the heart of Knowledge Adventure's *Space Adventure II,* but a child on the cusp of literacy can go over the top by following the printed text on the screen while listening to it being read aloud.

*Space Adventure II,* for ages eight through adult, is a whole library of information. It includes more than 20 short films, over 400 reference entries, maps of the night skies and animated characters who ask and answer the kinds of questions kids ask—such as "Where did the Moon come from?" and "How can we get there from here?"

Planetary Society members—young and still-young—can design a robot for a mission to Mars, and figure out when to send it, what it will do when it gets there and how to test it before it goes. Then, when it's ready, they can watch it hurtle through space on the computer monitor to see if it really works.

On birthdays, youngsters can see how the sky looked from anywhere on Earth (their hometown, the White House or Down Under in the southern hemisphere) on the night they were born.

And kids who had to be in bed on those July nights when comet Shoemaker-Levy 9 was breaking apart can see the spectacle re-created as the fragments of the comet hit Jupiter in their alphabetical glory.

If looking up gets boring, they can probe the secrets of planet Earth. *Space Adventure II* includes the data NASA used to discover the ruins of the ancient city of Ubar, which had remained hidden for thousands of years beneath the Sahara's sands.

But in some important ways CD-ROM cannot compete with books. The pleasure of holding a book is simply different from the pleasure of sitting at a keyboard and using a mouse. No computer can replace the joy of turning pages and perhaps pulling paper tabs. No monitor can be hidden beneath the bedcovers when the lights go out, and there is no portable CD-ROM (not yet) to carry outside into the night to check on the phase of the Moon.

These delights belong to books. And, for the holidays, we recommend Seymour Simon's *Comets, Meteors, and Asteroids,* for kids in the middle grades. This splendidly illustrated—with photographs and diagrams—account includes a description of the Oort cloud, as well as close-ups of meteorites from Antarctica, and an asteroid named Gaspra photographed in space by the *Galileo* spacecraft in 1991.

And for the littlest folk who cuddle on your lap while you watch the news, we suggest *Space Vehicles* by Anne Rockwell and David Brion. This is a very simple explanation of rockets, probes, satellites, modules, rovers and shuttles, even a future space station. It features whimsical illustrations, in paint-box colors, of not people but kittens, as the astro-cats that maneuver these contraptions through space.

*—Reviewed by Bettyann Kevles*

### Still Available:
### *Moon Shot: The Inside Story of America's Race to the Moon*

By Alan Shepard and Deke Slayton. The story of *Apollo* and the early days of the space program as told by two of the original *Mercury* Seven astronauts. (Reviewed July/August 1994.)
Retail price: $21.95
Member price: $19.00

### *The Making of a Soviet Scientist: My Adventures in Nuclear Fusion and Space From Stalin to Star Wars*

By Roald Z. Sagdeev. A chronicle of science and politics in the Soviet Union during the Cold War years. (Reviewed September/October 1994.)
Retail price: $24.95
Member price: $22.00

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# Society News

## Wanted: Today's Heroes of Mars Exploration

The Planetary Society is seeking nominees for the second annual Thomas O. Paine Memorial Award for the Advancement of Human Exploration of Mars.

The award—a memorial plaque, the Mars flag and a possible cash prize—recognizes those who make noteworthy achievements in the pursuit of the human exploration of Mars. (The cash award might be presented in cases where the award selection committee feels it can assist work that advances Mars exploration.)

The deadline for nominations is December 30, 1994. Applications must be submitted on an official application form. For a copy of this form and nomination procedures, write or call Society headquarters. *—Charlene M. Anderson, Director of Publications*

## Mars Rover to Explore Hawaiian Volcano in Next Series of Telepresence Tests

The Russian Mars Rover is set to roll across the volcanic landscape of Hawaii. On February 27 through March 11, 1995, the rover—similar to the robotic vehicle under development for *Mars '98*—is scheduled to prowl around Hawaii's Mount Kilauea.

In cooperation with scientists and engineers from Russia, NASA Ames Research Center, McDonnell Douglas and the Jason Foundation, The Planetary Society will participate in this series of robotics tests. The rover has already been tested on Mars-like terrain in Death Valley and Kamchatka.

Planetary Society members are invited to visit the test site and see the team in action. The Society is also planning a number of other events in Hawaii for this time. For more information, write to me at Planetary Society headquarters, 65 North Catalina Avenue, Pasadena, CA 91106-2301, or call (818) 793-5100.
*—Susan Lendroth, Manager of Events and Communications*

## NSTA Meeting Features a Day for the Planets

Once again The Planetary Society will join forces with the National Science Teachers Association to cosponsor the association's annual convention, to be held March 23 to 26, 1995, in Philadelphia.

Join us on Planetary Society Day, March 25, for exciting presentations by planetary scientists such as Christopher McKay, winner of the 1993 Paine Award for the Advancement of Human Exploration of Mars; Adriana Ocampo, leader of the Society's geological expedition to Belize in January; and Steven Dick, a science historian at the United States Naval Observatory who writes frequently about the search for extraterrestrial life. For information and a registration packet, contact Susan Lendroth at Society headquarters. *—SL*

## Society Members Reach for the New Millennium

The Planetary Society is expanding its New Millennium Committee. The members of this group work to advance long-range projects in planetary exploration and the search for extraterrestrial life.

This past summer, Richard Weisman of Seattle, Washington, became committee chairman. Through his efforts, 68 members have joined and donated approximately $50,000 to the Society.

The New Millennium Committee was formed in 1982 to establish a support group of leaders within the Society. Under founding chairman David Brown, president of Time Energy Systems in Houston, Texas, the committee has helped advance several ambitious scientific and educational activities and has donated close to $300,000 toward scholarships, asteroid detection, the search for extraterrestrial intelligence and international cooperation in planetary exploration. The Society is deeply indebted to Brown, Weisman and other members of this group, including Steven Spielberg, whose $100,000 donation launched the Megachannel Extraterrestrial Assay in 1985; George Awad of New York City; Polly Brooks of Tucson, Arizona; Emmanuel Cashell of Sydney, Australia; and Abe Gomel of Montreal, Canada.

For information on how you can join the New Millennium Committee, please contact Richard Weisman or Diana Marquez at Society headquarters.*—Diana Marquez, Director of Development*

## More *Apollo* Memories

On July 20, 1994, President Bill Clinton and Vice President Al Gore led a White House ceremony commemorating the 25th anniversary of the *Apollo 11* lunar landing. Astronauts Neil Armstrong, Buzz Aldrin and Michael Collins attended, along with many other *Apollo* veterans. Among the government and space leaders attending this celebration were Planetary Society Directors Carl Sagan, Louis Friedman and Norm Augustine.

Earlier that day, Aldrin spoke before members of Congress at a breakfast sponsored by *Spaceweek,* the National Space Society and Women in Aerospace. Aldrin asserted that humans are about to take the next step outward—to Mars.
*—CMA*

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# Questions and Answers

***If there is no gravity in space, yet the Sun's gravity holds the planets around it, why don't spacecraft like the* Voyagers *fall in toward it?***
**—Thomas Ramsey (age 11), Emery, Utah**

The *Voyagers* do fall in toward the Sun. So do all spacecraft and planets in solar orbit. The orbit is the "free fall" path that bodies take when acted upon by gravity alone. It is not correct to say there is no gravity in space. By definition, the gravitational influence of the Sun extends throughout the entire solar system. It is this gravitational force that keeps the planets and the spacecraft on their elliptical orbits.

The size and shape of the elliptical orbits are determined by the initial velocity and position of the spacecraft. (Velocity is the rate at which an object moves in a *particular* direction, rather than just *any* direction, which is speed.) For a spacecraft launched from this planet, the initial velocity is Earth's orbital velocity plus the launch velocity. Earth's velocity is what puts the spacecraft on the curved elliptical path. If we could cancel out all that initial orbital velocity, then the spacecraft's path would be a straight line into the Sun.

The misunderstanding about there being no gravity in space may have come from the vernacular use of the word "weightless" applied to an object that is in free fall. What "weightless" really means is that no force counteracting the gravity is being expended —for example the force of Earth's surface, which holds us up and causes us to have a weight when we rest on it. If there were no surface and we were freely falling, then we would be said to have no weight.

Weight should not be confused with mass, which is an intrinsic property of all objects. The amount of matter an object contains is its mass. Even when they are freely falling, objects have mass.
—LOUIS D. FRIEDMAN,
*Executive Director*

***If we were to design a robotic interstellar mission to travel to the nearest star system, what is the shortest time in which such a mission could be accomplished using current propulsion technology?***

***Also, what is the greatest speed the spacecraft would attain? (The mission could be designed to take advantage of gravitational assists.)***
**—Teal Cooper, Dallas, Texas**

*Astronaut Loren J. Shriver is having a snack on board the space shuttle* Atlantis *as it orbits Earth. Away from the force of Earth's surface, these little chocolate asteroids are on a free fall path through space.*

*Photograph: NASA*

The nearest star system, Alpha Centauri, is 4.3 light-years, or 4 trillion kilometers (2.5 trillion miles), away. Jet Propulsion Laboratory engineers have estimated that currently available electrical thrusters powered by large nuclear-electric power plants might be able to get a small robotic spacecraft up to a speed of 150 kilometers (90 miles) per second or 0.05 percent of the speed of light. (Gravitational assists will not improve that speed significantly.) At 150 kilometers per second, it will take 8,600 years to reach the nearest star system.

If we use *physically feasible* but not *currently available* technology, in the form of powerful Sun-pumped laser beams pushing very small robotic probes, it is conceivable that speeds approaching 1 to 5 percent of the speed of light could be attained, and the probe would reach Alpha Centauri in the lifetime of the humans who sent it.The real challenge would be to design a probe that weighs only a few grams, yet can send pictures back over interstellar distances.
—ROBERT L. FORWARD,
*Forward Unlimited*

***Is Earth the only planet in the solar system whose axial tilt changes several degrees to cause the seasons? If so, why?***
**—Greg P. Goethel,**
**Los Angeles, California**

Many of the planets rotate every day about an axis that is tilted substantially with respect to the plane in which they revolve around the Sun during their year. Earth's obliquity (the angular tilt of its axis) is about 23.5 degrees from the vertical. Mars' obliquity is about 24 degrees, so the seasons are much the same on the two planets. Venus has hardly any obliquity (2.5 degrees). Uranus is tilted over so far that sometimes its poles almost point directly at the Sun.

The tilted axis of a planet is probably due to collisions of the planet with other very large bodies early in the history of the formation of the planet. A collision between Earth and a Mars-sized object probably created the Moon, setting our obliquity at the same time.

The tilt of Earth's axis is nearly constant. The seasons occur because the direction the axis points is fixed. Earth's axis always points in the general direction of Polaris, the North Star, which is why the star is a useful navigation aid in the northern hemisphere. During summer there, Polaris lies in the direction of the Sun, so the northern hemisphere is bathed in sunlight. During winter, when Earth has moved halfway around its orbit, Polaris lies in the opposite direction from the Sun.

Although the tilt of Earth's axis is constant over a year, it does undergo slow modification due to the gravitational pull of the other planets. These small variations are thought to have caused the ice ages on Earth. If Earth tilts a little closer toward the Sun, then the poles receive more sunlight in summer and vice versa. It is still not clear why our planet's climate is so sensitive to these small changes in tilt (about 2 degrees) that occur over about 40,000 years. Earth's orbit about the Sun is elliptical and the shape of the orbit also undergoes a slow change over about 100,000 years, which also contributes to the ice ages.

Mars'obliquity does fluctuate, varying through a range of 25 degrees, but this also takes place over 100,000 years. It is only the presence of the Moon that keeps Earth's obliquity relatively stable over long periods of time. Without the Moon's stabilizing influence, climate changes would have been so severe on our world that some have questioned the ability of life to have evolved here.
—BRIAN TOON,
*NASA Ames Research Center*

*The International Astronomical Union recently approved the name "Dactyl" for the tiny moon that* Galileo *discovered orbiting asteroid Ida.*
*Photograph: JPL/NASA*

# Factinos

Slight temperature differences in the two comet-forming regions of the solar system cause comets to form in different ways, say NASA researchers. "We predict that comets from the Kuiper belt and Oort cloud contain structurally different forms of water ice," say Peter Jenniskens and David Blake at NASA Ames Research Center in Moffett Field, California.

According to the researchers, Kuiper belt comets, from the outer region of the solar system beyond Pluto's orbit, probably formed at temperatures colder than minus 220 degrees Celsius (minus 370 degrees Fahrenheit). Oort cloud comets, most likely formed in the Neptune-Uranus region and then expelled to much greater distances from the Sun, probably took shape at temperatures warmer than minus 195 degrees Celsius (minus 320 degrees Fahrenheit).

Jenniskens and Blake's predictions are based on laboratory simulations of cometary ice formation under conditions thought to exist when the objects formed.
—from NASA Ames Research Center

Ken Edgett, a planetary scientist from Arizona State University, has discovered two types of sand dunes on Mars that are common on Earth. After poring over *Viking* images, Edgett has finally found star dunes and linear dunes.

On Earth these dunes form in response to changing weather. Winds that blow from all directions equally tend to form star-shaped dunes, while winds that alternate between two main directions create linear dunes. Edgett's discovery indicates that, in at least a few places, martian winds are variable in direction, pointing to a more complex picture for weather on the Red Planet than planetary scientists previously had.
—from *Astronomy*

Last spring *Galileo* returned the first image ever recorded of a satellite orbiting an asteroid (see the July/August issue of *The Planetary Report*). In this sharper new close-up of Ida's moon Dactyl (see photo at left), features as small as 50 meters (about 165 feet) across are visible on the tiny satellite, which is only 1 kilometer (0.6 mile) in diameter.

Infrared spectra taken by *Galileo* suggest that the moon isn't just a chip gouged from Ida. These data show that the surface abundance of the minerals pyroxene and olivine on the satellite differs from that on Ida, says Robert W. Carlson of the Jet Propulsion Laboratory. However, Michael J.S. Belton of the Kitt Peak National Observatory in Tucson, Arizona, says that both the asteroid and its moon ultimately stem from the breakup of a much larger body that formed the Koronis asteroid family.
—from *Science News*

# Holiday Gift Guide!

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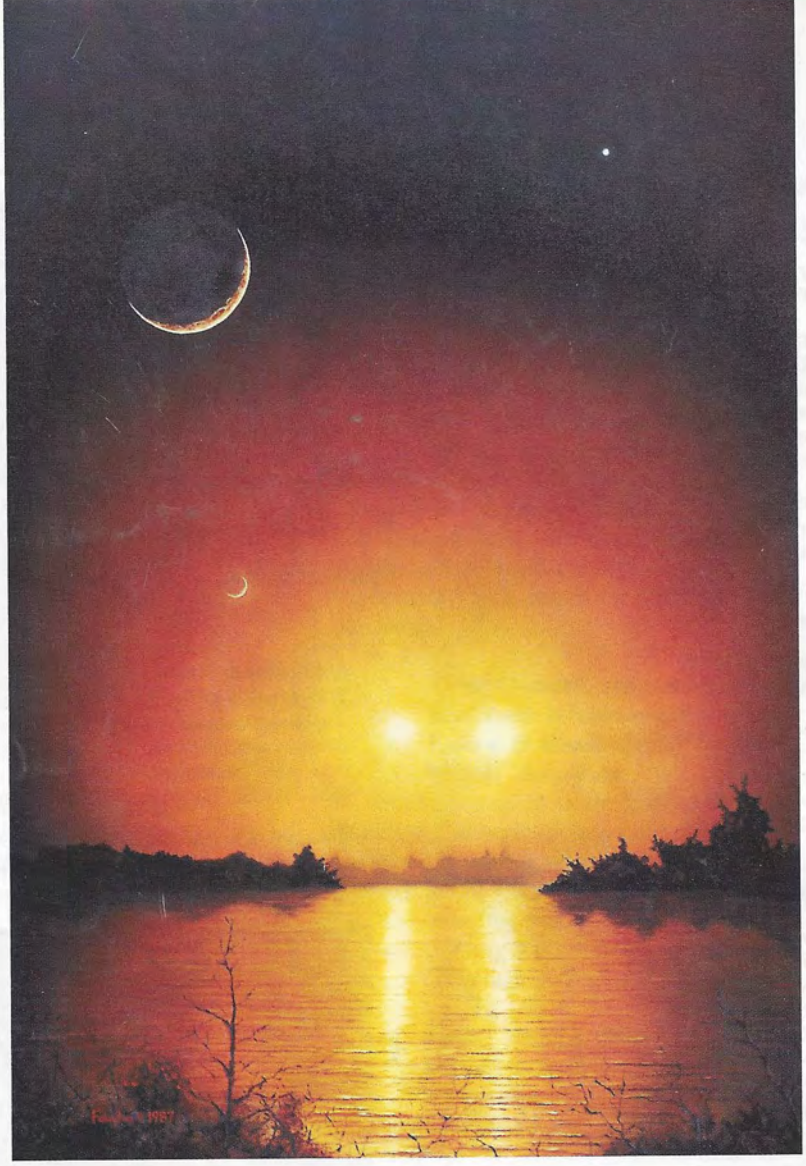

No matter how likely it seems, we have never "seen" planets or solar systems like our own around other stars. The lakeshore of a distant planet in orbit around a double star is the setting for "Binary Sunset."

Edwin Faughn is the art director of the Memphis Museum Planetarium in Memphis, Tennessee, where many original multimedia productions featuring his work have been created and sold to planetariums worldwide. His artwork has also appeared in *Sky & Telescope* and *Astronomy* magazines.

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