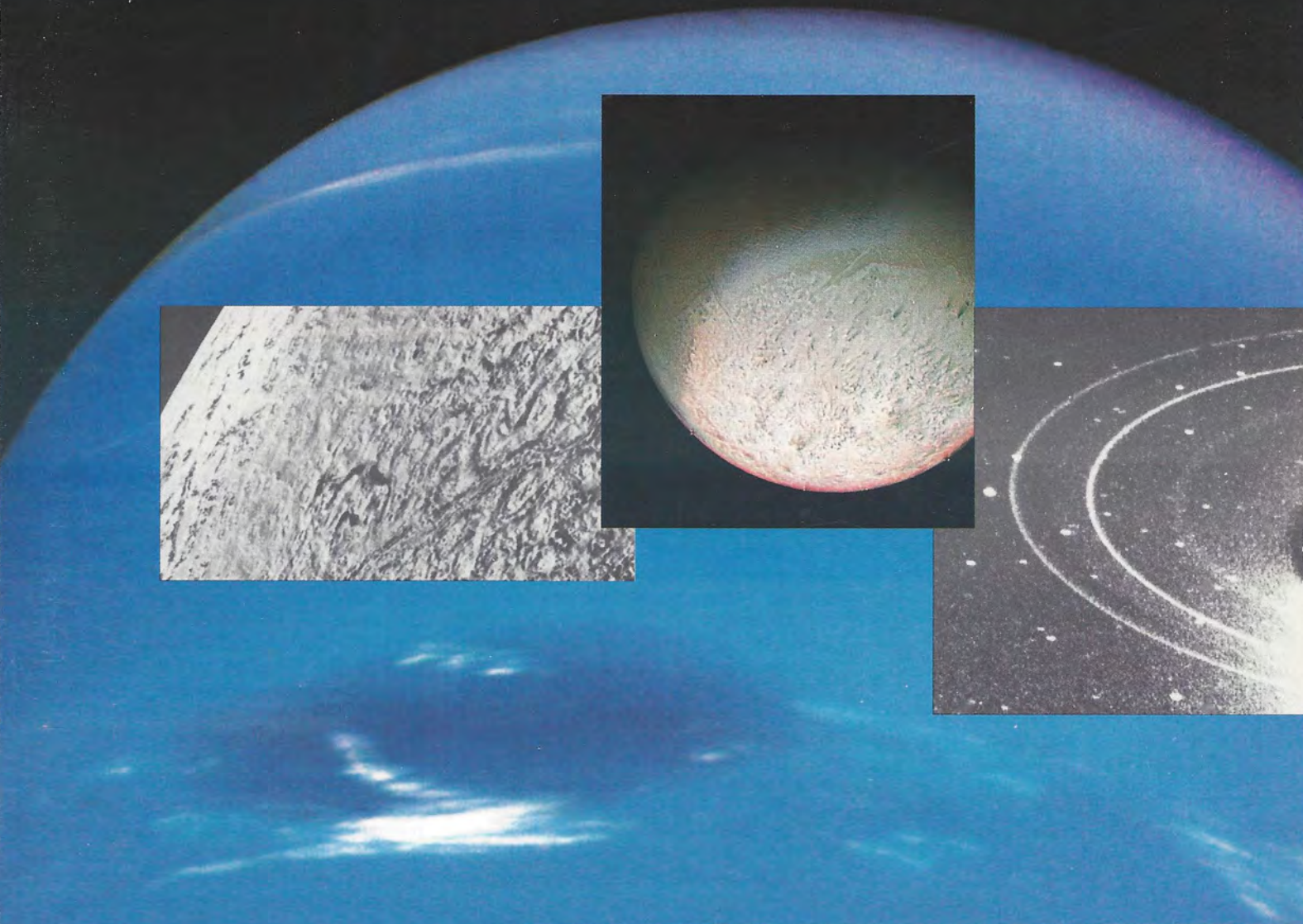
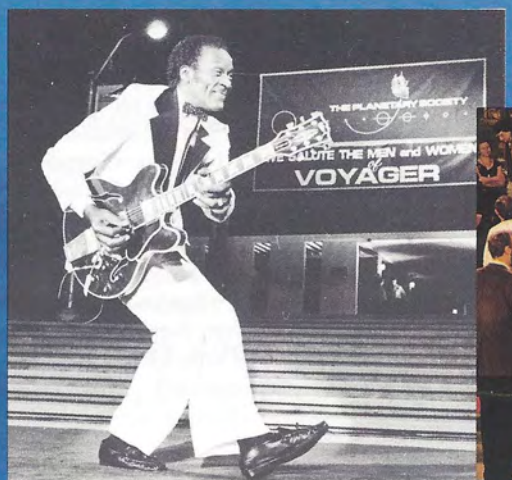
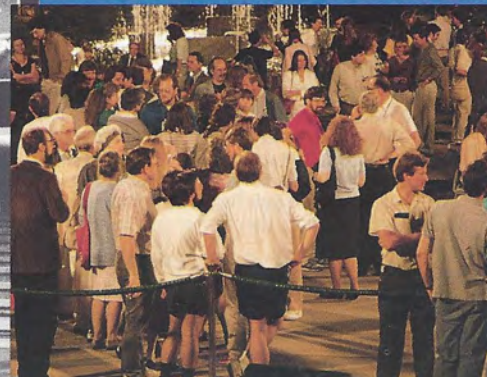
The PLANETARY REPORT

Volume IX Number 6 November/December 1989



What a Planet! What a Party!





A Publication of
THE PLANETARY SOCIETY

The Planetary Report (ISSN 0736-3680) is published six times yearly at the editorial offices of The Planetary Society, 65 North Catalina Avenue, Pasadena, CA 91106, (818) 793-5100. It is available to members of The Planetary Society. Annual dues are $20 in the US, $25 in Canada, and $30 outside the US or Canada.

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In Canada, Second Class Mail Registration Number 9567

COVER: During early August 1989, the Great Dark Spot of Neptune became a familiar sight worldwide. Then, as* Voyager 2 *flew through the neptunian system, unexpected images came fast and furious, including the highway-like features on Triton, its bright south pole and possible volcanic features, and complete rings around the planet. After the encounter, The Planetary Society threw a party for* Voyager, *and Chuck Berry serenaded the spacecraft on its way out of our solar system.

Photographs: JPL/NASA, J. R. Rost and Dan MacMedan

Planetfest '89: Sharing the Neptune Encounter

For five days, August 23 to 27, as the Jet Propulsion Laboratory (JPL) steered *Voyager 2* past Neptune and The Planetary Society hosted Planetfest '89, Pasadena became the center of the solar system. At least that's how it seemed to Society staff and volunteers, who worked long and hard to make the Pasadena Planetary Festival happen. From the opening symposium on Wednesday to the "wrap party" on Sunday night, we worked, fretted, partied and—with over 15,000 Planetfest guests—celebrated the completion of *Voyager 2*'s Grand Tour of the solar system.

The centerpiece of Planetfest '89 was the "videowall": 16 high-resolution color monitors linked together by computer to form one giant screen. There we broadcast "*Voyager* Watch," featuring live images of Neptune, its rings and moons as they were received at JPL. Nearly 5,000 people joined us on Thursday, the night of closest approach, and many hundreds spent the entire night at the videowall, participating in *Voyager 2*'s historic last encounter.

The daily press briefings at JPL were also piped into the videowall so that Planetfest attendees could hear the latest discoveries and analysis as they were announced. During periods when the spacecraft was performing experiments rather than transmitting images, the videowall played "The Best of *Voyager,*" a specially prepared videotape of spacecraft images and computer graphics recapitulating the many surprises and achievements of the mission. With live images, press announcements and thrilling graphics, the videowall set a quick pace for other Planetfest activities.

In organizing Planetfest we wanted to make sure that when people were ready to take a break from the videowall, there were plenty of things to see and do. The most popular feature was the Planetary Society store, which offered everything from glitter pencils to T-shirts to spacecraft models. Artist Kim Poor set up his Novagraphics art gallery where people could watch space artists creating images and buy copies of their work.

JPL set up informative displays on their upcoming missions and posted the latest released images from *Voyager* for close-up viewing. Several aerospace companies brought exhibits of their latest projects, and the World Space Foundation hung a solar sail from the ceiling of the conference center.

Planetfest '89 was all this and much more, as you'll read on the following pages. Planning Planetfest took a year and a half. It all began under the direction of film producer Claire Townsend, who laid the foundation. When Claire left to begin law school, I took over as Director, and while I can't claim to have enjoyed *every* minute, Planetfest '89 certainly is something I'll never forget.

I wish I could personally thank everyone who helped make Planetfest '89 possible, but that would probably take the entire *Planetary Report*. People literally came from around the world—from Norway and Australia, for example—to experience the encounter and Planetfest, and we thank all of them for coming.

Will we do it again? I hope so, but not before we recover from this one! The Planetary Society will hold major public events at upcoming planetary encounters—for example, when *Magellan* reaches Venus next August—and no doubt sometime we'll do a full-blown Planetfest again. Keep reading *The Planetary Report* and watch for announcements of Society activities. I hope to see you there.
—Angela Brown, Planetfest '89 Director

PLANETS AND POLITICS

REFLECTIONS ON THE PRESIDENTIAL MOON-MARS INITIATIVE

BY CARL SAGAN

In his capacity as Distinguished Visiting Scientist at the Jet Propulsion Laboratory, Planetary Society President Carl Sagan recently shared his views of President George Bush's new space policy with JPL scientists, engineers and administrators. This article comprises brief excerpts from his talk.

The full text of Sagan's address is now available as a pamphlet published by The Planetary Society. With "Planets and Politics" we are inaugurating a new pamphlet series to provide our members with in-depth background on space policy, history and scientific discovery. If you would like a copy of the pamphlet, please send $3.00 to: Pamphlets, The Planetary Society, 65 N. Catalina Avenue, Pasadena, CA 91106.

On July 20, 1989, in his speech marking the 20th anniversary of the *Apollo 11* landing, President George Bush gave the first authoritative response to President Mikhail Gorbachev's proposal that Americans and Soviets go together to Mars. There he talked about manned missions to Mars and about going back to the Moon, "to stay." I applaud that speech as far as it went. It had some omissions and deficiencies—some of which perhaps are a matter of perceived political necessity.

Some of the omissions: There was no mention of robotic precursor missions to Mars or to the Moon or to anywhere else. I think that is simply a detail. President Kennedy's May 1961, "We're going to the Moon," speech didn't mention *Rangers, Lunar Orbiters* or *Surveyors*. We are not going to set people down on Mars without much more robotic exploration of the planet—for safety reasons and to maximize scientific and other return.

There was no mention of the possibility that the design of space station or heavy-lift vehicles needs to be reconsidered in the light of this new goal. This follows in a very natural way from the Mars goal. If we are serious about the Mars goal, we want a space station focused on long-duration spaceflight both at zero-g and "spun up" for artificial gravity. We need practice in "storm shelters" to protect interplanetary crews at times of violent solar flares. We need to develop vehicle assembly skills in Earth orbit. These are the sorts of things that should be the focus of the US space station.

There is no question that if we're imagining a human mission to Mars in the 2010s, NASA needs intermediate milestones. The Moon is certainly there, it's only a few days distant, and it's a reasonable place to test things out.

To me a lunar "outpost" means a small intermittently occupied facility; a lunar "base" means a large permanently occupied facility. An outpost is unlikely to distract us from the main objective. A base may be a dead end. NASA Associate Administrator Frank Martin has imagined an exercise in which you go to the space station for a year, then go down to the lunar outpost for a month, and then back to the space station for a year—in this way modeling the Earth-Mars transit, the Mars surface excursion, and then the Mars-Earth return. Martin stressed that during this period it would be essential to keep the Mars goal constantly before the public.

How do you keep that Mars goal constantly before the public while you have astronauts on the Moon? You go to Mars with robots. There's a succession of missions. Not just rovers and sample returns but penetrators and balloons and orbiters—a wide range of fully justified missions to Mars and elsewhere.

If we are interested in exploring the planets with humans, it's fair to ask us to compete—to justify why we want to spend all this money in the face of so many other pressing demands on the discretionary federal budget. I believe there are excellent arguments, but we have to make them. There are only two sources for this money if we do not dip into taxes specifically earmarked for other vital purposes. Since more than 50 percent of non-earmarked taxes already goes to the Department of Defense (DOD), the only sources for this money are either new taxes or the DOD budget. We have all heard the President's view on taxes. That leaves the DOD budget.

But that's the main place that funds for all the other social issues must come from. The key issue before NASA then is broadening its constituency—demonstrating to citizens not passionately fond of spaceflight for its own sake that it is in their interest and in the national interest that a set of slow steps extended over a period of decades be organized toward humans landing on the planet Mars.

Environmental issues are becoming politically important worldwide. Any politician skeptical about the reality of the greenhouse effect on Earth can productively contemplate the greenhouse effect on Venus. Early studies of ozonosphere depletion by chlorofluorocarbons were based on research on Venus' atmosphere. The antiseptic martian surface is what happens when your ozone goes away. Nuclear winter was discovered by planetary scientists who worked on martian dust storms. Additional unexpected environmental dangers may be discovered by studies of other planets. NASA could do a much better job in justifying planetary exploration by stressing its role in protecting our small world.

NASA must embrace another constituency if the grand long-term initiative to send people to Mars is to become a reality: the peace constituency. I would have been much happier with Mr. Bush's speech if it had included a sentence that began something like: "I will propose to Mr. Gorbachev that together we . . . " The idea of the United States and the Soviet Union engaged in a stirring, peaceful, high technology, long-term goal of clear historical importance, bringing the two nations together in a great enterprise, sealing the end of the Cold War, can justify the Mars initiative to many people who are left untouched by quasi-religious arguments of the "because it is there" variety.

There is so much that can be done if these two nations work together. Polls indicate that a properly prepared and presented program would be supported by the American people.

In the long run, the binding up of the wounds on Earth and the exploration of Mars might go hand-in-hand, each activity aiding the other. The first voyage of men and women from our planet to Mars is clearly the key step in transforming us into a multiplanet species. □

Voyager Watch: Getting Everybody Involved!

HARDY SOULS STAYED UP ALL NIGHT THURSDAY FOR THE CLIMAX OF *VOYAGER* WATCH. THE VIDE

The Planetary Society initiated *Voyager* Watch to involve its members and the public in the historic Grand Tour of the outer solar system, climaxed by the Neptune encounter. From Kennesaw, Georgia to Kuala Lumpur, more than 46,000 Planetary Society members received invitations to local *Voyager* Watch activities, and everyone was invited to join Society staff and advisors in Pasadena for Planetfest '89.

With partial funding from the Norris Foundation, The Planetary Society developed *Voyager* Watch as an outreach program to educate and excite the public about planetary exploration and the discovery of new worlds. The program had three main components: distributing free *Voyager* information packets, loaning out audiovisual materials on the Grand Tour to science organizations and schools, and cosponsoring *Voyager* Watch events worldwide.

The *Voyager* Watch packets were a hit. We've filled more than 4,000 orders, and many people asked for extras to be sent to sons, daughters, siblings or colleagues. About half of the requests came from teachers who planned to use the information packets in the classroom. Among several overseas requests was one from a Leningrad member who periodically gives talks for schoolchildren. As one teacher said, "Who knows, perhaps we'll stimulate some dreams of being a *human* solar system explorer."

Each information packet included a reservation form for borrowing special audiovisual materials: the videotape *Jupiter, Saturn and Uranus* and *The Grand Tour,* a slide and audiotape set developed by The Planetary Society for *Voyager* Watch. Al Hibbs, the "Voice of *Voyager*" through all the planetary encounters, narrates the 40-slide show.

The most satisfying aspect of *Voyager* Watch was the chance it gave members of The Planetary Society and general public to meet others who shared their excitement for planetary exploration. And thousands took advantage of that opportunity, at events ranging from small star parties to all-night Neptune vigils. To name a few such events: hundreds watched Triton at Triton—that is, the Cernan Space Center of Triton College, River Grove, Illinois; members in Dublin, Ireland met in Phoenix Park to train telescopes on the outer planets; and more than a thousand people attended a 24-hour *Voyager* Watch in Ohio cosponsored by the Astronomy Club of Akron.

From Georgia, Wes McCoy wrote that the "Cobb County *Voyager* Watch was a complete success despite pouring rain and intense lightning. Fourteen high school science club students greeted at least 420 *Voyager* Watch participants from 11 different Georgia counties. . . .

The false color in this picture of Neptune highlights details of cloud structures and gives an indication of their altitude. Highest-altitude features have a pinkish tinge. Screening out the ultraviolet enabled Voyager 2's wide-angle camera to look deep into the atmosphere at the Great Dark Spot and other lower-altitude regions, which appear dark blue.

Image: JPL/NASA

ISU Tunes In *Voyager* Watch

In a special international *Voyager* Watch activity, The Planetary Society helped arrange for images of the Neptune system to be broadcast live to Strasbourg, France, site of this year's session of the International Space University. (The ISU is a nonprofit, interdisciplinary institution designed to educate the world's future space professionals.)

More than a thousand people gathered in the city's grand new conference and music center on the evening of August 25. William J. Kosmann of JPL and Mikhail Marov of Moscow's Institute of Applied Mathematics were on hand to provide commentary as views from *Voyager* appeared line by line on a giant television screen. Strange cloud bands and spots on Neptune were revealed, and though the program ended before highest-resolution images of Triton came in, the audience was enthralled.

Afterward Nina Uche, a Nigerian journalist and student at ISU, and James Logan, the University's provost, led a discussion by four people who had all experienced space travel: Oleg Atkov of the USSR; Jean-Louis Chrétien and Patrick Baudry of France; and Bruce McCandless of the US.

By the end of the evening all who attended, including the ISU faculty and its 125 students from 26 nations, knew they had shared a once-in-a-lifetime adventure.
—James D. Burke, Technical Editor

PHOTOS: J. R. ROST

WALL WAS THE CENTERPIECE OF *VOYAGER* WATCH.

The students set up an inspired refreshment stand, selling MOON pies, MARS bars, and a punch we called the Pan Galactic Gargle Blaster!"

Voyager Watch owes its success to the many Planetary Society members who participated. To quote one final letter: "It has been great! And now we have *Magellan* and *Galileo* to look forward to!" *—Susan Lendroth, Manager of Events and Communications*

Our House Is a Very Fine House

SOCIETY MEMBERS WHO HELPED BUY OUR HOUSE (INSET) DROPPED IN TO SEE IT DEDICATED. PHOTOS: J. R. ROST

The Neptune encounter and Planetfest '89 activities were the perfect occasion for the dedication of The Planetary Society's international headquarters building, which we now own, and for thanking our members, who donated $250,000 for the down payment. Our monthly payment, which now goes toward equity, is roughly the same amount that we used to pay in rent.

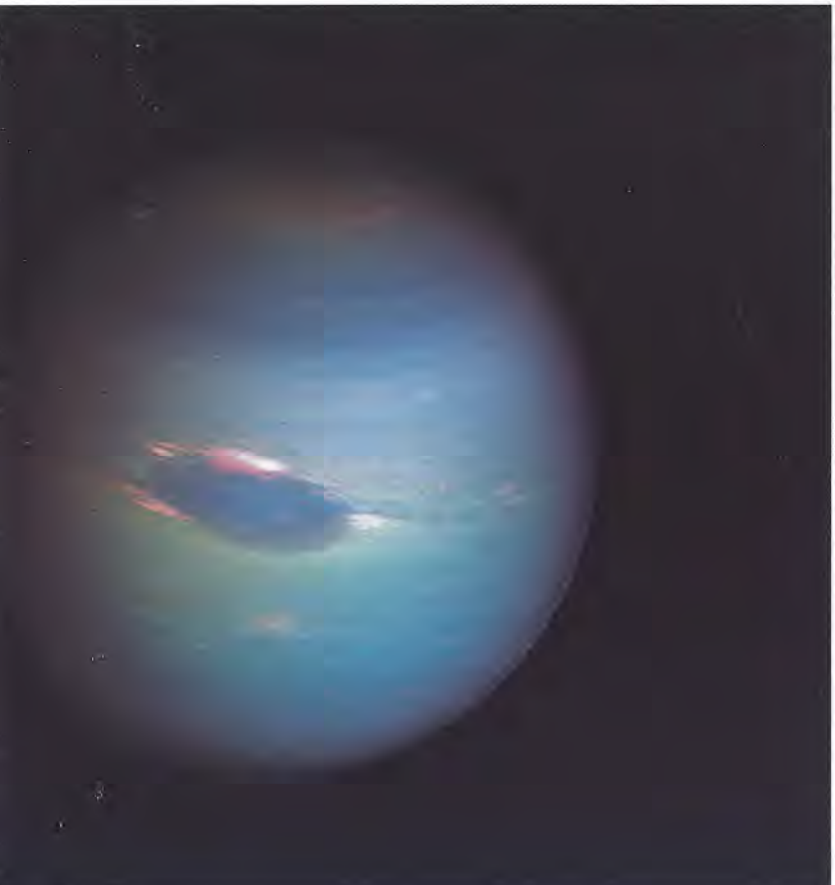
The building is a Craftsman classic, the work of the renowned architectural team of Charles and Henry Greene. Built in 1903, the same year the Wright brothers first demonstrated that craft heavier than air could fly, the Society's headquarters building has been witness to several generations of rapid technological change, as Pasadena has become the center of US planetary science. The Jet Propulsion Laboratory and California Institute of Technology are within a few minutes of our offices. Members and staff alike think this house is a fitting place to carry on the work of supporting the exploration of the cosmos and the search for extraterrestrial intelligence.

The formal dedication took place on August 23, the day before Planetfest got officially under way. Gathering members and guests around the hearth, we unveiled five plaques containing nearly 1,500 names of members who donated $100 or more to the International Headquarters Building Fund. [Note: we still have a substantial mortgage and room for many more donors if you would like your name added to our honor roll.] And then the party moved outside, where refreshment tables were set up so that members could meet and talk about things planetary in the afternoon sunshine (and perhaps bask in the glow of home ownership).

Meanwhile, latecomers continued to line up on the front porch to sign the guest register. Everyone was encouraged to roam around the house, either on their own or guided by staff members, who like to point out the spring-loaded secret door in the paneling of the finance and personnel office. Society President Carl Sagan and Vice President Bruce Murray were on hand to greet members from all over the US and around the world.

Throughout August and September we have had visitors drop in, some to view the plaque with their name, others just to see where our work is conducted. House tours are popular, as are visits to the sales department with the many items available to members at discount prices. Work is back to normal now that Planetfest '89 and the Neptune encounter are over, but the welcome mat is still out for members who may be in the Pasadena area. We'll be happy to show you the secret door.

—Tim Lynch, Director of Programs and Development



Voyager Retrospective: A Symposium on Exploration

For Planetary Society President Carl Sagan and Vice President Bruce Murray it has become a tradition, on the eve of a planetary encounter, to invite representatives of the artistic, political and academic communities for a discussion of science and discovery and their meaning, beyond the realm of the specialist, for humankind. The first such symposium, "Mars and the Mind of Man," brought together novelist Arthur C. Clarke, New York Times *science editor Walter Sullivan and poet and novelist Ray Bradbury as* Mariner 9 *orbited the Red Planet. Other panels followed upon* Voyager 1*'s encounter with Jupiter in 1979 and Saturn in 1980, and* Voyager 2*'s encounter with Uranus in 1986.*

Then on August 23, 1989—about 53 hours before Voyager 2*'s closest approach to Neptune—Sagan and Murray were joined by William Goetzmann of the University of Texas at Austin, a distinguished historian of exploration, and Ed Stone,* Voyager *Project Scientist, before an audience of 2,000 at the Pasadena Civic Auditorium. Here we reprint a sampling of their talks on* Voyager*'s final planetary encounter.* —Karl Stull, Copy Editor

THE PASADENA CIVIC AUDITORIUM HOSTED THE OPENING SYMPOSIUM. PHOTO: J. R. ROST

Carl Sagan

Tonight it is my job to praise, to extol, to celebrate the astonishing triumph of the *Voyager* mission. This is high technology at its best.

It is rocket technology that launches *Voyager* to the planets and ultimately to the stars. It is nuclear technology that provides the power source. In fact, it's not just any old radioisotope—it's plutonium that powers the *Voyager* spacecraft. Precisely the same technology used for the apparatus of nuclear war, *Voyager* uses for historic, praiseworthy, exploratory goals that harm no one. Even America's adversaries admire and respect *Voyager*. We have here much to be proud of.

I will not run through the multitude of discoveries that *Voyager* has made in its exploration of 50 worlds. But let me just mention two areas in which *Voyager* has played a fundamental role. Think of how central they are to our understanding of where we come from.

One set of findings, coming from studies of moons and ring systems, is the idea that worlds are destroyed—not once but many times—destroyed by cometary impact and then reformed from the debris.

The other has to do with the abundance of organic chemistry in the outer solar system. *Voyager* has, particularly at Titan, revealed a world in which organic molecules are being made today at enormous rates. Temperatures are, of course, so low that liquid water is not a commonplace on Titan, so we are not talking about the origin of life per se. But many of the steps happening in the atmosphere of Titan today are the kinds of first chemical steps that occurred in the early history of the Earth at the time of the origin of life, some 4 billion years ago.

After *Voyager 2* passes Neptune, it will encounter no more planets as far as we know. But it is by no means the end of the *Voyager* mission. There is an extraordinary opportunity coming up a few months from now, and that is for one or both *Voyager* spacecraft to look back at the solar system and photograph the planets against the background stars. You can imagine Jupiter a few pixels in size, Saturn slightly elongate because the rings will give that aspect. Then maybe over here on the other side of the Sun will be a little red dot, and that'll be Mars. And a slightly yellowish dot and that will be Venus. And there between them a little blue dot—that'll be us. That's all we are from Neptune—a blue dot. That's home. That's Earth. It seems to me that such a picture can have a very powerful influence on our understanding of ourselves.

I think it's a great pity the engineers responsible for this spacecraft are not better known. I mean known personally—their names known. They should be on the postage stamps.
—Carl Sagan

The two *Voyager* spacecraft, which were not only managed but physically constructed at the Jet Propulsion Laboratory, came in on time, on cost, and vastly exceeding the design specifications of the manufacturers. They were guaranteed only to work out to Saturn in 1980 and 1981. Well, here it is 1989, and both spacecraft are working phenomenally well.

The engineers are getting smarter faster than the spacecraft is getting stupid. And so, the spacecraft is able to do things in the Neptune system it was unable to do in the Uranus, Saturn and Jupiter systems. I think it's a great pity that the engineers responsible for this spacecraft are not better known. I mean known personally—their names known. They should be on the postage stamps. Think of how useful that would be in a society concerned about generating enough scientists and engineers to stay competitive internationally.

From here on, the job of exploration of the solar system is much more focused: It is to gain detailed understanding of worlds of particular interest. One of the most exciting prospects, called for in speeches in the last two years by the President of the Soviet Union and the President of the United States, is sending human beings to the planet Mars.

The Soviets have explicitly called on the United States to join them in the exploration of Mars with robots and ma-

chines. The Soviets have adopted the program of The Planetary Society. Now there is just one small remaining step. And that is for the United States to recognize that this grand program should from the beginning be international, involving the Europeans, the Japanese and the Soviets. I hope the first human footfalls on Mars come soon—maybe 2010, 2015, 2020. The *Voyager* spacecraft will then still be sending their information back to Earth. So if I'm still around, I look forward to the concatenation of humans on Mars and the *Voyager* spacecraft entering the interstellar medium sometime in the first or second decade of the 21st century—the beginning of the third millennium.

Ed Stone

Those of us who have been involved with the *Voyager* Project have been exceedingly fortunate. One thing I've noticed about these encounters—this is now the sixth—two with Jupiter, two with Saturn, one with Uranus, and now Neptune—it provides a snapshot of the whole scientific process of discovery—years of activity compressed into a matter of a week or even a few days. And that is really an incredible experience.

Another interesting aspect is that everyone can sit in their living room and, essentially at the same time, share in the discoveries that the scientists and engineers are making.

The project started in 1972. One of those names that Carl was mentioning, who should be remembered, is Bud Schurmeier, now retired [from JPL; he heads up the Society's Mars Balloon guide-rope design team] who as project manager oversaw the design of the spacecraft, which was so essential to the ability of subsequent generations of engineers to extend *Voyager*'s reach. The spacecraft design was such that we have been able to extend it by a factor of nine beyond its original design capability. Quite a remarkable tribute, not only to Schurmeier and his team but to the current generation of engineers who learned how to take advantage of all the capability that was built into it so cleverly 15 years ago.

Voyager returned images of Jupiter, Saturn, Uranus and Neptune. Even Uranus and Neptune, which are rather small compared to Jupiter and Saturn, are four times the diameter of the Earth. We believe buried deep inside of these giant planets there is perhaps an object about the size of the Earth—somewhat more massive—made of rocky material and a lot of icy material, which is melted because of the great temperatures and pressures. But it was accumulated as ice. The giant planets formed far from the Sun where water was frozen and therefore could be easily accumulated to make giant planets. The most remote planets formed so far from the Sun that there was a lot of methane, and methane, which is natural gas, absorbs the red sunlight so the reflected sunlight looks blue-green. So the colors—even the colors—are telling us that we are seeing planets which differ from Earth because of the conditions under which they formed.

[A *Voyager* encounter] provides a snapshot of the whole scientific process of discovery—years of activity compressed into a matter of a week or even a few days. —*Ed Stone*

In *Voyager*'s images of Neptune, we discovered a large, dark spot, which is just a bit darker than the blue-green color of the planet. That spot is about the size of the Earth. Further south we found a smaller dark spot with a nice white cloud at its center. They look like huge hurricane-like storm systems.

Now all this dynamic activity is a surprise because winds require energy —some source of energy to drive them. The amount of energy available to drive the wind system on Neptune is only about 1/20th of that available at Jupiter to drive its Great Red Spot. Yet at Neptune we find a Great Dark Spot, we find a small dark spot, we find clouds, which essentially come and go in a few days' time. A surprisingly active atmosphere for having such a feeble energy source.

We have found that there is indeed a complete ring around Neptune. This ring is so faint that when a star goes behind it, no more than 2 percent of the starlight is occulted. From Earth it was just not measurable. Even in *Voyager* images it's just barely measurable. Right next to it is one of the new moons which *Voyager* has discovered. It's likely that moon has something to do with that ring being where it is. Perhaps it's a shepherd moon. We believe narrow rings require some sort of shepherding mechanism—that is, bodies in orbit inside and outside of each ring . . .

William Goetzmann

I'm the historian here. My specialty is not Neptune; I've written on the history of exploration, and I've come to conclude that exploration is a social and cultural process. It's hard to get pictures of processes. But let me take you back in time to give you some idea that there are precedents for what we are seeing today.

In anticipation of the transit of Venus across the face of the Sun in 1769, there were 151 observers with varying kinds of instruments watching from 78 stations around the world, under all sorts of conditions from the decks of ships on rolling seas to remote stations with primitive instruments, as the scientific world prepared to watch the planet on its mysterious parade across the life-giving Sun.

To give you some idea of the intense American interest in the transit of Venus, David Rittenhouse of Philadel-

Low-level flight over Triton is a computer-generated effect: In a process called photoclinometry, the computer scans the amount of light in every part of a planetary image to make an elevation map, and so infers shape from shading. Geometric reprojection provides the low angle of view.

Image: JPL/NASA

THE AUDITORIUM WAS PACKED FOR THE "*VOYAGER* RETROSPECTIVE" SYMPOSIUM.

ED STONE AND WILLIAM GOETZMANN JOINED CARL

phia *intercepted* a lens destined for John Winthrop at Harvard, who was also going to view Venus. He used it to make his own powerful telescope, working day and night for the great event. June 3, 1769 found him ready, lying prone in a muddy field just outside of Philadelphia, propped up by an assistant, every muscle tense, his eyes fastened to the telescope. Then, just as Venus made its appearance on the edge of the Sun's disc, he signaled contact and promptly fell into a dead faint out of sheer excitement. Lucky man, his swoon lasted six minutes, so he came to just in time to record the planet's disappearance from the Sun's face.

Exploration is a special searching activity invented by humans perhaps 40,000 years ago, as evidenced by those first daring people who crossed over the landbridge from Asia to North America. It was not an automatic reflex, else all cultures would embrace exploration. A great many people stayed home in Siberia, and we know that not all later cultures embraced exploration. For example, during the Ming dynasty the neo-Confucianists made a conscious effort to stop Chinese exploration and, for that matter, contact with the outside world.

Then, just as Venus made its appearance on the edge of the Sun's disc, he signaled contact and promptly fell into a dead faint out of sheer excitement.
—William Goetzmann

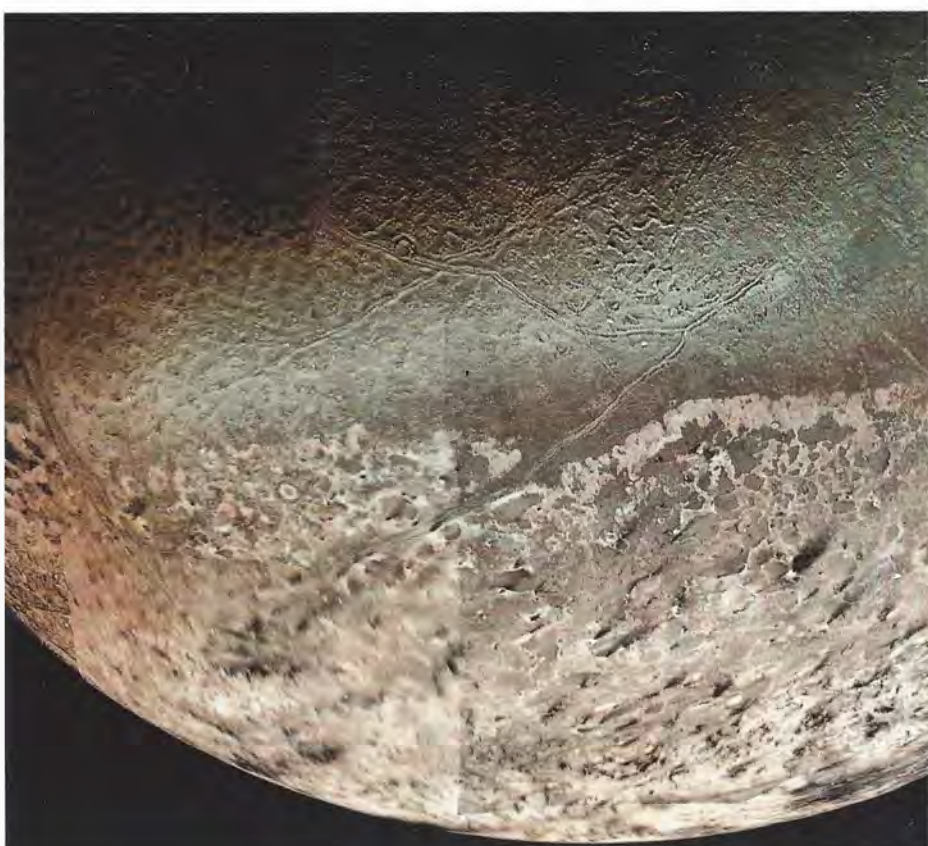
Documentable exploring activity appears to have taken place in three great ages—each one stimulated by the discovery of a new scientific paradigm. The first of these, called by historians the Great Age of Discovery, was the age in which Columbus and Magellan are key figures. The motive for far-flung oceanic exploration in that age was ostensibly to out-flank the Islamic control of trade routes to Cathay, but it was also stimulated by the rediscovery of ancient geographical knowledge.

In the latter 17th century—the age of Newton and Locke and others—a new age of discovery began to take shape, based on much more sophisticated science that mapped the circumference of the Earth and began to track the solar system with some precision. Naturalists and mapmakers went forth over the whole Earth collecting and mapping and characterizing a tremendous range of ecologies. Here the great figure of the age was the father of modern geography, Alexander von Humboldt, a scientific adventurer who braved the tangled jungles and vampire bats and electric eels that could stun a horse. (He found out that electric eels could stun a horse after he tested it out on himself.) All this activity in the 18th and 19th centuries created a romantic, adventurous, scientific-based Second Great Age of Discovery, whose key figures were, besides Humboldt, Captain James Cook, who charted the Pacific, and Charles Darwin, who made sense out of the world's infinitely varied species.

As a result of scientific revolutions, and these two great dramatic ages of discovery, a third intellectual paradigm began to appear. It would be called Modernism. The scientific innovations behind Modernism were quantum mechanics, Heisenberg's uncertainty principle, relativity theory and Freud's discovery of the subconscious. Modernism engendered a Third Great Age of Discovery and made new heroes of exploration: Yuri Gagarin; John Glenn; and Neil Armstrong, who with Buzz Aldrin first set foot on the Moon, marking the fantastic end of a journey contemplated by dreamers for centuries.

The downside of Modernism has been a dangerous absorption with self and a total relativizing of values, creating what Tom Wolfe has called "the me generation."

If for no other reason, it's because of this bleak prospect that we need *Challenger* and *Viking* and *Voyager.* They represent our curiosity and even respect for the world outside ourselves, and a distraction from the destructive potential



SAGAN FOR THE PANEL DISCUSSION.

BRUCE MURRAY FIELDED QUESTIONS FROM THE AUDIENCE. PHOTOS: J. R. ROST

of the deadly atomic sublime. Instead, through these vehicles, which are extensions of ourselves, we have opened up a new environment, which may well enlist the enthusiasms of all the nations of Earth.

With respect to *Voyager* and other space probes, all we have to offer, I think, is hope and the healthy-minded curiosity that enables a civilized people to welcome the future and continue to search for, and absorb and make use of, the new and novel.

As we reach out to the solar system, we demonstrate belief in ourselves. In a chance universe, we bet on a chance that the new galactic knowledge may be the salvation of the Earth. Far beyond the planets we may well find the inspiration that sustains our civilization, that has room for many cultures, including the culture of theoretical science.

A distinct boundary separates the terrains of Triton: the brighter, hemispheric ice cap turns abruptly into the darker terrain with its highway-like features. Visible in the bright terrain are dozens of dark smudges, perhaps indicating airborne materials spewed from active fumaroles (volcanic vents in the crust) and carried to the northeast by winds.

Image: JPL/NASA

Bruce Murray

Voyager at Neptune, surprisingly, had its origin in May 1961: That's when John F. Kennedy gave his *Apollo* speech, which was a Cold War response to the stunning Soviet success with *Sputnik*, and with Yuri Gagarin, the first man in space. He made what turns out to be a brilliant decision to commit the US to a muscle-flexing endeavor, technologically, but one that was positive, open and full of real achievement—both personal and scientific.

When the US was in that business of exploring space with men, we also had gotten into the business of exploring space with robots. With one exception all the probes that have flown to planets, including *Voyager*, were begun before or while there were astronauts on the Moon. *Voyager*—originally, the *Mariner*-Jupiter-Saturn mission—was approved in 1972. Only the *Pioneer* Venus mission was started later and completed.

Voyager 2 is out there performing better than we had ever intended or expected. It's radioing the data back to a society that's completely changed. Many things are better, some not so good. It keeps on going, setting the standards for us. We should hope to do as extraordinary a thing in the future.

I want to remind you of something. Just eight years ago in the late summer, early fall of 1981, there was an attempt to readjust the priorities of the federal government. David Stockman, who was head of OMB [Office of Management and Budget] under Reagan, was trying to implement in a logical way the priorities which were going to be imposed.

There was a serious budget proposal debated in Washington that would have not only killed *Magellan*, not only killed *Galileo*, but it also would have descoped the DSN [Deep Space Network, whose antennas track *Voyager* and other planetary missions], and there would have been no Uranus or Neptune encounters. That almost happened.

The same society that could do something as extraordinary as *Voyager* almost walked away from it. That's the flip-side of the democratic system: that we can decide to be mediocre. We have the freedom of choice, and we exercise this throughout our society.

Voyager survived. And through five presidents, eight Congresses, this achievement has gone on. And that's really a lesson on what we can do as a people if we so choose.

On July 20, 1989 President Bush finally gave a new destination for Americans in space. This goal of a return to the Moon and on to Mars was a critically important step. Without that, we were doomed to a permanent mediocrity as a spacefaring nation. Thirteen billion dollars, which is the NASA budget now, wouldn't make any difference if we didn't have a place to go.

A proper role for humans in space is exploration, not driving a truck. The tragedy of *Challenger* was that we killed seven brave and admirable people trying to launch a communications satellite. We ought to face that.
—*Bruce Murray*

A proper role for humans in space is exploration, not driving a truck. The truck driving is okay as a *part* of it. The tragedy of *Challenger* was that we killed seven brave and admirable people trying to launch a communications satellite. We ought to face that. We ought to be honest with ourselves as people. We lived a fantasy. We paid a price, both in life and in our capacity to do new things.

But we have an opportunity for rebirth and renewal. I believe that the Bush proposal is very serious. There's going to be debate for several years over it. We will, I hope, come out with an international program that's broadly supported in the United States and represents a new level of US interaction with the rest of the world. We have the opportunity. We also have the capacity to become simply a consumer nation and mortgage ourselves to the Japanese and go down the tubes. All these things are possible. □

Athenaeum Encounter: A Dress-Up Dinner for *Voyager*

For one bright night of Planetfest '89, Planetary Society people traded the attire and accoutrements of work for ball gowns and black ties at a gala dinner celebrating *Voyager*. (However, at least one engineer, Society Executive Director Louis Friedman, was seen to be wearing his calculator watch.) Over 400 people packed the Athenaeum of the California Institute of Technology to enjoy good food and to reminisce about the doughty little spacecraft that have now completed the first exploration of the outer planets.

It was a night to remember and for remembering. Society President and *Voyager* imaging team member Carl Sagan described the highlights and significance of the *Voyager* odyssey. *Voyager* has recorded so many "firsts" in its 12-year adventure, there can never be another mission like it. The initial reconnaissance of the solar system—except for Pluto—is complete.

Artist and Society Consultant Jon Lomberg told of the development of the *Voyager* record, which is carrying the sounds and sights of Earth to whatever civilization might encounter the spacecraft on their never-ending journeys through the galaxy.

The breadth of appreciation and affection for *Voyager* was reflected in the diversity of guests who accepted The Planetary Society's invitation to celebrate the mission with us. The current NASA Administrator, Richard Truly, and two former agency heads, Thomas Paine and James Fletcher, mingled with a large contingent of Society volunteers who were taking a break from their exhausting festival duties. Also on hand were the number two through five ranking NASA officials and the President of Caltech. The leaders of the three main Soviet space agencies—Valery Barsukov of the Vernadsky Institute, Roald Kremnev of Glavkosmos and Alec Galeev of the Space Research Institute—joined in saluting *Voyager* with past Directors of the Jet Propulsion Laboratory William Pickering and Bruce Murray and present Director Lew Allen.

Two of the world's leading space artists—Robert McCall of the United States and Andrei Sokolov of the Soviet Union—recalled the inspiration they have drawn from *Voyager*, as did writers Patrick Moore from the United Kingdom and Robert Forward of the US. Gene Roddenberry, creator of "Star Trek," once again showed his support for the space program and The Planetary Society.

A contingent of astronauts, including Buzz Aldrin, added glamour to the occasion. Four past and present *Voyager* Project Managers—Bud Schurmeier, John Casani, Ek Davis and Norm Haynes—joined Project Scientist Ed Stone in remembering some of the stories behind *Voyager*'s accomplishments.

Leaders of industry, scholars, members of Congress, members of the New Millennium Committee of The Planetary Society and many other friends joined us in this salute to *Voyager*, even as the spacecraft were carrying the best wishes of Earth out to the universe.

—Charlene M. Anderson, Director of Publications

Science from *Phobos*: A Soviet Symposium

Nearly 2,000 Planetfest enthusiasts crowded into the exhibition hall of the Pasadena Center on August 26, 1989 to hear five Soviet space scientists describe the Mars and Phobos data acquired by the *Phobos 2* spacecraft.

Alexander Zakharov, Project Scientist for *Phobos* and Scientific Secretary of the Space Research Institute, led off with an overview of the mission, from launch to its premature end in March 1989. He described the orbital geometry and the principal experiments aboard. He also mentioned some interesting solar observations sent back by *Phobos 2*.

Vasily Moroz, head of the planetary science department of the Space Research Institute, discussed the overall objectives of the Mars measurements, which included readings from the Soviet/French instrument called the ISM. This scanning instrument, a novel infrared spectrometer, acquired important information about both the surface and atmosphere of Mars.

Boris Zhukov, key member of the *Phobos* television team, followed with a description of the television system, which delivered some of the best images to date of Mars' diminutive moon Phobos.

Margarita Naraeva of Glavkosmos (the space engineering organization) delighted the crowd with a tale of individual enterprise. As young and rather obscure engineers, she and a colleague worked on their own to develop a scanning instrument that would eventually make the first close-up images of the lunar surface. But designing the instrument was only the beginning. They had to persuade the bureaucrats that such a device could have been produced by a couple of independents who were, in effect, working out of a garage. They were successful, and so was *Luna 9*.

For the *Phobos* mission Naraeva worked on the termoskan instrument, a scanning radiometer that produced

Valles Marineris, spanning nearly a fifth of the martian globe, was imaged by the termoskan. The light and dark shading represents differences in heat radiated from the surface, with the lightest areas being hottest.

Image: Margarita Naraeva, Glavkosmos

PHOTO: KEN WONG

TWENTIETH CENTURY IS BY Y. TSIRKUNOR.

PHOTO: J. R. ROST

THE SCULPTURE *COOPERATION* BY E.Y. MISKO CAPTIVATED ART SHOW VIEWERS.

International Space Art Show

The International Space Art Show at Planetfest '89 was a marvelous celebration of humankind's first chapter of planetary exploration. Thousands of visitors strolled quietly through the display of more than a hundred paintings, exploring far beyond Earth's boundaries, from the exuberant, splashy *Galaxy Metamorphosis* diptych by Narimanbekov Togrul to Michael Carroll's glinting *Particle Beam at Phobos*. Curious onlookers kneeled to get a better view into Richard Murry's *Star Base Colony of Condradonn,* a three-dimensional glimpse of what it might be like to live in a city of alien spires and pearl-like minarets.

Exploration of the universe is a subject of study for artists as well as scientists. Art can communicate the wonder at the heart of science. The imagination has the power to take us where our spacecraft have yet to go, to envision the myriad possibilities of other worlds.

For astronomical artists, Planetfest '89 was a time to gain vision for future work and to excite the public about space exploration through completed works. Planetfest attracted artists from around the world, including nine from the Soviet Union who were brought over through the efforts of The Planetary Society and the International Association for the Astronomical Arts (IAAA) and the generosity of the Soros Foundation.

The show represented a wide range of styles, from the compelling realism of John R. Foster to the fantastic imaginings of Beth Avary and V. A. Myagkov. Mark Mercury's *Moon Picnic* offered a wry look at the recreational side of space, with fully suited astronauts enjoying an old-fashioned picnic and a game of catch. Andrei Sokolov's study of the Mississippi River Basin as seen from the *Soyuz* spacecraft was accompanied by working sketches that illuminated the creative process.

The response to the art show was overwhelmingly positive. Visitors lined up next to Dennis Davidson's evocative moonscapes to have their pictures taken. The artists and their work were covered by three national television networks as well as by several local newspapers and television stations.

Anyone interested in another showing can see the traveling exhibit at San Diego's Reuben H. Fleet Space Theater or, in 1991, at the Smithsonian's Air and Space Museum.

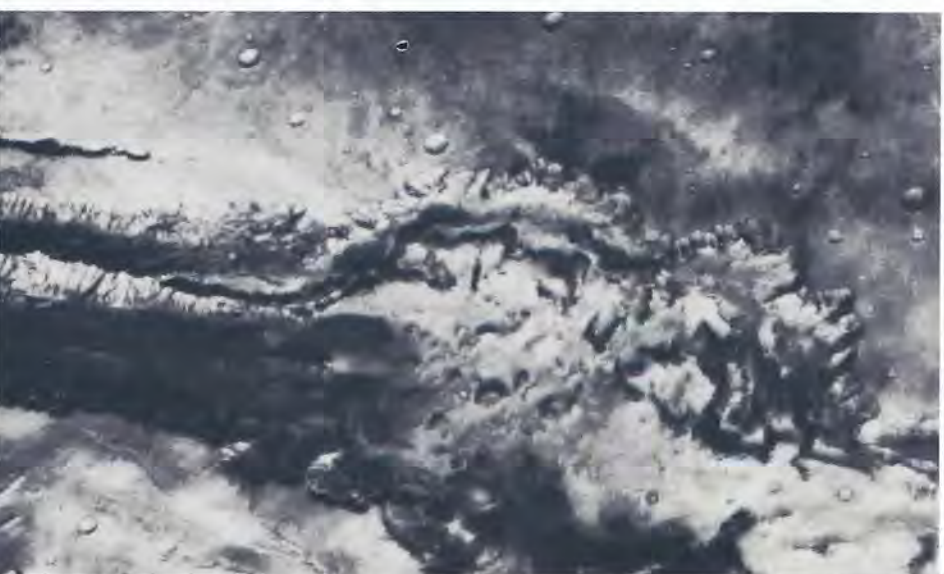
The International Space Art Show was part of a program of workshops and exhibitions jointly sponsored by The Planetary Society, the IAAA and the Union of Artists of the USSR. Called "Dialogues: Communication through the Art of the Cosmos," this program began in 1987 when the Soviet Union invited a number of IAAA members to travel there and exhibit their work. *—Deirdre von Dornum, Editorial Assistant*

thermal-infrared images of the surface of Mars at higher resolution than even the *Mars Observer* instrument will be able to acquire. (For more on the termoskan, see page 22 of the July/August 1989 *Planetary Report*.)

Leonid Ksanfomaliti from the Space Research Institute completed the panel. He described the KRFM experiment, a multichannel filter spectrometer covering wavelengths from the ultraviolet to the infrared. The KRFM studied the martian surface and atmosphere and also observed Phobos.

Following the presentation, questions from the audience were handled in a very open style, with a free give and take on such general-interest topics as the Soviet attitude toward piloted spaceflight and the US shuttle program.

This forum was one of the first occasions for person-to-person, two-way communication between an American lay audience and Soviet scientists. I hope it will prove a step toward a much broader dialog between scientists and an interested public in both countries. *—Bruce Murray, Vice President*



Voyager at Neptune: Sorting Out the Early Results

by Clark R. Chapman

Never before have human beings sent an explorer so far to study a new place. *Voyager*'s final encounter, at our planetary system's periphery, was destined to boost our knowledge more than any previous planetary encounter. Nearer planets had been scrutinized through telescopes or visited by precursor probes. But distant Neptune, not even known to exist until the last century, remained a tiny, fuzzy blob in our largest telescopes. *Voyager*'s swingby, 12 years after its launch, was our first chance to study that dimly lit world close up. Since the rare Grand Tour alignment of Jupiter and Saturn has passed, gravity assists to the outer solar system won't be feasible again for many years. *Voyager*'s studies of Neptune may be the last in our lifetime.

There were new moons, rings, ring arcs within rings, ethereal cloud features (casting shadows!), an unexpectedly skewed magnetic field—this was a magnificent final opportunity for comparative planetology.

Triton: Star of the Show

There were no oceans of liquid nitrogen. Nor was there appreciable global haze to shield this large moon from our view, as Saturn's Titan was hidden by its organic smog.

Atmosphere there was, including haze layers, clouds (volcanic plumes?) and —hard to believe—wind streaks reminiscent of Mars. All this weather was present despite Triton's minimal barometric pressure, which is only a hundred-thousandth of sea-level pressure on Earth. Once again, a new world's geology seemed to defy description, let alone interpretation.

Geologists do their science through analogy with features they already understand. They drew parallels with Mars, Ganymede, Enceladus, Ariel, Miranda and many other bodies, but the pictures on these pages tell the true story: Triton is unique, and it will take years before its complex geology is understood. What can we make of the "highway interchange"? And the "black mushroom"? And the "cantaloupe" terrain? This is a frigid world at 37 kelvins (minus 236 degrees Celsius). Out in the realm of comets, how can it be so devoid of impact craters?

As in previous encounters, *Voyager* geologists had to consider the possibility that an apparently dead, frozen moon remains geologically active to this day, despite the lack of a plausible internal source of energy. Just after the encounter Larry Soderblom of the US Geological Survey told astonished reporters that he thought Triton's geysers were still active. They might have been erupting as *Voyager* watched: Clouds were poised 10 kilometers (6 miles) over some of the dark streaks. At the very least, in Soderblom's estimation, they were active within the last century, as this hemisphere of Triton has been slowly approaching its summer.

Results Keep Coming

Voyager scientists have only skimmed the cream from the data received during the few short days of the August encounter. As the reporters were leaving Pasadena on Monday, August 28, plasma wave and infrared data from encounter night, which had been stored on *Voyager*'s digital tape recorder, were still crossing the four "light-hours"

ABOVE: The "black mushroom" is one of three irregularly shaped, bright-bordered spots in this image of Triton, showing an expanse of about 1,000 kilometers (600 miles).

RIGHT: The Great Dark Spot was snapped in a "close up" just 45 hours before Voyager 2's closest approach to Neptune. The ethereal beauty of the storm is highlighted by the intricate wispy structure of the adjacent cirrus-like clouds. *Images: JPL/NASA*

back to Earth. The radio science team had not yet received its 992 pounds of magnetic tape from the Canberra tracking station by the end of Tuesday's "final" press conference, where researchers tried to summarize *Voyager*'s discoveries.

Many new results will appear in the "thirty-day report" in *Science* magazine late this year, and still more will be announced at a December geophysics meeting. But the real work of understanding *Voyager*'s observations of the outermost solar system will take years.

When the *Voyager* science teams were selected in the mid-1970s, only one geologist was included. The outer solar system, after all, consisted of "gas bag" planets, interesting only to physicists, astronomers and cosmochemists. Planetary satellites were frozen rocks of little importance, or so we thought then.

That all changed in 1979 when the two *Voyagers* flew by Jupiter. Add-on *Voyager* geologists still resist accepting how easy it is for interesting things to happen in the frigid outer solar system, where water and water ice play the roles of lava and terrestrial rock. Io and Europa were shockers during the Jupiter encounter, and so was Enceladus at Saturn (see July/August *Planetary Report*). After the Uranus encounter Ariel and remarkable Miranda amazed scientists again, and now Triton has done it too. Planetary geologists have yet to see Pluto (perhaps Triton's twin). It's safe to say, with CRAF/*Cassini* on the horizon, that asteroids and comets may yet astonish us.

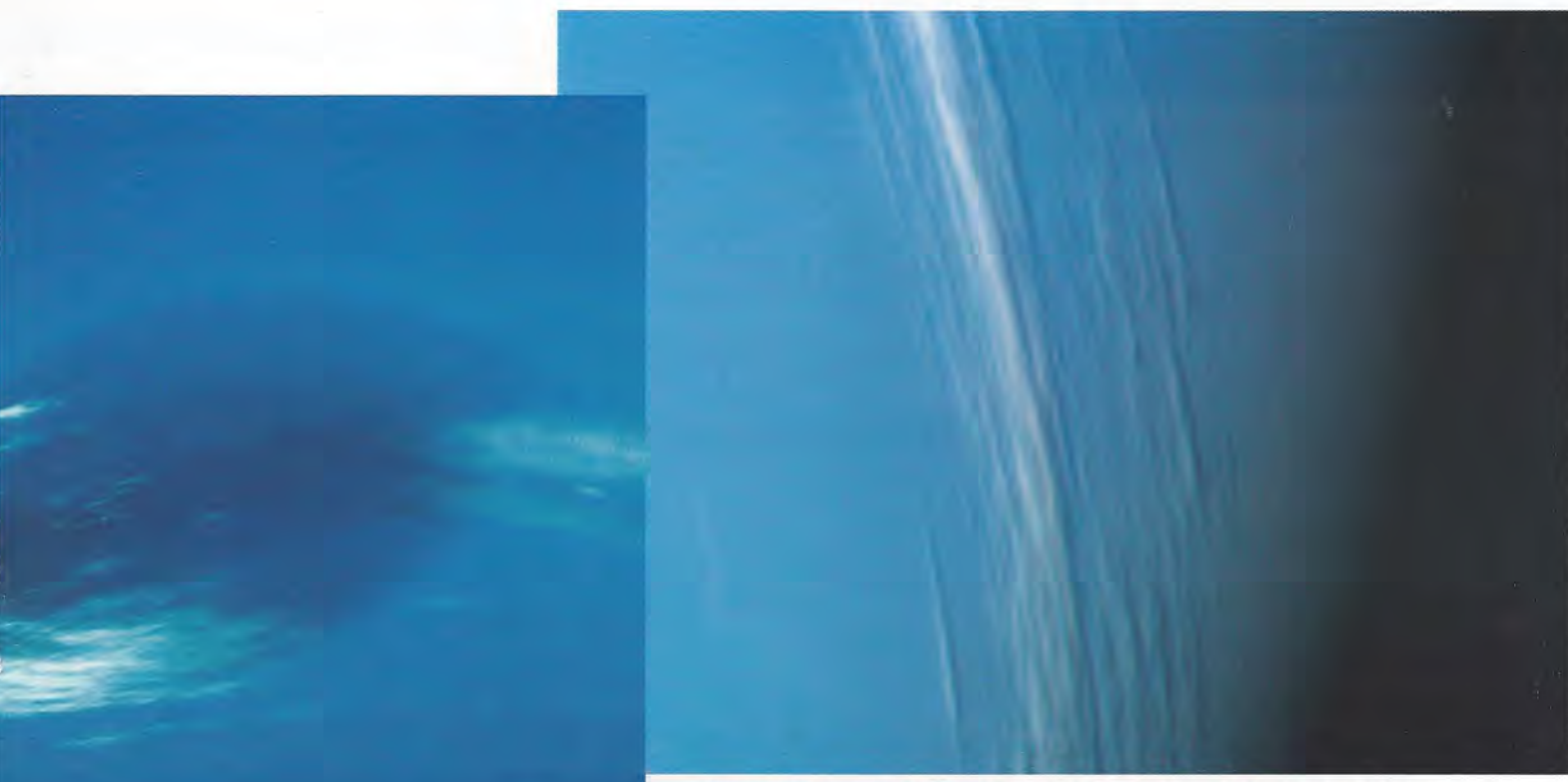
Arcs or Rings?

The neptunian mystery of "ring arcs" was a special target in the design of *Voyager*'s encounter sequences. In the early 1980s astronomers noted that just before Neptune passed in front of a star, the star would blink out. The blinkouts were seen only rarely, and not in pairs as required by the geometry of a ring: If a star seems to pass into a ring, it must pass out again too. Astronomers couldn't decide if Neptune was surrounded by moonlets, or quite what. Finally they settled on ring arcs, or incomplete rings, as the most likely explanation. Theories emerged to account for why ring particles might bunch up into discrete clumps.

Mark Showalter was the lucky scientist to see *Voyager*'s first image of a neptunian ring arc. He was on the midnight shift, watching the monitors in Building 264 at the Jet Propulsion Laboratory (JPL) on Friday, August 11. He awakened colleagues in the middle of the night, one of whom came in with a bottle of champagne.

The two ring arcs announced to the press later that day were faint. A week after the press release, the ring scientists had not confirmed the existence of the inner arc. They were up against a deadline for specifying camera-pointing parameters for the "retargetable" ring-arc pictures. (*Voyager*'s picture-taking schedule had long been frozen, but flexibility remained to change the camera's aim as new targets were discovered during the final weeks.) They decided to home in on what appeared to be three discrete arcs that were all stretched out in the same orbit.

As the images later revealed, Neptune has complete rings after all. They are not as splendid as Saturn's rings, nor as dense as the uranian rings (which explains the sporadic ground-based observations: Neptune's rings are too tenuous, except at "arc" segments,



ABOVE: This remarkable view of Neptune's cirrus-like clouds is the first good picture of cloud shadows on any of the outer planets. The cloud streaks are between 50 and 200 kilometers (30 to 130 miles) long. From measurement of shadow widths and consideration of the Sun's direction, scientists estimate the height of the clouds above the lower cloud deck to be about 50 kilometers. Image: JPL/NASA

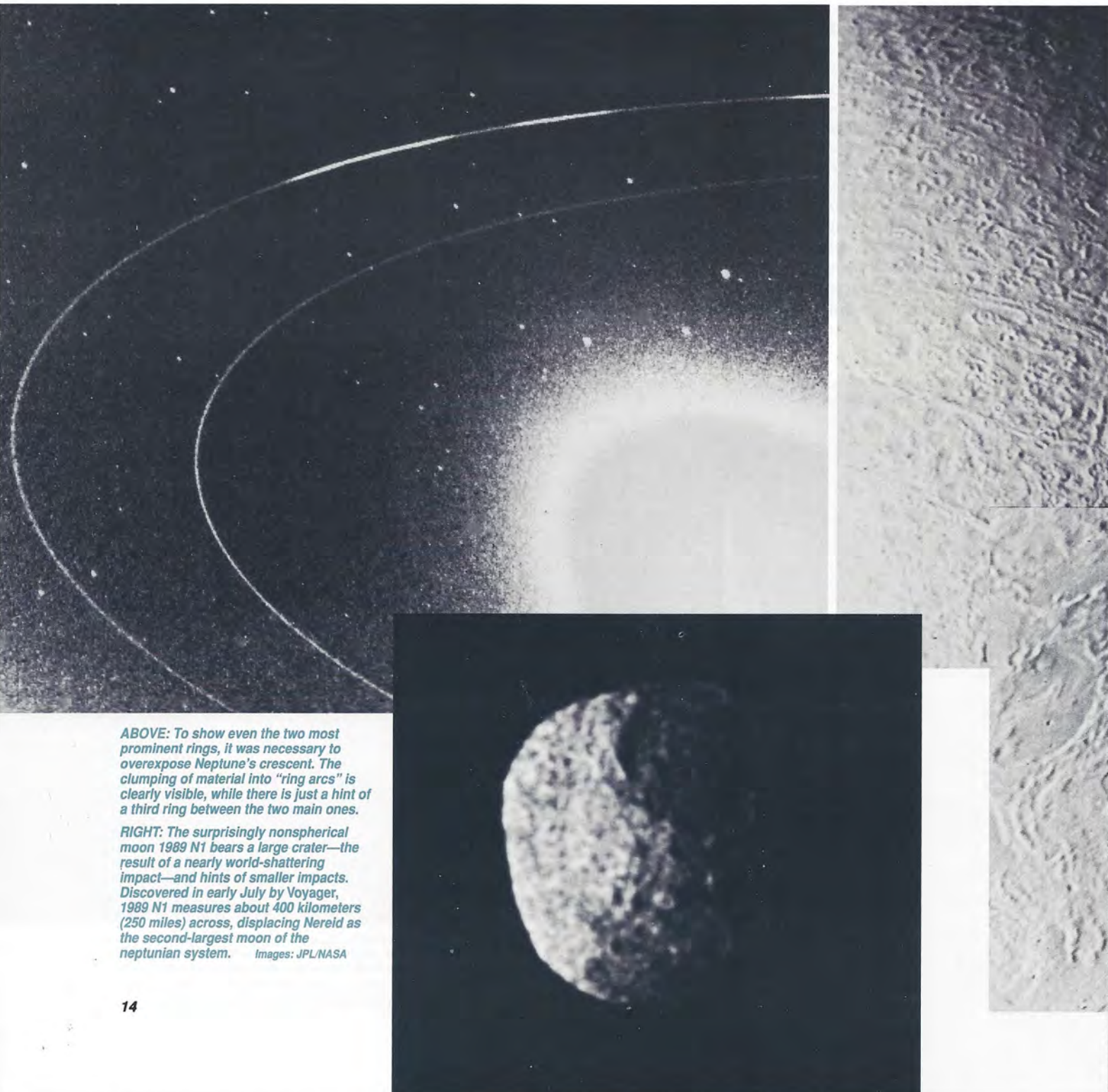
to block starlight). Still Neptune has a unique ring sheet extending inward from the gap between the two brightest rings most of the way toward the planet. Preliminary analyses suggest that the seemingly faint sheet is composed of larger particles than the more visible rings.

While the three targeted ring arcs proved to be parts of a complete ring, the question remains as to why ring particles sometimes clump into arcs. Which of the theories published before encounter was right? None of them was. One theory, for example, required the presence of a large neptunian moon in a tilted orbit, but no such moon exists. *Voyager* has proven that planetary rings—once thought to be unique to Saturn—commonly encircle planets, but physicists are only beginning to understand the processes that mold them.

New Moons and Few Moons

Voyager could hardly *not* have found at least some new neptunian companions. Neptune's second moon, Nereid, wasn't discovered until 1949, and that took one of the world's largest telescopes. (*Voyager* did not pass near enough to Nereid to reveal much: It is a medium-dark object about 350 kilometers, or 220 miles, across.) Before the encounter, scientists knew that dark satellites hundreds of kilometers across could still be lurking near Neptune, undetected from the ground.

In mid-July *Voyager* spotted 1989 N1. JPL engineers programmed some



ABOVE: To show even the two most prominent rings, it was necessary to overexpose Neptune's crescent. The clumping of material into "ring arcs" is clearly visible, while there is just a hint of a third ring between the two main ones.

RIGHT: The surprisingly nonspherical moon 1989 N1 bears a large crater—the result of a nearly world-shattering impact—and hints of smaller impacts. Discovered in early July by Voyager, 1989 N1 measures about 400 kilometers (250 miles) across, displacing Nereid as the second-largest moon of the neptunian system. *Images: JPL/NASA*

retargetable frames to study the new moon, a black object that proved to be larger than Nereid and surprisingly irregular in shape. A large crater testified to a long-ago collision that nearly shattered the moon. As one *Voyager* scientist remarked, "N1 is a survivor."

Other new moons sighted as the spacecraft closed in were disparagingly termed "rocks." Even so, the second *Voyager*-discovered moon is an egg-shaped body having about 10,000 times the mass of the projectile thought to have wiped out the dinosaurs on Earth 65 million years ago. Only six new moons had been announced by the final press conference, somewhat fewer than Project Scientist Ed Stone originally predicted. However, some objects seen in the images had been relegated to the back burner during all the encounter excitement; perhaps more moons are in the works.

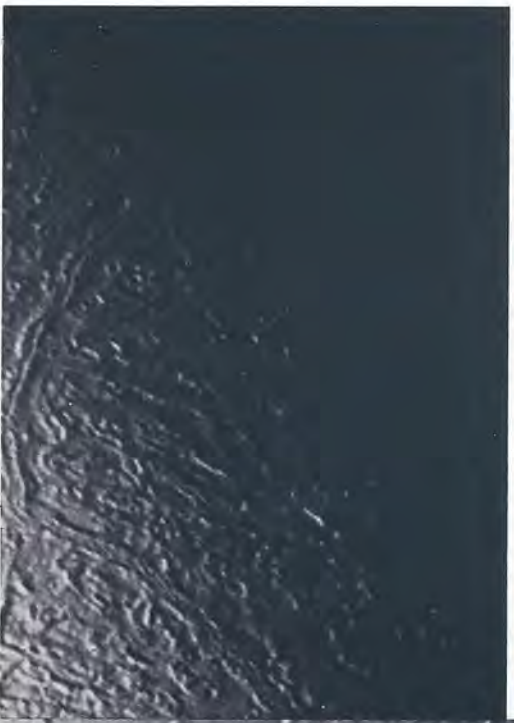
Triton: A Loose Cannon?

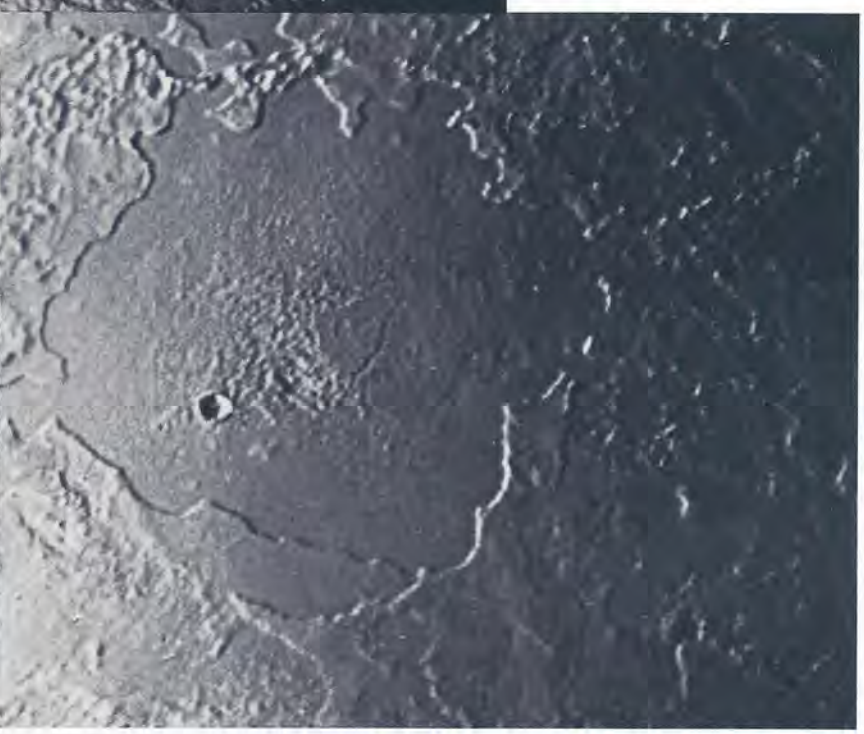
Neptune, under the prevailing theory about the early history of the solar system, may have been the slowest of the planets to be built up by accretion of small bodies (planetesimals) and gas. If so, we would expect it to be surrounded by much left-over debris. That is why its few moons and rather meager ring system are a bit of a surprise.

During the encounter scientists tossed around the idea that Triton cleared out many of the moons. This suggestion comes out of the possibility that Triton was captured long ago from an independent orbit around the Sun after crashing into an earlier neptunian moon. Such a collision would explain Triton's peculiar orbit, which carries it around Neptune in the "wrong" direction compared with all other large moons. After the collision Triton's orbit around Neptune would at first have been very elongated; then tidal forces would have begun to circularize the orbit.

For a billion years Triton would have been dragged through any pre-existing satellite system. Tides would have heated Triton's interior, keeping its surface geologically active. This scenario, with Triton as a system-sweeping, hot-bellied marauder, has gained enough standing that some theorists are now surprised that even the six new satellites remain, and in nicely flat, circular orbits, at that.

There are many mysteries to be analyzed in the coming months and years.





LEFT: The "highway intersection" on Triton bears some resemblance to icy features on other outer-planet moons, such as Uranus' Ariel. But most of Triton's topography is new to us and its origin mysterious. Despite the vaguely circular structures seen here, Triton is notable for its virtual lack of impact craters. Resolution in this image shows details down to 2.5 kilometers (1.6 miles).

BELOW: This "frozen lake" on Triton is about 250 kilometers (150 miles) across. On a world where water ice (perhaps mixed with ammonia) acts like rock, fluid water is the analog of lava. The multiple layers of this terrain resemble terrestrial volcanic craters known as calderas. As for the impact crater within the lake, it is one of the largest detected anywhere on this crater-poor moon. *Images: JPL/NASA*

The Great Eye of Neptune

The central and most beautiful part of the neptunian system is the planet itself. Early expectations that its deep atmosphere would show a wealth of detail for measuring its winds proved false. Beyond the four spots that had been charted for weeks, few other cloud features stayed put long enough. Neptune's great "eye" (the Great Dark Spot) and associated currents glide around with surprising ease and rapidity, throwing into question our theories about the comparative importance of sunlight and internally generated heat for driving planetary meteorology.

Many instruments probed through Neptune's cloud layers and mapped out the planet's oddly tilted and offset magnetosphere. But the implications of all these measurements await more definitive reduction of the data. For now, we can await *Voyager*'s swan song, when it looks back toward the Sun next spring and photographs our whole solar system before it sails out into the cosmos.

Clark R. Chapman will resume his "News and Reviews" column in the next issue.

Science Fiction Writers' Symposium

On the Saturday evening of Planetfest, a constellation of some of the brightest stars in science fiction assembled for a panel discussion, for which it was my pleasure to serve as moderator.

Robert L. Forward talked about several concepts now only proposed in physics journals that, if true, would revolutionize our societies. "Space warps and time machines," he said, "are allowed by the general theory of relativity." He proposed using matter/antimatter rockets for space travel.

Gregory Benford remarked that The Planetary Society is "one of the few groups in the world which you can truly say has the future in its bones, when there are many, it seems to me, that have the past in their bones."

He suggested that we are at the end of the era of chemical exploration of the solar system and offered nuclear propulsion as the next step.

David Brin saw fusion rather than fission as the wave of the future for rockets. He also reflected on a remarkable change in human attitudes in modern times. "Throughout human history," he said, "almost every civilization has had a golden age that they looked back to. And the way people won arguments over what was true was to find the *oldest* text. Today, it's hard for us to conceive of it that way. If you want to find out what's true, you find the *latest* review paper on the topic."

He told the audience that we should get out into space where there are infinite resources that can make the whole planet wealthy.

Larry Niven said, "The most dangerous thing you can see ahead of you is the falling level of education in this country."

He also drew attention to the speculations of novelist Greg Bear, who says that 50 years from now our descendants will not be recognizably human. There are "so many advances coming that it's just *all* going to change. I find this scary because I can see some of it going on now."

Frederik Pohl remarked on the changes he has seen in ideas about extraterrestrials during his decades as a writer: "On Mercury you had the little tiny people; on Jupiter you had the big, fat ones. They all did about the same thing. They came to Earth to steal our women and our water."

He described himself as an optimist, yet he presented the panel's gloomiest forecast: "I think the ozone layer's in trouble. I think that acid rain is probably going to kill off most of the green stuff on the Earth. But what makes me an optimist is that I think that a few people will survive and then maybe they'll have the sense to do things right."

The other writers were generally more optimistic. Robert Forward seemed to capture the majority view when he said, "There's no reason—except that we prefer to use our money in other ways—that we can't go to the Moon now, and go to Mars now, and go visit Triton a few decades from now. Our future is really limited by our will and our desire and our imagination—a little bit. All we need to do is get busy, and we can explore the universe." *—Thomas R. McDonough, SETI Coordinator*

Beyond Neptune: An International Symposium

An international symposium of space leaders made a fitting conclusion for Planetfest. The audience of 1,500 people heard representatives from the world's leading space agencies give their perspectives on the future of planetary exploration.

The discussion of international cooperation was noteworthy, because these leaders will have a great deal to do with planning any joint missions for the next decade and beyond. Also of particular interest to Planetary Society members (those who have been following our development of the Mars Balloon guiderope) were the several references to the use of balloons for exploring Mars and Venus by the Soviet, French and Japanese representatives.

Carl Sagan, President of The Planetary Society, welcomed the audience and invited them to look ahead to a resurgence and greater internationalization of planetary exploration. He noted the interest in human exploration of Mars as a major American/Soviet goal and, supporting that goal, the robotic missions now under study in all spacefaring countries.

Jun Nishimura, Director General of Japan's Institute of Space and Aeronautical Science, outlined an ambitious Japanese plan for planetary exploration. Their new launch vehicle, being readied for a test flight next year, will inject a payload on a lunar swingby trajectory. A mission to put surface penetrators on the Moon could be launched as early as 1995. Japan is studying a surface-penetrator mission to Venus for the same time period and a comet sample-return mission for the early 21st century.

Jacques Blamont, chief scientist of France's Centre National d'Études Spatiales, was provocative as always. He offered for discussion the idea that Mars could be used as a "toxic waste dump" or as a site for many activities we are afraid to carry out on Earth (for example, in genetic engineering). Carl Sagan, in rebuttal, stressed our obligation not to make the same mistakes on other worlds that we've made on this one.

Vasily Moroz, head of the planetary science department of the USSR's Space Research Institute, described ambitious Soviet plans for Mars exploration from the *Mars '94* mission onward, noting that political changes in the USSR will have a major effect in defining mission planning in the next decade. He emphasized that the prospect of international cooperation was an important factor in Soviet decisions about which missions to fly as well as the scope of missions. The *Phobos* and *Mars '94* missions have

RIGHT: Triton was perhaps the most-anticipated Voyager target since the saturnian moon Titan. And still the reality surpassed expectation when Triton disclosed its exotic, and apparently active, terrain to Voyager 2.

FAR RIGHT: Within the great expanse of Neptune's southern hemisphere, "D2" is one of three smaller siblings of the Great Dark Spot.

Images: JPL/NASA

Planetfest Volunteers: Ready, Willing and a Little Short on Sleep

We were a tireless and dedicated force of about 140 volunteers coping with crowds that topped 15,000. We started with the House Dedication on Wednesday and didn't stop until after the Wrap Party on Sunday.

Where did all this support come from? Several weeks prior to Planetfest '89 all California members from San Luis Obispo to San Diego were mailed information about the events and given the opportunity to volunteer for all kinds of jobs, from security guards to projectionists. Some chose a particular area of interest, and others asked to be assigned where most needed. Volunteers served as supervisors and staff at every Planetfest venue—at the Planetary Society store, speakers' forum, film festival, exhibits and registration. Some enlisted to work for a four-hour tour, some were there all day for three days.

The Planetfest crowds were enormous, and the most demanding job of the entire festival was a stint in the Planetary Society store. Workers assigned to that area would come back from their shifts with a glazed look, and everyone immediately knew they had been in "the black hole for volunteers"—so named because the more people we sent to the store, the more it seemed to need. And yet many volunteers stayed on past their assigned time and even came back the next day.

Thursday, many stayed all night to help with *Voyager* Watch through Neptune closest approach, and they were back again Friday morning. This Thursday night bunch started a wall of "volunteer space art" that just kept getting bigger, and zanier, as the weekend drew on. Commented one volunteer art critic, "It's like *Doonesbury* with brain damage."

The volunteer room, upstairs and away from the hectic crowd, became a very welcome retreat. Here volunteers returned from their work assignments, rested their tired bodies, perhaps added to the art wall and helped consume as many as 14 pizzas a day.

Visitors to our room included many from The Planetary Society's Volunteer Network, and so I had a chance to meet some "old friends" in person for the first time. Many had come just to attend Planetfest but ended up volunteering; we welcomed fellow volunteers from as far away as West Germany, Australia and the USSR.

It was wonderful to have so many spontaneous volunteers, willing to put in a few hours. As one volunteer from Canada said, "When you have volunteers coming out of the woodwork, then you know you really have something."

—Marshalle Wells, Volunteer Coordinator

ESSAY CONTEST WINNER ALI DEPRIEST (LEFT) RECEIVED HER AWARD FROM PLANETFEST DIRECTOR ANGELA BROWN. PHOTO: KEN WONG

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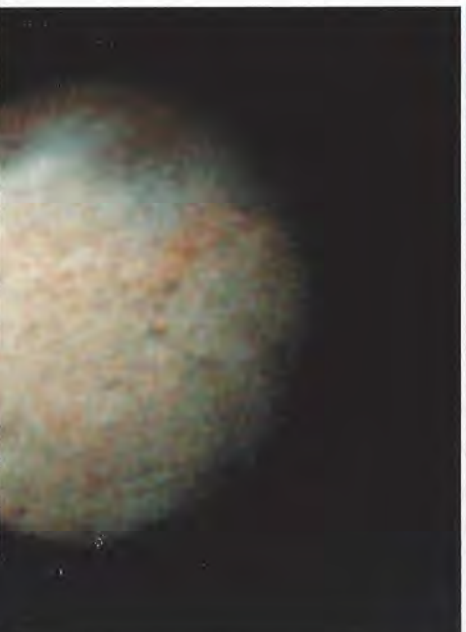
each had more than a dozen nations participating.

Geoffrey Briggs, Director of NASA's Solar System Exploration Division, spoke with great optimism about America's return to planetary exploration, with *Magellan* on its way to a 1990 encounter at Venus, and with *Galileo* and *Mars Observer* scheduled for launch. While supporting greater international cooperation in principle, Briggs did not make reference to specific missions, except for *Cassini,* which is being undertaken as a joint mission with the European Space Agency.

Lew Allen, Director of the Jet Propulsion Laboratory, looked "Beyond Neptune" in terms of distance as well as time, and talked about the search for planets around other stars. He characterized the search for planets around other stars as a key component, along with investigations of our own solar system, in understanding the nature and evolution of planetary systems. *—Louis D. Friedman, Executive Director*



Questions & Answers

I'm fascinated with the prospect of viewing movies or videos of Mars' surface complete with sound. I'm talking about crystal clear pictures, not the ghost-like television pictures we saw from* Apollo 11. *Is such a thing possible? Is it too expensive? Are there plans for video cameras like this on any of the upcoming Mars or Venus missions?
—James L. Beeler, New York, New York

Yes, what you propose is possible. But the lighting conditions, along with how much dust is on the lens, will govern whether you get "crystal clear" pictures. The addition of sound would allow us to use a commercial camera design. There are several camera designs being discussed for future Mars missions. Some of them are included on the rover payloads, some are on instrument packages connected to balloons and some are designed to take pictures from orbits. Cameras designed for Venus are not that mature. We haven't started developing the technology for our electronics to survive at these very hot temperatures [about 900 degrees Fahrenheit].

The *Mars Observer* camera will take still pictures from a spacecraft orbiting Mars at an average altitude of about 360 kilometers (230 miles). To my knowledge, no video/sound cameras are being planned on any future mission. The *Voyagers*, however, did record magnetospheric vibrations in the audio frequency range, and the late Fred Scarf of TRW produced phonograph records presenting the eerie sounds of Jupiter and Saturn. If there were a strong scientific requirement for adding sound to the mission, it could surely be included. The amount of information that is sent back is a very valuable resource. We have to justify every bit, so sound would compete with the video, engineering status and all other desirable measurements.
—G. EDWARD DANIELSON, *California Institute of Technology*

What if the sensor tail [or "SNAKE" from the Mars balloon] becomes snagged under or between a pile of rocks on Mars? How would it unsnag itself?
—Jordan S. Katz, Washington, DC

We are designing the guide-rope for the Mars balloon so that it is as snag-free as possible and testing that design under many different types of surface conditions. A design that is stiff but somewhat flexible seems to work very well. This permits the SNAKE to go across or around areas where it might become snagged. In wind, it's possible that if the balloon sinks too close to the ground the SNAKE could become snagged. In a later calm, the buoyancy of the balloon would unsnag the guide-rope. However, this is an extremely risky situation and the mission is designed to avoid it by either not having the balloon sink too close to the ground or not letting the guide-rope snag.
—LOUIS D. FRIEDMAN, *The Planetary Society*

FACTINOS

Saturn's moon Titan may not be entirely covered with an ethane ocean, as some scientists have suggested, but might have some dry land or icy surface. Researchers at the California Institute of Technology and the Jet Propulsion Laboratory found variabilities in Titan's surface by bouncing radar echoes off the moon in June 1989.

"Titan is the most interesting, and the most difficult, radar target in the solar system," said Duane O. Muhlman, leader of the research group. He also said, "The surface may resemble oceans and continents, but this is pure speculation."
—from the California Institute of Technology

◇

Now arsenic has been added to the poisonous brew that makes up the atmospheres of Jupiter and Saturn. Keith S. Noll of the University of Arizona reports that he and his colleagues found arsine gas (AsH_3) in the atmospheres of these gas giants.

The researchers detected only traces of arsine—0.3 to 1.1 parts per billion (ppb) in Jupiter and 0.7 to 2.7 ppb in Saturn. Although these amounts seem miniscule, they are really quite large. Arsenic is only the eighth element and the heaviest detected so far in the two planets. Noll says the measured quantities give insights into the chemistry and dynamics of the deep atmospheres that can't be studied any other way.
—from *Sky & Telescope*

◇

One of Saturn's strangest-looking moons is Iapetus, icy-bright on one side but mysteriously dark on the other.

Now Edward A. Cloutis of the University of Alberta in Edmonton says spectral measurements of the dark side resemble those of tar sands on Earth. After studying tar sand samples from northwestern Alberta, Cloutis reported that the best match for the dark-side spectrum of Iapetus is a mixture of 90 percent clay and 10 percent coal tar representing organic material. Still, neither the clay/coal tar mixture nor the tar sand provides a perfect spectral match for Iapetus' dark stuff. An iron-substituted clay "seems to be a necessary component," according to Cloutis, and some amount of a highly polymerized hydrocarbon improves the spectral match.
—from *Science News*

World Watch

by Louis D. Friedman

WASHINGTON, DC—Final congressional action on the NASA appropriation for fiscal year 1990 came in September. Included in the bill was a new start for the Comet Rendezvous Asteroid Flyby (CRAF)/*Cassini*. A number of organizations that worked on its behalf ought to be congratulated.

Foremost is NASA, which staunchly supported the mission through all the debates. Lennard Fisk and others in the Office of Space Science and Applications presented the arguments for CRAF/*Cassini* extremely well.

The scientists and engineers who developed and will carry out the two missions also deserve congratulations, especially project personnel Tobias Owen of the State University of New York and Marcia Neugebauer of the Jet Propulsion Laboratory, and project manager Ron Draper of the Jet Propulsion Laboratory.

Many groups, and notably The Planetary Society, conducted both public information and grassroots campaigns. Particularly effective were the Division for Planetary Sciences of the American Astronomical Society and the National Space Society (and their political action arm Spacecause). The latter joined with us in a combined effort. We wish to thank all our members throughout the country who wrote letters and made phone calls on behalf of CRAF/*Cassini* in response to our mailings and announcements.

MOSCOW AND PASADENA—In recent forums, various Soviet space officials have spoken about planning for planetary exploration in rather surprising terms. One such presentation was given at the meeting of the American Institute of Aeronautics and Astronautics (AIAA), held in August at the Jet Propulsion Laboratory, by Valery Barsukov, Director of the Vernadsky Institute (he is also the leader of the US/USSR group implementing the space cooperation agreement in planetary exploration).

Barsukov described a series of new missions—to Mercury, Venus, Mars and the Moon—which he said Soviet space authorities were planning for the next two decades. He also described a *Mars '94* mission somewhat smaller than the one previously planned. It still included the Mars balloon (on which The Planetary Society is working with the French space agency) and small meteorological stations, but there was to be no rover and no large lander. Following *Mars '94*, Barsukov said, there would be a sample-return mission to Mars. In addition, he listed a 1998 mission to Venus with penetrators and a 2002 or 2003 mission to orbit Mercury. He also told of Soviet planning for a human-occupied lunar base.

Barsukov's presentation surprised American scientists and seemed to surprise many of the Soviets who had accompanied him to the conference. The list of missions was not so much an approved plan but more a list of candidate studies that might be approved in the future.

To some extent, the inconsistency in statements on mission planning reflects uncertainty resulting from democratic reforms in the Soviet Union. *Perestroika* and the reorganization of government ministries have called previous plans into question. Moreover, the greater openness in Soviet policy discussions enables different groups to advocate missions and present them as plans, although they are only proposals. This style of debate is analogous to what goes on in various NASA and National Academy of Sciences planning meetings.

Another interesting example of *perestroika*, mentioned by several officials, is the "reversing" of the money flow between science and industry. In prior years, industry received money for space missions and then contracted with the Soviet Academy of Sciences for support on these missions. It appears that now the Academy will be awarded money for space missions and will then contract with industry to build the spacecraft. In theory, this reorganization gives the scientists a greater say in future missions. Whether the plan works in practice remains to be seen.

One mission that seems more concrete than most—because it has been described by many officials in many forums—is *Mars '94*, although it has been scaled back. The smaller design lowers the cost and shortens the schedule.

The Mars balloon, being put aboard *Mars '94* by the French space agency (CNES), remains the centerpiece of the mission. The balloon will survey large regions of Mars at low altitude, stabilized in its flight by an instrument-bearing guide-rope that is being designed by The Planetary Society. High above in its twelve-hour orbit, the *Phobos*-type spacecraft will relay communications from the Mars balloon. Also planned is a communications link between the Soviet Mars balloon and the American *Mars Observer*. It is now a major element of mission planning and should help greatly in the search for future lander and rover exploration sites.

Three Soviet space officials—Barsukov, Alex Galeev, Director of the Space Research Institute, and Roald Kremnev, Director of the Babakin Center of Glavkosmos—presented the description of *Mars '94* during the AIAA conference and at a Mars balloon technical review with The Planetary Society and CNES. However, final project approval awaits an overall review of Mars exploration and completion of an official plan for the next decade. While *Mars '94* is regarded as a certainty, it can only be approved as part of the "national Mars program," which is one element in a 14-point science and technology plan ordered by the Supreme Soviet. The process is not unlike the Moon/Mars initiative proposed by President Bush, which is now being developed by NASA into a plan for implementation.

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

AT THE "WRAP PARTY" JPL STAFF GATHERED TO HEAR CARL SAGAN. PHOTOS: J. R. ROST

ALL *VOYAGER* PROJECT MEMBERS RECEIVED COMMEMORATIVE MEDALLIONS.

WILLIAM KOSMANN IS WITH THE MISSION PLANNING OFFICE.

CHUCK BERRY GOT THE CROWD DANCING WITH A RENDITION OF "JOHNNY B. GOODE."

The Wrap Party

On the Sunday after encounter, The Planetary Society threw a "wrap party" at the Jet Propulsion Laboratory mall, with all members of the *Voyager* Project invited as our honored guests. The celebration was produced for The Planetary Society by Ann Druyan and Geoff Haines-Stiles.

Huge helpings of good Armenian food (thanks to planetary favorite Burger Continental), along with some Dixieland music and good old rock 'n' roll, put everyone in the mood to celebrate. But mixed in, too, was a tumult of impressions and feelings about the Neptune encounter . . .

Society President Carl Sagan bade farewell to the *Voyagers* for us all. His benediction, televised in the US, Japan, the Soviet Union and around the world, reminded us that the *Voyagers* extended our vision, in every sense, and that the legacy of *Voyager* is hope.

For many in the crowd of 2,000, the work of a decade or more was coming to an end. For everyone it was a time to consider the end of an era. This prose poem by Kate Robinett gives some idea of what that was like.

A surprise appearance by Chuck Berry blew away any possibility of post-encounter letdown. "Go, *Voyager*, go," sang the legendary rock 'n' roller, adapting "Johnny B. Goode," his contribution to the music on the *Voyager* interstellar record, as staid scientists boogied.

As a final tribute, The Planetary Society presented a brass medal to each of the men and women of the *Voyager* Project, so that in years to come they can remember with pride not only the achievements of *Voyager* but the enduring gratitude and admiration of our members worldwide. —*Karl Stull, Copy Editor*

Parting Is Such Sweet Sorrow

by Kate Robinett

To part with a *Voyager* encounter is difficult. Having been carried on the wings of discovery to witness a becoming, the unveiling of a beauty that transcends all that we call familiar. To have been a welcomer of worlds . . .

How can one soften the reentry from such heights? A party, a celebration. Food. Many of us had forgotten to eat. Who could eat when the universe was being unfurled? Tables heavily laden with dolmas, baklava, roast beef. Our taste buds, seemingly in hibernation during the encounter, suddenly awakened. As did our ears. Encounters, though exhausting, leave you acutely sensitive to the bizarre, the unexplained: Chuck Berry where only a few days before Dan Quayle had stood? What strange physical law could account for this? Why, of course, the interstellar record that *Voyager* carries on its crest includes Berry's "Johnny B. Goode." Only now it was "*Voyager* Be Good."

"I've got to get a picture of this!" The same hands that only days before had grasped the first images of Triton now captured on film another strange sight: Famous scientists dancing on the steps of Building 180. Were we to harness this momentum . . .

The fuel of the future is joy.

And as we laughed and ate and danced and engaged in a myriad of recollections and revelations, our little *Voyager* continued on with the serious business of nudging the heavens to awaken the stars.

Kate Robinett is a member of the Voyager *Mission Planning Office.*

A Benediction for *Voyager 2*

by Carl Sagan

CARL SAGAN BADE GOOD BYE AND GOOD LUCK TO THE *VOYAGERS*. PHOTO: SUSAN LENDROTH

Every human culture has rites of passage. They mark the transition from one stage of life to another. We are gathered here to celebrate *Voyager*'s rite of passage. A machine designed, built and operated here at the Jet Propulsion Laboratory has broken free of the Sun's gravity, explored most of the worlds of the solar system and is now on its way to the great dark ocean of interstellar space. It carries a phonograph record of greetings, pictures and the world's great music to any beings who might encounter it there.

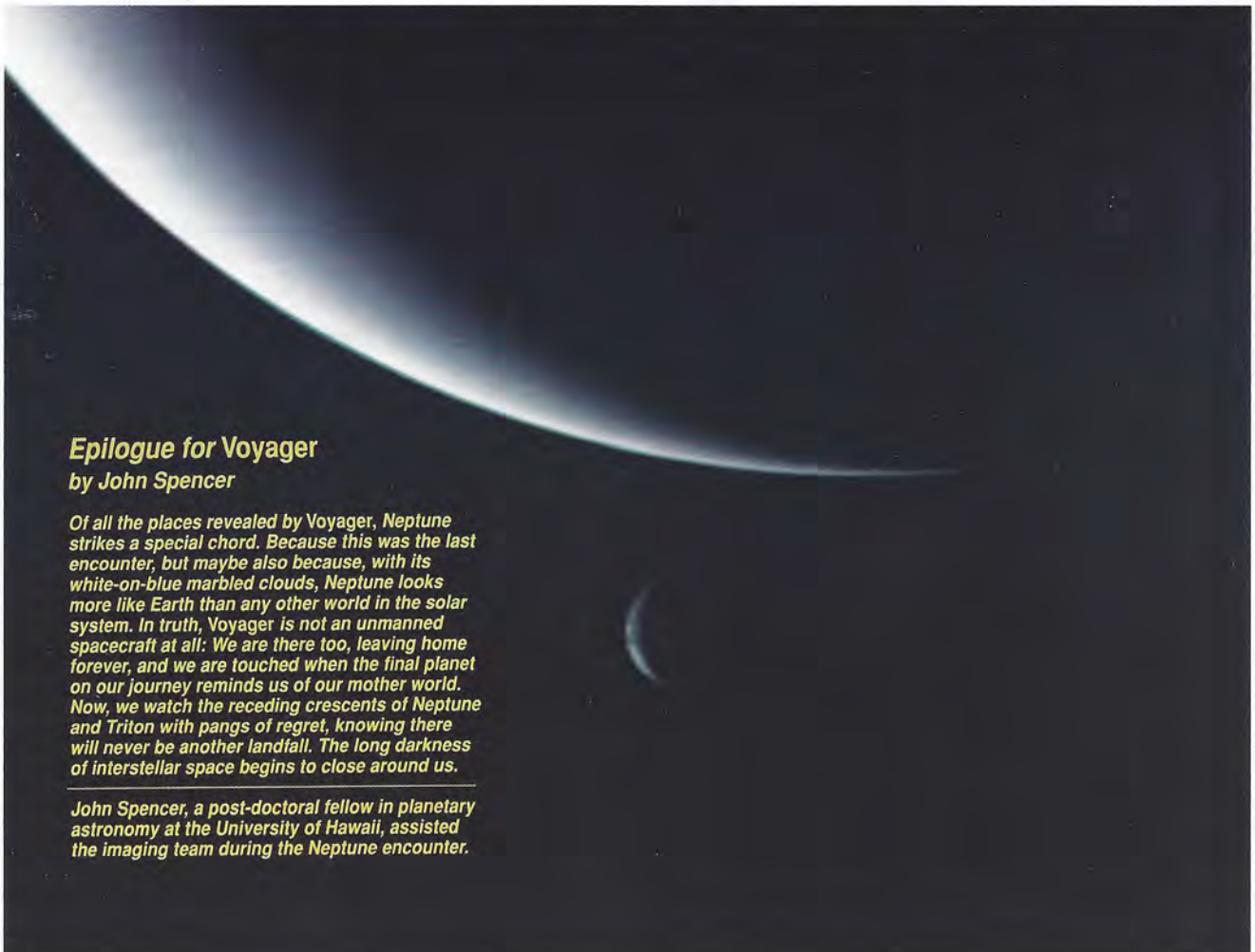
The men and women responsible are gathered here. You are heroes of human accomplishment. Your deeds will be remembered in the history books. Our remote descendants may live on some of the remote worlds first revealed to us by *Voyager*. If so, they will look back on you as we look back on Christopher Columbus.

Voyager left a planet blighted and imperiled by nuclear weapons, climatic change, poverty and injustice. The species that launched her was a danger to itself. But *Voyager* has given us a stirring cosmic perspective. We have seen evidence of the destruction and reconstitution of worlds. We have witnessed the early building blocks of life assembling themselves. But we have found not a trace, not a hint, of life itself. *Voyager* reminds us of the rarity and preciousness of what our planet holds, of our responsibility to preserve life on Earth.

If we are capable of such grand, long-term, benign, visionary, high-technology endeavors as *Voyager*, can we not use our technological gifts and long-term vision to put *this* planet right?

Perhaps the Neptune flyby marks not just *Voyager*'s rite of passage, but the beginning of our own: the binding up of the peoples and nations and generations to take care of one another, to cherish the Earth and bravely to venture forth —in the footsteps of *Voyager*—to the planets and the stars.

Carl Sagan of Cornell is Distinguished Visiting Scientist at JPL and a member of the Voyager *Imaging Team.*



Epilogue for Voyager

by John Spencer

Of all the places revealed by* Voyager, *Neptune strikes a special chord. Because this was the last encounter, but maybe also because, with its white-on-blue marbled clouds, Neptune looks more like Earth than any other world in the solar system. In truth,* Voyager *is not an unmanned spacecraft at all: We are there too, leaving home forever, and we are touched when the final planet on our journey reminds us of our mother world. Now, we watch the receding crescents of Neptune and Triton with pangs of regret, knowing there will never be another landfall. The long darkness of interstellar space begins to close around us.

John Spencer, a post-doctoral fellow in planetary astronomy at the University of Hawaii, assisted the imaging team during the Neptune encounter.

Image: JPL/NASA

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LANDMANNALAUGER—William Hartmann painted this landscape during the US/USSR Space Art Exchange Workshop in Iceland, sponsored by The Planetary Society. "The scene reminded me of the young Earth, in the first one or two billion years, before there were any plants in the landscape," he says. "Without plants, there are beautiful and intricate patterns of erosion. It's strange to see Earth with abundant flowing water but no plant cover."

William K. Hartmann is a planetary scientist and space artist who lives and works in Tucson, Arizona. He is currently working on a book about the US/USSR Space Art Exchange.

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