# The PLANETARY REPORT

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Return to the Saturnian System

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***COVER: The* Huygens *probe descends through Titan's murky, brownish-orange atmosphere of nitrogen and carbon-based molecules, beaming its findings to the distant* Cassini *orbiter. The probe is equipped with a variety of scientific sensors to measure the physical properties of the moon's atmosphere; it also carries an imaging device to return pictures of Titan's possibly hydrocarbon-lake-dotted surface. The* Cassini/Huygens *mission is scheduled to reach the Saturn system in 2004.***
***Painting courtesy of the European Space Agency***

# FROM THE EDITOR

It's not often that you become aware that you stand at a crossroads in history, and that the choice to be made will determine the foreseeable future. But that is the situation for those who are now deciding what road the United States will take to build its space station. The teams evaluating the redesign, the politicians and administrators directing it, and the legislators who will fund it are all making choices that will determine how and when humanity will take its next steps into space.

Planetary Society members have a stake in this decision. For our Canadian, European and Japanese members, as well as members in the former Soviet Union, it may determine whether your countries will explore space in cooperation with the US. For our US members, it may determine if NASA will pursue the human exploration of the solar system and continue to send robotic explorers to the planets.

With a bimonthly publication, we cannot hope to keep you abreast of this rapidly changing situation in *The Planetary Report.* I urge you to be on the alert for developments in the space station story reported in daily newspapers and weekly magazines, and on radio and television.

Read this issue's World Watch for background on the NASA budget that is driving the space station redesign. If you live in the US, let your representatives know how you feel about it. This summer will see a turning point in humanity's exploration of the solar system. Make sure you play a role in setting the direction.

Meanwhile, we continue to cover other aspects of planetary exploration:

 —*Charlene M. Anderson*

# Members' Dialogue

***EDITOR'S NOTE: In the May/June column, we printed a letter by Clay Kallam regarding The Planetary Society and Mars exploration. This generated some interesting responses so we omitted the News Briefs this time in order to share more letters with our members.***

I read Clay Kallam's letter in the May/June 1993 issue of *The Planetary Report* and felt moved to respond. I too have been a member of The Planetary Society for many years and have often wondered about the Society's obsession with the exploration of Mars.

The Society's focus on Mars exploration has been quite slanted and is beginning to smell of parochialism. A definite focus has been the Russian rover and the Jet Propulsion Laboratory (JPL) rover for a couple of years now, to the virtual exclusion of other robotic development programs both within and outside the US. While I applaud and support the Society's efforts to internationalize space exploration, let's try to remember that the Society's job is to advocate for the good of humankind, not for the scientists of the Russian Republic or JPL!

The Society has strong ties with the Russians and with JPL, and that's good. But it is beginning to look as though it is in the business of marketing those two organizations' scientific and technical capabilities. That adversely affects the Society's credibility as an objective, nonpartisan organization dedicated to the ideal of furthering humankind's knowledge and presence beyond the bounds of Earth.
—PAUL KLARER, *Albuquerque, New Mexico*

In your May/June 1993 issue there was a letter from a charter member criticizing the Society's focus on a human mission to Mars. I also have been a member of The Planetary Society almost since the beginning. As I see it, without the Society's support the US would probably not be a participant in this project at all.

By simply reading *The Planetary Report*, I can see that the Society has not focused all of its efforts on Mars. We are kept informed on all aspects of our current active space projects, and there are the multiple efforts of the Society geared toward education. In my opinion, the most exciting venture of The Planetary Society by far has been its successful bringing together of countries worldwide to work in a cooperative and united frame of mind.

I have never been a person of means, but through my membership in the Society I feel I am part of each of its successes. I am proud to be a member of The Planetary Society, and through it, a member of the space program. *Our* accomplishments to date have been monumental, and I see these as being mere stepping-stones to the potential we can reach as a unit.
—DEBBIE J. NYGAARD, *Acton, California*

Clay Kallam may have missed the point. We have now explored the Moon to a sufficient level of detail to allow the establishment of a lunar base. Once that is accomplished, our next target has to be Mars.

After the Moon, Mars is the easiest body to photograph, land on and explore, and before we go there we must have a better understanding of what we are up against or we will fail and lives will be needlessly lost.

The Planetary Society is right to be at the forefront of martian exploration so long as we get a firm, unshakable grip on the Moon first.
—BRIAN PORTLOCK, *Stretford, United Kingdom*

I am responding to Clay Kallam's call for a members' forum on sending humans to Mars. I do not believe that terrestrial lifeforms have any intrinsic right to terraform and/or colonize other planets. In fact, considering our track record at home, such an idea is pretty terrifying.

However, sending scientific or artistic missions off-planet, to Mars or elsewhere, is not the same thing. I would like to see some discussion of sending artists, philosophers, teachers and poets along with the scientists. May I please sign up?
—JUDITH WASSERMAN, *Palo Alto, California*

The letter from Clay Kallam in the May/June *Planetary Report* expresses my views exactly. Please pay attention to him. There is time enough to invade other planets once we've proven we can take care of this one. Another charter member . . .
—DELL SUMMERFIELD, *Modesto, California*

I have just read Louis Friedman's report on President Clinton's directive to redesign space station *Freedom* (see the March/April 1993 *Planetary Report*). For a more neutral account, I suggest the May 3, 1993, issue of *Aviation Week & Space Technology*, which paints a less rosy picture. One article in that issue suggests that vague goals and bitterness amongst station engineers will at best conceive a station which is underpowered, requires many astronaut hours for maintenance and falls far short of the original research objectives. A second article suggests that NASA is losing some of its most powerful assets by snubbing its international partners. In *The Planetary Report*, Friedman even boasts that The Planetary Society was partially responsible for bringing the US to this state of affairs!

This approach is typical of the Society in recent years. Instead of supporting technology having positive ramifications for space exploration, the Society has spent much of its time as a political special interest group, denouncing competing factions. Another example of this is the Society's strong opposition to the Strategic Defense Initiative (SDI). Ironically, in the July/August 1992 issue of *The Planetary Report*, many of the authors attribute current capabilities in low-cost microspacecraft to advances derived from SDI funding. But the Society continues to work to kill this and other space-related programs, hoping the money will be directed to its pet projects.

Granted, the current economic climate breeds fierce fighting for limited research funds, but The Planetary Society has only exacerbated this situation.
—THOMAS D. PREVISH, *Pleasant View, Utah*

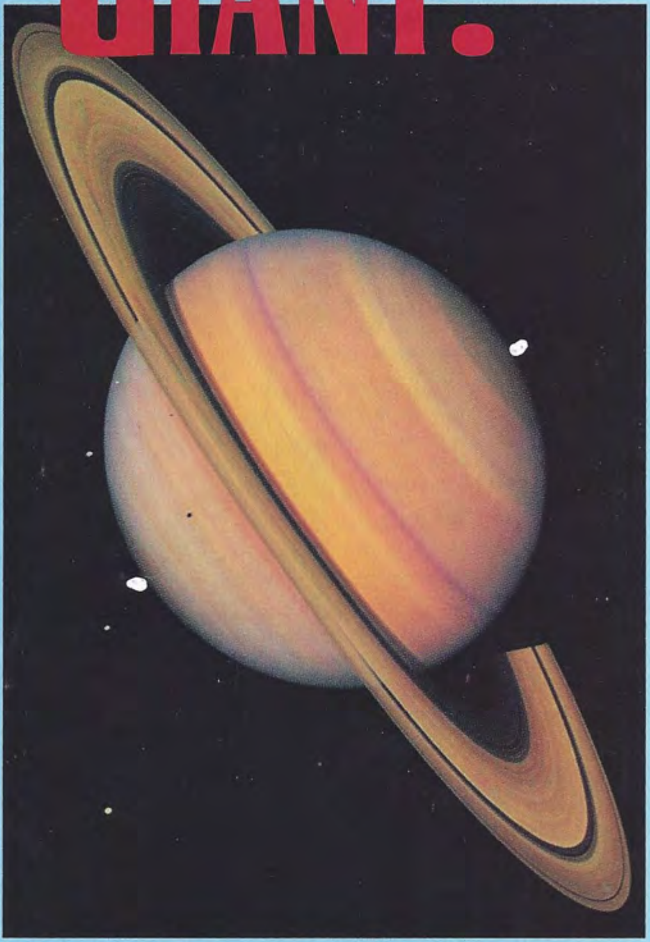
*We support the very specific goals of reduced costs and the early production of results intended through space station redesign and do not consider them vague at all. The other stated goal of the redesign is to permit room in the NASA budget for valuable space science and advanced technology initiatives. These include a number of missions long supported by our members.*

*I am not sure what "faction" Mr. Prevish thinks we denounce. We have always tried to offer constructive and positive opinions, as in "A Space Station Worth the Cost" (see the July/August 1987 issue of* The Planetary Report*). We never took a position on the Strategic Defense Initiative, and our advocacy of using microspacecraft technology was made with full recognition of developments in the SDI program.*
*—Louis D. Friedman, Executive Director*

# MEETING WITH

# A MAJESTIC GIANT:

# THE CASSINI MISSION TO SATURN



*ABOVE: This 1981* Voyager 2 *image shows Saturn's vast ring system, as well as three small icy moons and the shadow of a fourth.* Reprocessed image: USGS

*LEFT: Although it is primarily designed to operate as it descends through Titan's atmosphere, the* Huygens *probe might survive its landing on the frigid moon. Titan's surface may hold lakes or oceans of liquid ethane and methane, sprinkled over a thin veneer of frozen methane and ammonia. The land surface and the ocean bottoms are believed to be covered by a deep layer of complex carbon compounds. Artistic license is used here to show Saturn, which may only be visible at infrared wavelengths from the surface.*
*Painting courtesy of the European Space Agency*

**by Charley Kohlhase**

In October of 1997, a two-story-tall robotic spacecraft will begin a journey of many years to the vast and exciting realm of Saturn. With a mass of roughly 2,500 kilograms (5,510 pounds) of dry hardware and 3,000 kilograms (6,615 pounds) of propellant, it needs a boost from the *Titan IV/Centaur* launch vehicle and several planetary gravity assists. Both are needed if *Cassini* is to reach Saturn with sufficient propellant to brake into Saturn orbit and accomplish its mission: to deliver a European-built probe to the large, hazy moon Titan, and then tour the saturnian system for nearly four years.

The *Cassini* mission has been undertaken by NASA, the European Space Agency (ESA) and the Italian Space Agency (ASI). It is named in honor of the French–Italian astronomer Jean Dominique Cassini, who discovered the prominent gap in Saturn's main rings (now called the Cassini division), as well as the icy moons Iapetus, Rhea, Tethys and Dione.

The probe that *Cassini* will deliver to Titan is named for Dutch scientist Christian Huygens. Using improved optics, he found in 1659 that the strange "arms" noted decades earlier by Galileo were actually a set of rings. While observing Saturn, Huygens also discovered the moon Titan, hence the choice of his name by ESA.

During its descent and possibly for a short time on Titan's surface, *Huygens* will beam data to the orbiter for storage and subsequent relay to Earth. Once these valuable data are safely received on Earth,

*The face of Saturn's moon Enceladus is relatively smooth, largely uncratered and coated with unusually pure water ice. The particle density in Saturn's E ring increases near Enceladus' orbit. These two clues suggest that there might be a connection: Could geysers of water from Enceladus be feeding the E ring?* Cassini *may find the answer to this intriguing question.*

*Image: JPL/NASA*

the orbiter will begin to intensively use its three dozen scientific sensors to examine the vast Saturn system.

## Saturn

Saturn is one of the four ringed gas giants in our solar system. It is second in size only to Jupiter, but is considerably larger than Uranus and Neptune. With a diameter nearly 10 times that of Earth, it would enclose more than 750 Earths—but with a density less than that of water, it would float in an ocean of water, were there one big enough to hold it.

Unlike the inner planets, Saturn does not have a rocky surface but is made of gases. Hydrogen and helium predominate, but methane, ammonia, acetylene, propane and phosphine have also been detected. The gases become denser and hotter as one descends from the cloud tops to the interior.

We see Saturn as banded in pastel yellows and grays. Interestingly, the colors of the four gas giants differ, partly as a result of their varying distances from the Sun (and hence their temperatures). Jupiter's colors run toward tans and reds, and the more distant Uranus and Neptune appear as shades of pale blue.

Saturn radiates about 80 percent more energy than it receives from the Sun, but this cannot be attributed to primordial heat loss, as is speculated for the more massive Jupiter. One explanation has its basis in data obtained by the *Voyagers*. They found much less helium in Saturn's outer atmosphere than in Jupiter's. Perhaps the missing helium, long ago condensed out of the cool upper atmosphere, has been sinking slowly toward the planet's interior, converting gravitational energy to heat when the fall of the helium raindrops is eventually stopped.

## The Amazing Rings

The rings of Saturn are a frigid cast of trillions of particles and icebergs, ranging in size from that of fine dust to that of a house. They march in orbits around their captor in a vast sheet of amazing expanse and thinness. It is believed that the ring fragments are primarily loosely packed snowballs of water ice, but slight colorations suggest that there are small amounts of rocky material, possibly even traces of rust.

Although the distance from the inner edge of the C ring to the outer edge of the A ring is about 13 times the distance across the United States, the thickness of the ring disk is not more than 10 to 30 meters (about 35 to 100 feet), with waves or "corrugations" in this sheet rising and falling by a couple of kilometers. If a model of the ring sheet were to be made from material about the thickness of a coin, its diameter would need to be at least 15 kilometers, or nearly 10 miles!

Numerous patterns, both simple and complex, are formed within this rotating sea of icy fragments. They are variously described as circular rings, eccentric rings, kinky rings, clumpy rings, resonance gaps, spokes, spiral density waves, bending waves and shepherding moons; there are, no doubt, tiny moonlets too small for the *Voyager* cameras to have detected. The elaborate choreography of this complex ring system of patterns is produced and orchestrated by the combined gravitational tugs from Saturn and its moons that lie out beyond the ring sheet, as well as by the tiny tugs and gentle collisions between neighboring particles.

How did the rings form in the first place? If one could collect all of the particles and icebergs into a single sphere, its diameter would not exceed about 300 kilometers (185 miles), roughly midway between the sizes of the moons Mimas and Phoebe. Are the rings simply leftover material that never formed into larger bodies when Saturn and its moons condensed aeons ago? Or, as suggested by the *Voyager* data, are they the shattered debris of moons broken apart by meteor impacts? If the impact theory is valid, small orbiting "ring moons" may be awaiting that moment when they too will be struck and transformed into magnificent rings. *Cassini* may well provide definitive answers to this puzzle.

## Titan

Of Saturn's dozen and a half or so icy moons, Titan is not only the largest but also the most intriguing. Its dense atmosphere hides a frigid landscape that may contain lakes or oceans of liquid ethane and methane sprinkled over a thin veneer of frozen methane and frozen ammonia, which in turn probably overlies a mantle of frozen water ice. Are there really oceans on Titan? Some scientific arguments say yes, but radar bounces from Earth seem to say no, or at least not everywhere.

Scientists are fascinated by Titan's

brownish-orange haze, which is believed to be made of complex organic (carbon-based) molecules. They are formed in Titan's atmosphere by the bombardment of nitrogen and methane molecules by ultraviolet radiation and high-energy particles. Further reactions can lead to such chemicals as methylene, acetylene, hydrogen cyanide, cyanogen, and other complex molecules.

Containing carbon, these complex organic molecules would clump together into larger particles, raining slowly down on the alien surface below. If this process has been going on for a few billion years, the accumulated layer could be as deep as several hundred meters! It is true that organic molecules provide basic building blocks for life, but they are not necessarily produced by life. And even though the Titan environment may resemble the chemical factory of primordial Earth, scientists expect it to be lifeless due to the extreme cold. But perhaps *Cassini* can still shed light on the chemistry of early Earth.

## Saturn's Other Moons

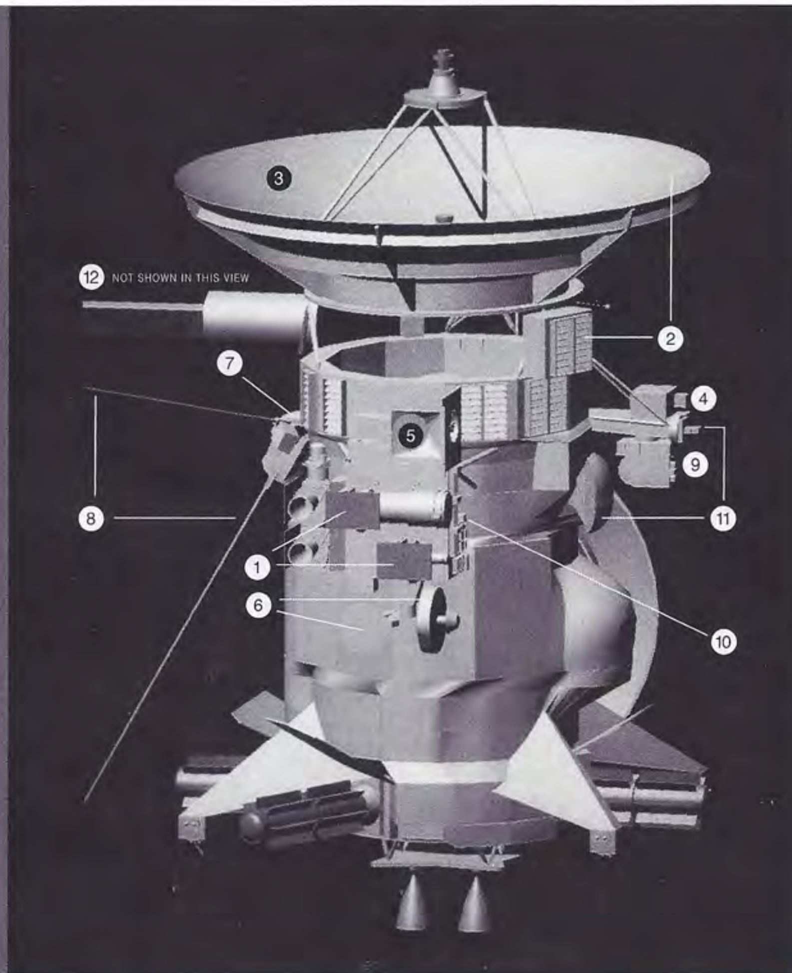
Titan may be Saturn's most intriguing satellite, but several of the smaller moons have their own peculiar mysteries. The surface of Enceladus is coated with unusually pure water ice, but much of this surface is smooth and uncratered. Also, Saturn's distant E ring has an increased particle density in the vicinity of Enceladus' orbit. What do these clues tell us? Could tidal stresses have heated the moon's interior and melted much of the surface, erasing most of the early impact craters? Could they even have created geysers of water or water ice to feed the E ring?

Iapetus is equally interesting. Dark as asphalt on its leading face (as it orbits the planet) and bright as snow on its trailing face, it perplexed early astronomers by disappearing on the left side (approaching the observer) of Saturn and reappearing on the right side. Arthur C. Clarke chose to feature this moon in his novel *2001: A Space Odyssey*, with its famous journey to the "eye of Iapetus," as it reminded him of a beacon. Was the dark material swept up from the outside, or did it rise up from the moon's interior?

Many of the other saturnian moons have their own telltale features, whether they be large impact craters (Mimas and Tethys), long trenches

*(continued on page 10)*

## CASSINI ORBITER EXPERIMENTS




1. **Imaging Science Subsystem** takes photos in visible, near-ultraviolet and near-infrared light.

2. **Radar** maps surface of Titan using radar imager to pierce veil of haze. Also used to measure heights of surface features.

3. **Radio Science Subsystem** searches for gravitational waves in the universe; studies the atmosphere, rings and gravity fields of Saturn and its moons by measuring telltale changes in radio waves sent from the spacecraft.

4. **Ion and Neutral Mass Spectrometer** examines neutral and charged particles near Titan, Saturn and the icy satellites to learn more about their extended atmospheres and ionospheres.

5. **Visual and Infrared Mapping Spectrometer** identifies the chemical composition of the surfaces, atmospheres and rings of Saturn and its moons by measuring frequencies of visible light and infrared energy given off by them.

6. **Composite Infrared Spectrometer** measures infrared energy from the surfaces, atmospheres and rings of Saturn and its moons to study their temperature and composition.

7. **Cosmic Dust Analyzer** studies ice and dust grains in and near the Saturn system.

8. **Radio and Plasma Wave Science** investigates plasma waves (generated by ionized gases flowing out from the Sun or ions trapped by Saturn's magnetic field), natural emissions of radio energy and dust.

9. **Cassini Plasma Spectrometer** explores plasma (highly ionized gas) within and near Saturn's magnetic field.

10. **Ultraviolet Imaging Spectrograph** measures ultraviolet energy from atmospheres and rings to study their structure, chemistry and composition.

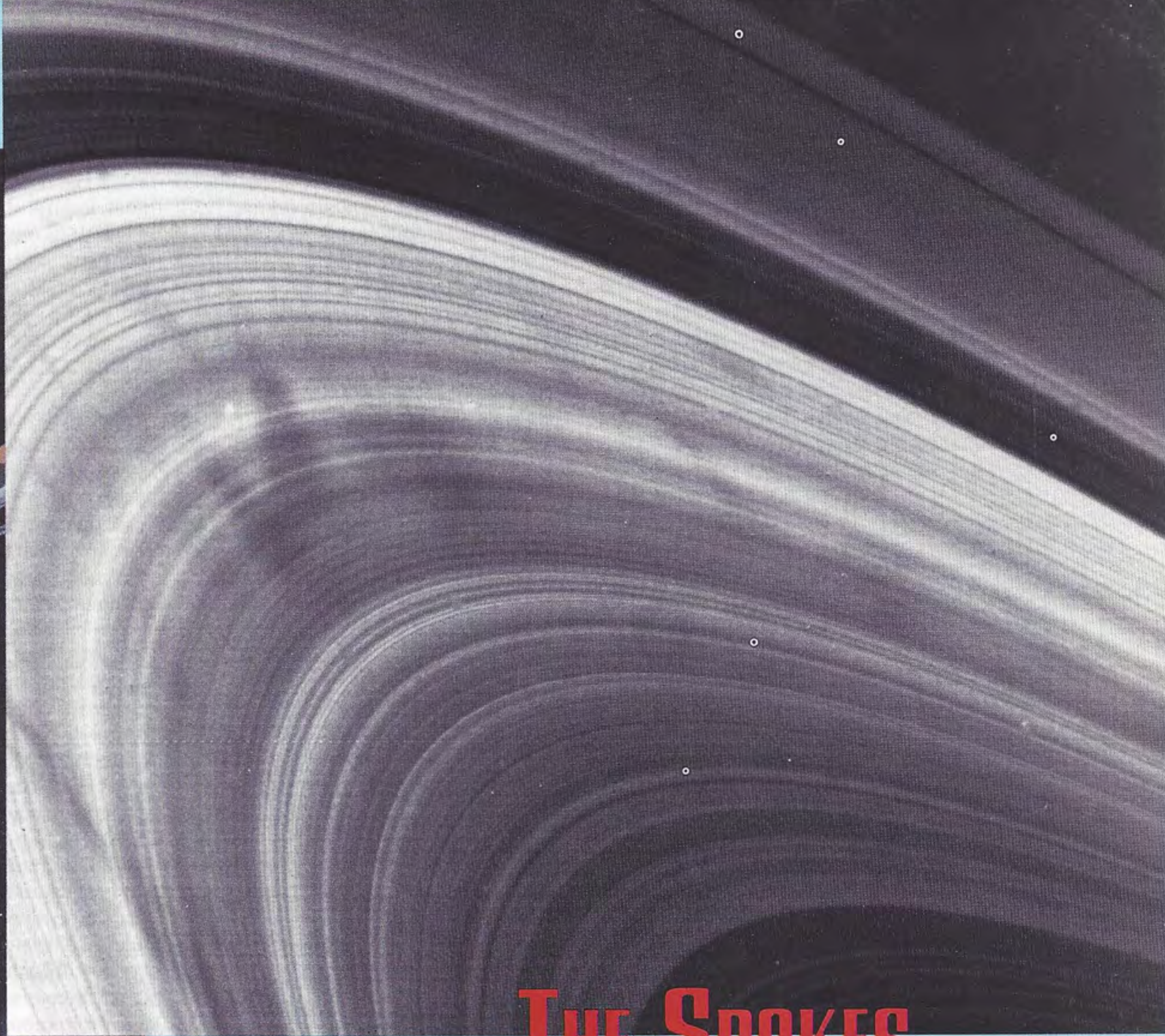
11. **Magnetospheric Imaging Instrument** images Saturn's magnetosphere and measures interactions between the magnetosphere and the solar wind, a flow of ionized gases streaming out from the Sun.

12. **Dual Technique Magnetometer** describes Saturn's magnetic field and its interactions with the solar wind, the rings and the moons of Saturn.

Illustration: JPL/NASA

# TITAN

*Titan's chiefly nitrogen atmosphere is colored brownish orange from what are believed to be complex carbon-based molecules. Over aeons, these molecules have been forming, clumping into larger particles and slowly falling to the surface below.* Image: JPL/NASA



# THE SPOKES

*Dark spokes form rapidly in Saturn's dense B ring, covering distances of several thousand kilometers in minutes. Scientists believe that meteor impacts with ring fragments produce clouds of charged dust, which are accelerated by Saturn's magnetic field, stirring up fine ring dust to form the spokes seen in this* Voyager 2 *image taken in August 1981.* *Image: JPL/NASA*

# PROBE RELEASE

*After releasing the* Huygens *probe for descent through the atmosphere of the large moon Titan,* Cassini *will explore Saturn's neighborhood for nearly four years.* *Painting: Michael Carroll*

*(continued from page 7)*
(Tethys), or perhaps smaller moons in the same orbit (Tethys and Dione). All in all, these icy moons are members of an interesting club, which *Cassini* plans to explore with its broad array of sensors.

## The *Cassini* Mission

Launch energies to go directly from Earth to Saturn are very great, so we must select launch times when other planets are in favorable positions in their orbits around the Sun to permit them to be used as gravity-assist swing-by bodies by *Cassini* to gain speed (relative to the Sun). In the technique of gravity assist, a spacecraft and swing-by body can mutually gain or lose speed relative to a central body they are both orbiting. Jupiter has the greatest mass for gravity assist, but its position relative to Saturn is favorable only once every 20 years, actually for about a one-month launch period in each of three successive years; the pattern repeats itself 20 years later.

The *Titan IV/Centaur* is very powerful, but it cannot boost the heavy *Cassini* spacecraft directly to Jupiter. It is possible, however, to first launch the spacecraft either to Venus or to an Earth-return swing-by so that it may pick up the added speed needed to reach Jupiter. This also allows the trajectory experts to find more launch opportunities and, when Jupiter is out of position, to occasionally find a long-trip-time, less attractive route if need be.

The primary launch period for *Cassini* opens on October 6, 1997, and lasts for three to four weeks. Following gravity-assist swing-bys of Venus (twice), Earth and Jupiter, *Cassini* arrives at Saturn in June of 2004, firing its liquid rocket engine for an hour and a half to brake into Saturn orbit, setting up the delivery of the *Huygens* probe to Titan some five months later.

After recovery and playback of the *Huygens* probe data, the orbiter will continue on its tour, making some five dozen orbits about the planet. During this tour, it will use precision navigation to achieve more than 30 close encounters with Titan, at least four close encounters with icy moons of high interest, such as Enceladus and Iapetus, and two dozen more distant flybys of other moons. Through the use of Titan gravity assists, with Saturn as the central body, *Cassini*'s orbits will be varied to permit excellent viewing of equatorial and polar zones, including the huge but invisible magnetosphere of energetic particles trapped by Saturn's magnetic field.

***A scale model of the* Huygens *probe, fitted with scaled parachutes, was recently tested in the transonic wind tunnel at Arnold Air Force Base in Tennessee. The results will be used to verify that the parachute and probe combination will work as designed at Titan.*** *Photograph: Arnold Engineering Development Center*

Because scan platforms were eliminated to reduce costs, the entire spacecraft must turn to point the cameras and other sensors at particular targets. More than half of each Earth day will be spent maneuvering to the desired pointing attitudes and collecting scientific data on the solid-state recorders. For the rest of the day, *Cassini* will point at Earth and play back the recorded data.

## International Cooperation

A sizable international team is designing, building and flying the *Cassini* spacecraft. In addition to some 1,300 academic and industrial partners in 16 European countries, there are more than 3,000 people scattered across 32 different states in the US.

The mission is managed for NASA by the Jet Propulsion Laboratory in Pasadena, California, where the *Cassini* orbiter is being designed and assembled. A team based at ESA's European Space Technology and Research Center (ESTEC) in Noordwijk, the Netherlands, is managing development of *Huygens*.

Although most of the orbiter and probe hardware comes from within their respective countries, key items are produced elsewhere. The Italian Space Agency is contributing the orbiter's 4-meter-diameter (13-foot) high-gain antenna for communications, as well as significant portions of three orbiter science experiments. On the other hand, the US is supplying the batteries and two science instruments for *Huygens*.

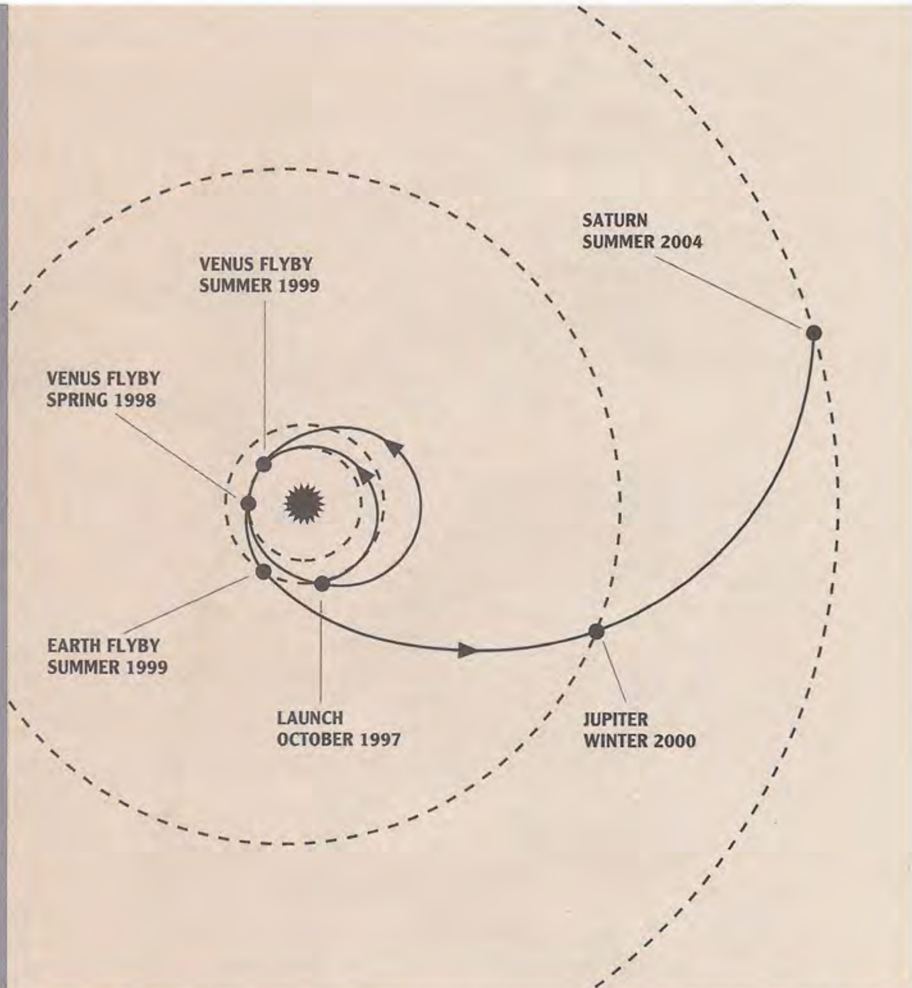
## The *Cassini* Orbiter

The orbiter is a large and sophisticated collection of high-quality hardware and software, integrated very carefully to meet a special challenge. Its primary purpose is to carry the many scientific sensors to the Saturn system and provide them with such essential services as power, attitude control and pointing, sequencing, environmental control, precision navigation, and data collection and broadcast to Earth.

The orbiter design is the result of years of brainstorming and performance trade-offs, subject of course to budget limitations. New technology is also folded in by way of such advances as solid-state data recorders with no moving parts, very high speed integrated circuit (VHSIC) chips and powerful application-specific integrated circuit (ASIC) parts for onboard computers, and reliable solid-state power switches to eliminate transients that usually occur with conventional power switches.

*Cassini* can provide over 650 watts of power to its engineering and scientific subsystems. It can point its sensors to accuracies of a tenth of a degree and maintain stability levels over 10 times slower than the motion of a clock's hour hand. It can control subsystem temperature levels to between 10 degrees and 40 degrees Celsius (50 and 104 degrees Fahrenheit), navigate to accuracies of 30 kilometers (about 20 miles), store some 4 billion binary bits of information, and broadcast data to Earth at rates as high as 140,000 bits per second.

CASSINI TRAJECTORY




Cassini's *almost seven-year-long journey to Saturn uses gravity assists from Venus, Earth and Jupiter to deliver the large spacecraft.* Chart: JPL/NASA

## The Huygens Probe

The 2.7-meter-diameter (8.9-foot) probe will enter Titan's atmosphere at about 6 kilometers per second (over 13,000 miles per hour). It will use a silica-based, shuttle-tile-like heat shield to dissipate a heat-energy input of 35 kilowatt-hours in less than a minute, reaching temperatures on its ablative front surface as high as 1,700 degrees Celsius (over 3,000 degrees Fahrenheit) in the process.

Shortly thereafter, the main parachute, which is 8.5 meters (27.9 feet) in diameter, is deployed at an altitude of 170 kilometers (105 miles), followed 30 seconds later by the release of the heat shield and its supporting structure, allowing the central module of scientific sensors to descend slowly through the murky atmosphere. At an altitude near 110 kilometers (68 miles), the main chute is released and a smaller drogue chute provides stability for the remaining descent to the alien surface.

The probe carries accelerometers to measure drag forces in the upper stratosphere, as well as other sensors to measure temperature and pressure. It will also carry an instrument to measure the structure and physical properties of the atmosphere, an aerosol collector and pyrolyzer to examine clouds and suspended particles, a gas chromatograph and mass spectrometer to measure the chemical composition of gases and particles in the atmosphere, a Doppler wind experiment to study the effects of winds on the probe, and a descent imager and spectral radiometer to take pictures of Titan's clouds and surface and to measure temperatures of particles in the atmosphere.

The probe's primary mission is conducted during its atmospheric descent of 2 to 2.5 hours, but there is always the chance that it might survive touchdown, given a landing speed of only 5 meters per second (about 11 miles per hour). If it doesn't tip over too far, and if it can continue to function on battery power until the orbiter flies over the horizon, it may be able to use the instruments in its surface science package to tell us more about that surface. Its tiltmeter can measure wave motion if it lands in liquid, and another device will be able to measure the liquid's index of refraction. A sounder can give readings of liquid depths of less than a kilometer.

## Summer 2008

If the *Cassini* mission goes as planned, its results should provide an exciting trail of discoveries and new understanding as the first decade in the next century winds down. All people who love to gaze at the stars and ponder the nature of other planetary realms will have much new food for thought. Theories about the evolution of the solar system and chemical processes on primordial Earth may be improved.

Bright young students will be inspired to devote their professional lives to one of the pure sciences or perhaps to the engineering challenges of the future. Indeed, nations that diversify in facing the future, choosing to meet both basic needs and exploratory pursuits, will gain strength from the process.

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*Charley Kohlhase is science and project engineering manager for the* Cassini *mission to Saturn. Outside work, he is active in wilderness preservation and photography.*

# A Vision for the New Millennium:

# What Do You Want The Planetary Society to Be in 2000?

***by* Louis D. Friedman *and* Charlene M. Anderson**

A new millennium is almost upon us, and with it comes a future filled with potential. The boundaries of that future are limited only by the laws of nature and the human will to achieve. Our species, if we so choose, could establish its presence out among the planets.

What role will The Planetary Society play in helping to create that expansive future?

The Society's Directors, Advisors and staff are beginning to chart a course into the next millennium. We are searching for innovative ideas and inspiring goals. And we are inviting you to brainstorm with us.

We ask that you take a few moments of your time to contemplate the possibilities and share with us your vision of The Planetary Society in the year 2000.

Here are some questions you might ask yourself:

- ***The Planetary Society's mission statement is "to promote planetary exploration and the search for extraterrestrial life." Would you add anything to this?***
- ***What should the Society accomplish before the turn of the millennium?***
- ***What role should the Society play in the space programs of Earth?***
- ***How should the Society accomplish its goals?***
- ***Who should the members of the Society be?***
- ***What will you—personally—have gained through your membership in The Planetary Society?***

There are many more questions that could be considered; these are just some suggested directions. Feel free to suggest other questions for the Board and staff to ponder. So be creative . . . be daring . . . be provocative . . . and challenge your fellow members as well.

Now, please take a moment to jot down your thoughts (in no more than *one* page). We will read what you send us, and the Board of Directors will use these ideas as it plans for The Planetary Society in the year 2000.

Please address your comments to the Board of Directors, The Planetary Society, 65 North Catalina Avenue, Pasadena, CA 91106. We would like to have your comments in hand by October 1, 1993. When we have digested all your various opinions, we will report to the membership on those we feel are the most helpful and challenging.

Your comments are important to us. You are the source of the Society's strength. You generate the momentum to get things done, and you provide the means to make all the Society's accomplishments possible. The course of The Planetary Society into the coming years will be determined by your actions. We want your help in creating plans and programs for the coming millennium. □

# Planetary Society Support Pays Off:

# Scientists Characterize Near-Earth Asteroids

by Richard P. Binzel and Shui Xu

**The Planetary Society seeks out research projects in which a small amount of seed money can help researchers pursue innovative ideas to substantially advance the exploration of the solar system and the search for extraterrestrial life. Through our members' donations, the Society has supported searches for extraterrestrial intelligence, asteroid discovery, the Mars Rover and Balloon, and many smaller projects.**

**Last year we gave a small grant to Richard Binzel at the Massachusetts Institute of Technology, and we are continuing to support his program. Having named him a Presidential Young Investigator, the National Science Foundation matches the private grants and donations he receives from other sources. Thus our support of his leading-edge research on near-Earth asteroids has doubled in value. Binzel is aided in this research by graduate student Shui Xu.**

**Here is their report to the Society's membership on the results of their research.**

A grant from The Planetary Society has enabled us to make great progress in our telescopic exploration of near-Earth asteroids. We have obtained and analyzed the spectra of eight newly discovered asteroids, and we were also able to study asteroid 4179 Toutatis as it made its close pass by Earth in late 1992 and early 1993.

Our spectral data reveal in detail how asteroids reflect the colors of visible and near-infrared light, allowing us to characterize the surface compositions of these small bodies. This information is essential in planning missions to such asteroids and in contemplating possible uses of space resources.

The key to our success was frequent access to a large-aperture telescope, in this case the 2.4-meter (94-inch) Hiltner telescope of the Michigan–Dartmouth–MIT Observatory on the southwest ridge of Kitt Peak in Arizona. Only with such a large telescope can we collect enough light to spread out a faint asteroid's spectral colors and analyze its composition.

## Ready to Get Set and Go

When they are discovered, most near-Earth asteroids appear as faint streaks on photographic plates or on CCD (charge-coupled device) arrays. They are not easy to see, even when they make their closest approaches to Earth, and they are observable for but a brief time. Because we have no idea when one might be discovered, we make contingency plans for observing so we can be ready to move when we get word of a discovery. In no other way can we hope to be in the right place at the right time.

The Planetary Society grant has not only enabled us to be ready to make these important first spectrographic measurements, but it has also supported our efforts later, in the time-consuming tasks of data reduction and analysis.

We have determined the spectral classes of the aforementioned eight asteroids. Most asteroids fall into one of three categories, denoted by the letters *S*, *C* and *M*, on the basis of their spectral colors. The S-class (for stony or perhaps stony-iron) asteroids are reddish. The M-class (metal) asteroids are reddish gray, and the C-class (carbon-bearing) asteroids are dull gray.

## A Diverse Collection

Four of the asteroids appear to have spectral characteristics placing them in the S class, similar to main-belt asteroids such as 951 Gaspra, which was investigated by the spacecraft *Galileo* in October of 1991. We found that 4179 Toutatis is also an S-class asteroid.

One asteroid displays C-class properties and seems to be a fairly pristine sample from the early solar system that may contain some water. Meteorite samples that display these properties are called carbonaceous chondrites. The C-class asteroids, along with extinct cometary nuclei that may lurk in near-Earth space, could become important watering holes for future space travelers.

Another asteroid displays spectral properties similar to those of ordinary chondrite meteorites, whose spectral class is known as Q. Planetary scientists have studied these meteorites and have found them to be composed of carbonaceous chondrite material that has experienced moderate heating since its formation in the early solar system.

The remaining two objects may be metal-rich (nickel-iron) M-class asteroids. To confirm this finding, however, we will need to take further measurements at either infrared or radar wavelengths. In this way we can determine if their composition is indeed nickel-iron or whether their neutral colors indicate the presence of other minerals.

Our key preliminary finding is that the near-Earth asteroid population presents us with a wide diversity of composition. Thus we must be sampling from a variety of asteroids from the main belt between Mars and Jupiter and perhaps from comets, both of which are believed to be the sources for near-Earth asteroids. All of the near-Earth asteroids await still further detailed resource assessment. With the continued support of The Planetary Society, we hope to go on taking the first steps toward these important assessments.

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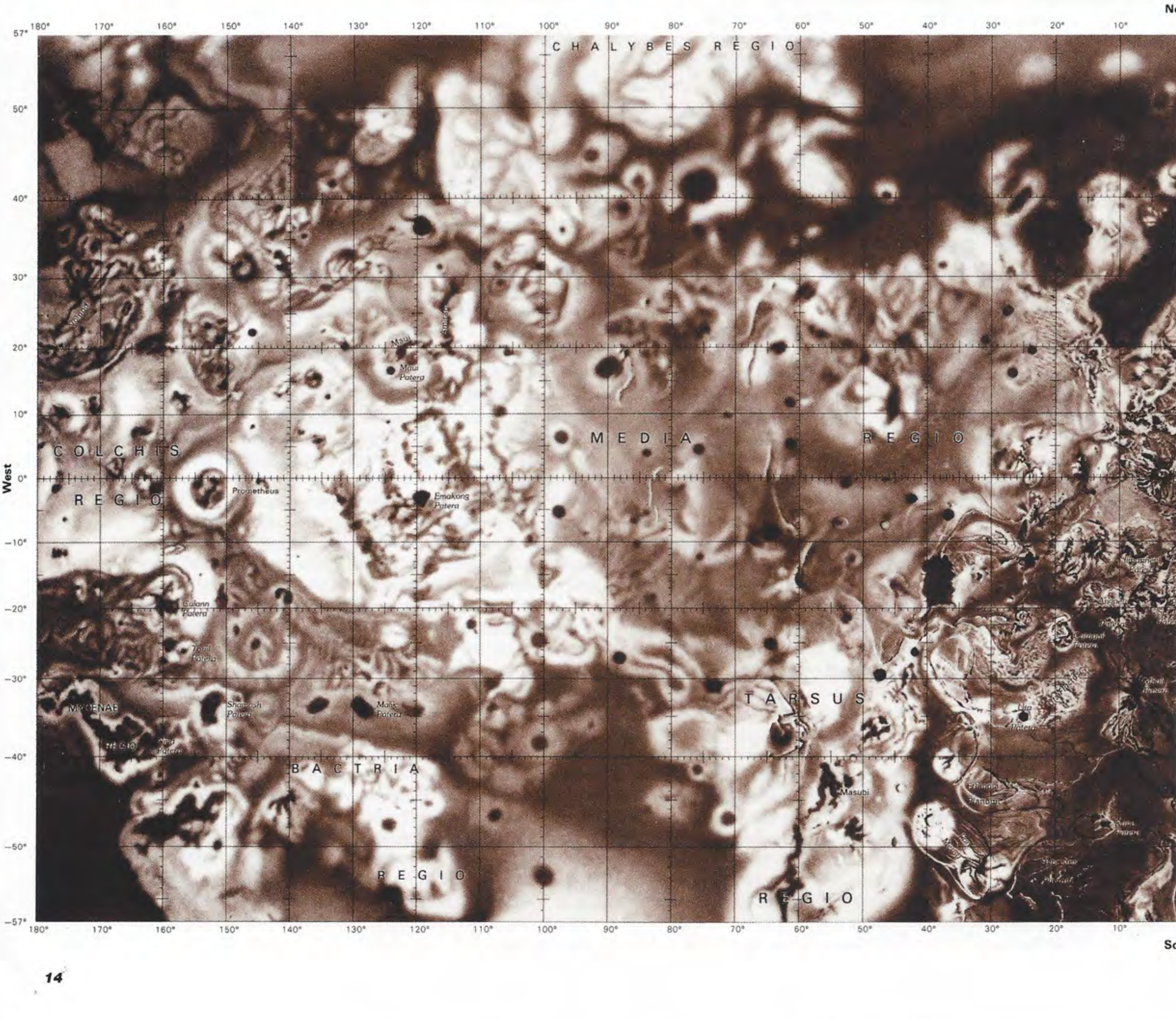
*Richard P. Binzel is an associate professor of planetary science at the Massachusetts Institute of Technology. In 1991 he received the Harold C. Urey Prize awarded by the Division for Planetary Sciences of the American Astronomical Society for outstanding achievement by a young scientist. Shui Xu is a graduate student in the Department of Earth, Atmospheric and Planetary Sciences at MIT. His thesis research is focused on the compositional properties of small asteroids.*

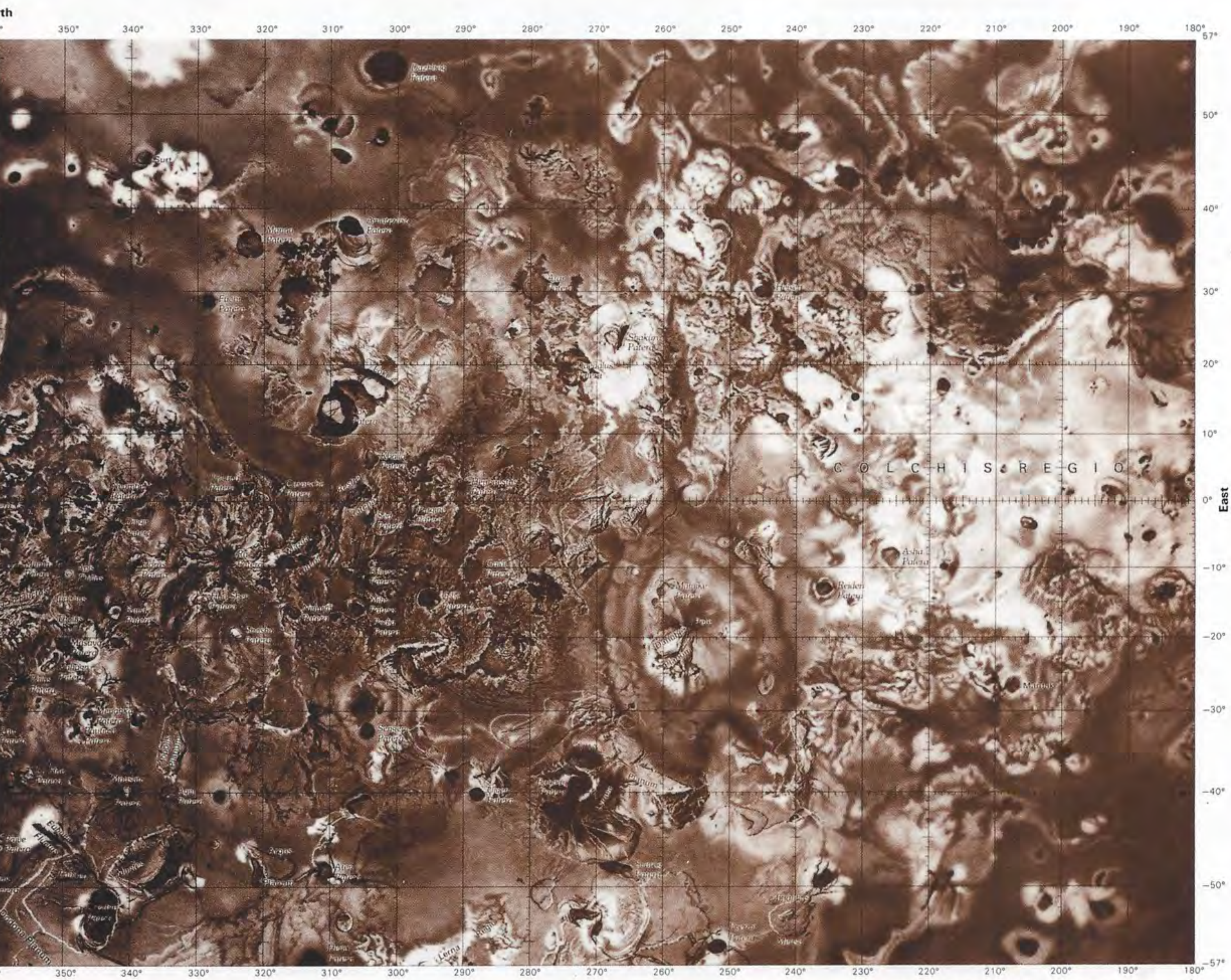
# Revisiting Io: Jupiter's Volcanic Satellite



Even before *Voyager 1* reached the jovian system in March 1979, planetary scientists suspected that Jupiter's innermost large satellite, Io, might be a very strange world. Since the 1950s, astronomers had been detecting radio bursts from Jupiter that seemed to be controlled by the position of Io in its orbit about the planet. Telescopic observers sometimes thought they saw the satellite brighten and then fade. Researchers looking at infrared wavelengths saw heat flowing from Io's surface that seemed to be 30 times the heat coming from an equivalent area on Earth. What was going on there?

Just three days before *Voyager 1* reached Jupiter, one group of brave researchers, led by Stanton Peale of the University of California, Santa Barbara, published a paper that predicted a mechanism to explain what was going on: Io is a volcanically active body.

Tides raised by massive Jupiter on one side and Io's sibling satellites—Europa and Ganymede—on the other side are caused by gravitational forces that alternately tug on and release Io. Though solid, its crust rises and falls much as Earth's liquid oceans do in tides raised by the gravity of our Moon. The friction from this tidal flexing pumps up enough energy to drive volcanoes that spew solid sulfur and sulfur dioxide gas hundreds of kilometers high. This sulfur dioxide gas then freezes out near the surface, forming spots of bright frost.




Map: Patricia Bridges, United States Geological Survey

# The Jovia

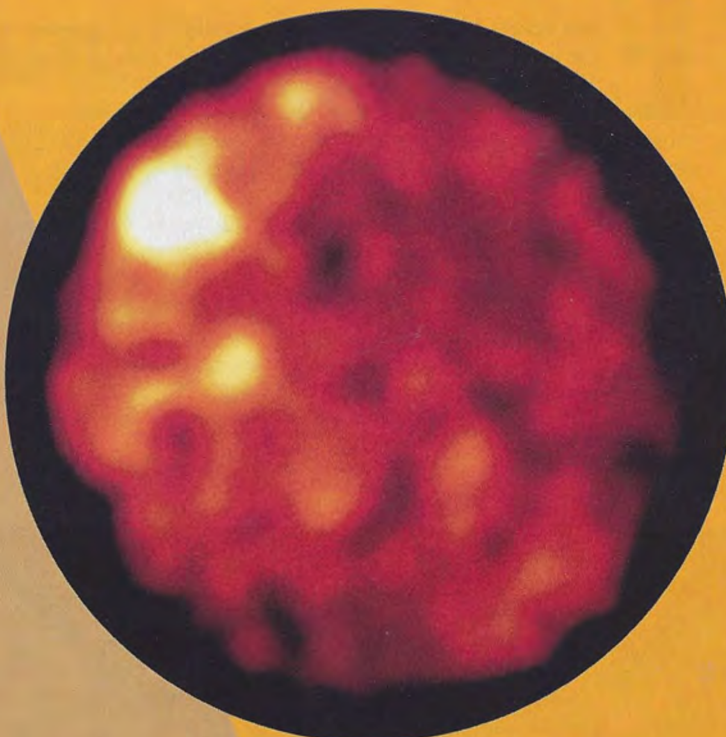
We now know that Io is the most volcanically active body in our solar system. During their brief flybys, the *Voyagers* observed nine plumes from active volcanoes. A plume erupting from one volcano, Pele, reached 250 kilometers (about 155 miles) in height. Velocities of volcanic ejecta approached 1 kilometer per second. Io is carpeted with volcanic calderas, vents and even lakes of molten sulfur. There is nothing on Earth to compare with this volcanic inferno.

A glance at the map on pages 14 and 15 shows what a different world Io is. Using the data returned by the *Voyagers*, Patricia Bridges of the United States Geological Survey's Astrogeology Branch in Flagstaff, Arizona, created this topographic map. Here the volcanically pocked face is rendered in great detail and stretched into a Mercator projection. *Voyager*'s instruments did not see the entire surface with the same degree of sharpness, so some regions appear softer than others.

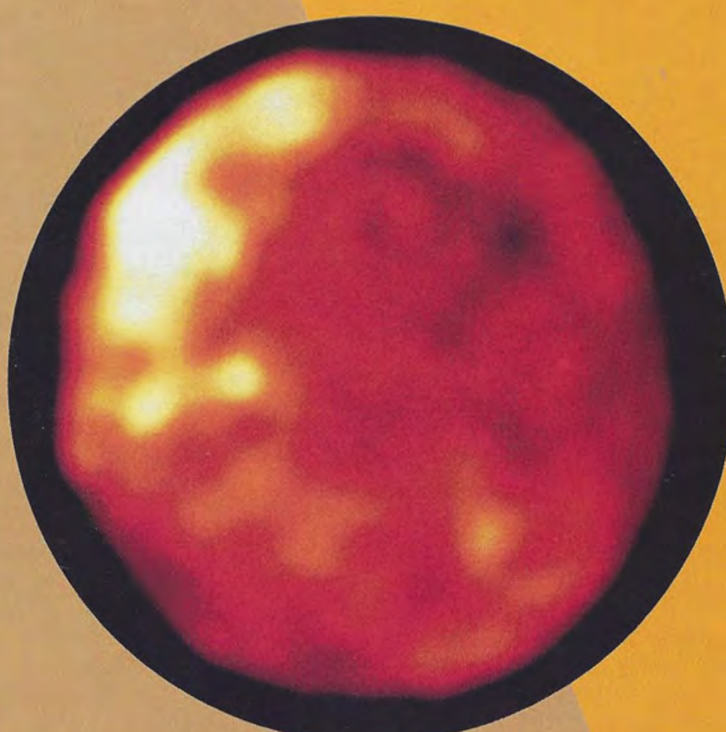
The great volcano Pele is located at minus 20 degrees latitude, 255 degrees longitude, near the center of the feature that looks like the hoofprint of a giant horse. Loki, another famous ionian volcano, is found at 20 degrees latitude, 300 degrees longitude. The dark, U-shaped region below it is probably a lake of molten sulfuric lava.

The vivid, pizza-parlor colors usually associated with Io are rendered monochromatically in this map. The red, orange, black and white colors seen in *Voyager*'s images are thought to be various colors of sulfur: The temperature of molten sulfur determines its hue, and color can be preserved as the sulfur lava cools and solidifies. Actually, because of image processing, the colors of *Voyager*'s images were quite a bit more intense than what a human eye might have seen. They are also vividly displayed in the collection of Hubble Space Telescope (HST), *Voyager* and computer-generated images seen on these pages.

Using HST, a group of astronomers led by Francesco Paresce of the European Space Agency and the Space Telescope Science Institute observed Io late in 1992. They sought to determine how the most

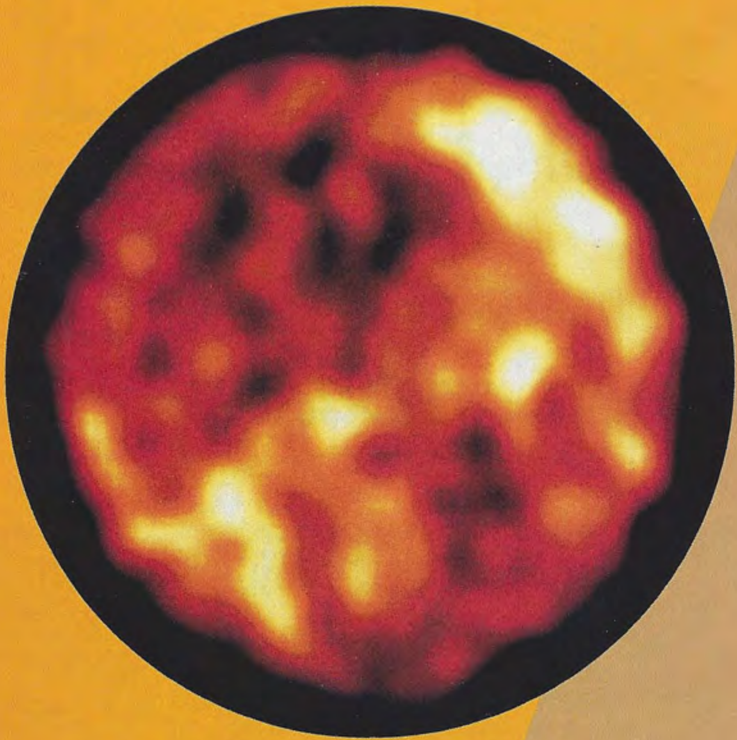


**Hubble Space Telescope View in Visible Light**

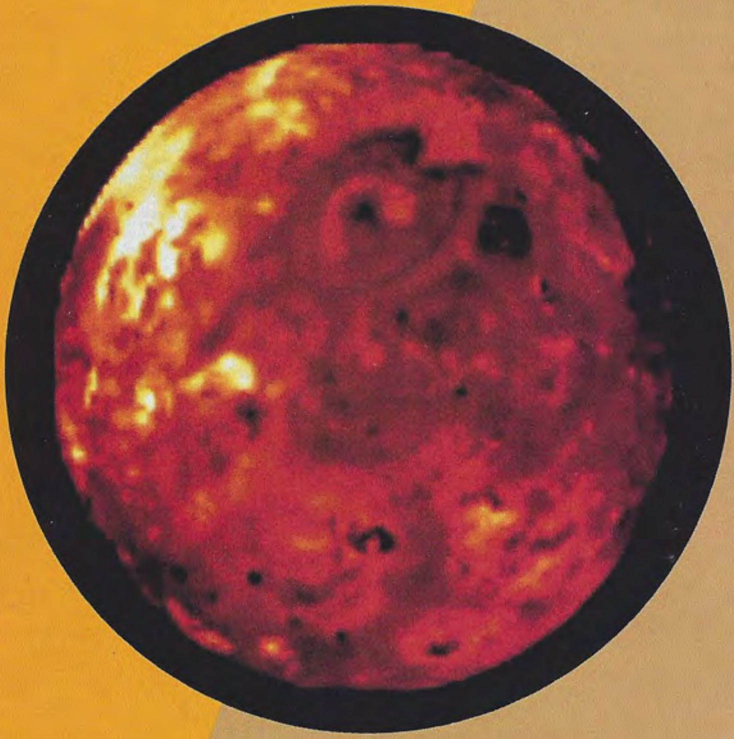


***Voyager* View at Space Telescope Resolution**

n Moon Io



Hubble Space Telescope View
in Ultraviolet Light



*Voyager* View at Closest Encounter

volcanically active body known might have changed in the 13 years since the *Voyagers* visited the jovian system.

Their surprising finding is that the surface appears to have changed very little, at least at the level of detail, or resolution, seen by Hubble's Faint Object Camera. This observation is consistent with other work by David Morrison, Joseph Veverka and David Pieri, which demonstrated that Io's large-scale surface markings have been stable for over 50 years, as seen in older Earth-based telescopic data.

The image at the upper left shows Io in visible light as it appeared on March 15, 1992, when it was 665 million kilometers (about 414 million miles) from Earth. Details down to 240 kilometers (about 150 miles) across are visible. Immediately below that image is a synthetic *Voyager* image, processed to match the resolution of HST. (An unmodified *Voyager* mosaic of the same face of Io, taken from 402,000 kilometers, or 250,000 miles, away, is seen at the bottom right.) By comparing these two images, we can see that the surface appears about the same.

This has puzzled scientists, for at the rate at which Io's volcanoes seem to erupt, they should lay down several centimeters of new material every year. Is some process removing or covering up the new volcanic debris as it is deposited?

HST also looked at Io in ultraviolet light. In the image at the upper right, the light and dark areas in the other images are reversed. This is probably because large portions of Io are covered with sulfur dioxide frost. This sulfur compound absorbs more ultraviolet light than other surface elements, so regions covered with it appear dark in the ultraviolet image. In visible light the reverse is true, so sulfur dioxide regions appear brighter.

The HST team plans to keep watching volcanic Io. Meanwhile, the *Galileo* spacecraft is on its way to the jovian system carrying a camera system capable of seeing the Galilean satellites with many times the resolution of *Voyager*'s cameras. We can anticipate new discoveries —and new questions—about this volcanic little world.

*—Charlene M. Anderson*

# The Future of Planetary Exploration:

## A Dialogue Between Daniel Goldin and Carl Sagan

***On December 4, 1992, just four days before the Galileo spacecraft encountered Earth for the last time on its journey to the outer solar system, The Planetary Society held an unusual program in Pasadena, California. Instead of a typical panel discussion or prepared lectures, Society President Carl Sagan and NASA Administrator Dan Goldin held a two-hour open dialogue before more than a thousand people at the California Institute of Technology's Beckman Auditorium. Members of the audience asked questions after the initial discussion period.***

***Goldin had been on the job less than a year at the time of this program, but he had already shaken up NASA's bureaucracy. The space agency was formed during the height of the Cold War, but the world has changed since then. Under Goldin's leadership, NASA is beginning to reflect those changes, and the vigor of his thought is demonstrated in this adaptation of his dialogue with the Society's President.***

***Daniel Goldin:*** As I thought about what I might talk about tonight, I let my mind wander back 500 years. Columbus was having a miserable day. He was in the middle of an ocean. His crew was cranky. They wanted to turn back. But he persevered and made some amazing discoveries. At various times, he thought he was in India, Japan, China and even the Garden of Eden. And what does that prove? It proves the European ignorance in the 1500s about the world. If we extrapolate to today and look at our space program, we're in the early 1500s. Humans have been to the Moon six times, but we've never returned any material from any other planetary body. We don't know if there are planets in any other solar system. We don't know how climate changes on other planets relate to what might happen on our own.

Back in the days of the *Mariners*, we had a very robust program. I worked on *Pioneers 10* and *11*, which weighed 550 pounds each and were on the cutting edge of technology. I think they cost $35 million or $40 million each. Since then, technology has moved at a record-breaking pace. Yet, instead of having a robust planetary program, we have exactly one planetary spacecraft. *Cassini* is a $4 billion program. God help us if we fail. We could lose the entire planetary program. *Cassini* took a decade from conception to congressional approval. It'll take almost a decade to build, and it will take a good fraction of a decade to get to Saturn. We didn't get to this point because we had bad people. We had brilliant, wonderful, enthusiastic people. But NASA only has four primary programs under development today—a shuttle, a space station, a planetary probe and a major astronomical facility [the Advanced X-ray Astrophysics Facility, AXAF]. Something has to change.

It's an opportune time for change because our world is changing. The Berlin Wall came down and it changed everything. America for five decades was focused on the "Evil Empire." It drove our education. It drove our highway program. It drove the soul of our country. NASA is a civil space program, but our origins are in the Cold War. We could reach out to Russia, and instead of having two competing programs with tremendous resources going into duplicating infrastructure, we could work together. Think of the possibilities.

Instead of using 10-year-old technology because we have a multi-billion-dollar program and having to play it safe to ensure success, let's get back to where we were with *Pioneer*, which took 11 months from inception to launch. We need to demonstrate again that we're not afraid to take risks.

***Carl Sagan:*** While I have debated all the other NASA administrators in my mind, and sometimes face to face, I have a very hard time arguing with Dan Goldin because I believe he is the first NASA administrator in a very long time who is willing to understand—because it takes some courage to do so—just what the problems are. In the question period, I'll try to be provocative, but I want to say here that he and I agree on many topics.

I completely agree that the space program is a creature of the Cold War. Now that the Cold War is over, there's a loss of direction.

I want to add a few words about *Mariner 2*, whose 30th anniversary it is. It was the first successful interplanetary mission in human history. *Mariner 2* was cheap. It was built fast. The scientists who would use the data built the instruments. A Jet Propulsion Laboratory team led by Marcia Neugebauer and Conway Snyder discovered the solar wind. The high radio brightness of Venus was revealed to come from an astonishingly hot surface.

If we could do *Mariner 2* at a very quick pace and very low cost with a harvest of absolutely fundamental scientific findings, why is it so hard for us to do such things now? Part of the reason is that the cream has been skimmed. It's inevitable that the easy discoveries are made early. Subsequent work becomes progressively harder, or you have to go farther from Earth to do it. That, in turn, means that the work becomes slower and costs more.

I pose the following question to you, Dan: You have been an eloquent proponent for what you summarized here tonight—getting cheaper missions going quickly. On the other hand, there are some questions which require larger, slower, more expensive missions. *Cassini*, of which you have been both an active critic and an active supporter, is a good example. You've argued that the real cost is something like $4 billion. That's a heck of a lot of money.

But think what it will do if it works. It will go into long-term orbit around Saturn. It will examine Saturn's rings. It will make close encounters with Saturn's major moons, including Enceladus, a most peculiar object because there's no way for its surface to have melted, and yet it has been; Iapetus, which has one of the darkest materials in the solar system on one side, and one of the brightest materials on the other; and Titan, which, according to many models, has a liquid-hydrocarbon ocean covering part of its surface. *Cassini* will drop a probe into Titan's atmosphere—a place where organic matter falls from the sky like manna from heaven, and the closest model of any place in the solar system to the events that preceded the origin of life on Earth four billion years ago.

That's a big return, and for a big return, it makes sense to make a big investment. Isn't there a danger that if we say small, cheap and fast, we get small, cheap and fast scientific results; that is, having skimmed much of the cream, we won't be able to approach the really deep issues?

***Goldin:*** Let me take an extreme position for the sake of discussion and say that if it were up to me, I would limit spacecraft to 500 pounds. I would allow no more than four years to build them. And I'd allow no more than two years for preliminary study before development, because I believe the technology is here—commercial, off-the-shelf technology. We're losing a tremendous amount of support for the current planetary program because there's not enough action for the American people. They have to wait 10 years to see results. And, as a planetary scientist, if you don't get onto that one expensive spacecraft, where are you going to go? Is it right, is it fair to have such a program? There's no multiplicity or diversity.

Sometimes diversity helps bring issues into focus. I have seen a study done by a number of very bold human beings who felt that they could perform the *Cassini* mission much faster and just as effectively for much less money. It's still only a study, and that's symbolic of the problem.

There's a very tight community that has been working together for a very long time, and they own the planetary program. They're not bad people, but they've gotten so comfortable with the program that you cannot have a divergence of opinion or you get attacked.

For example, a young man from JPL approached me about the Pluto mission. I didn't even know there *was* a Pluto mission. And he said, "Mr. Goldin, the prevailing thought says if we're going to go to Pluto, we must have the right scientific instruments. But once you put that many instruments on the spacecraft, it gets heavy." I think he said about 800 pounds. "It'll take us a decade to build. And if we put it on the biggest rocket we have, it'll take 15 years to get there. What if we make the spacecraft smaller, with fewer instruments? We could get it out there in seven years. We could build it in four or five years, so that 12 years from now, we could be at Pluto, instead of 25 years from now." I embraced the idea because I thought Pluto was such a challenging mission. If we could prove the concept of a small—he was talking about 200 pounds—spacecraft going to Pluto, we could convince everybody that there's another way to do things. A number of people attacked me in the press: "What right does the NASA administrator have to interfere with the scientific process?"

NASA's "scientific process" was pulled together because the space physicists, the astrophysicists, the planetary program, the life sciences and the microgravity communities were arguing with each other in Congress, and getting each other's programs canceled because the important thing was to get their own program going. Six years ago, they called a truce, saying, "We'll all get together at some nice place, and 500 of us space scientists will come to a consensus on America's space program."

***The space program belongs to the American people, not to the people working on the program.***

**—Daniel Goldin**

In those six years, the research and analysis money that funds university scientists has gone down 25 percent; the planetary program has dropped about 20 percent; and the physics and astronomy program has dropped 25 percent in constant fiscal 1992 dollars. The mission-operations and data-analysis budget went up 233 percent. The space program belongs to the American people, not to the people working on the program. I submit it's not right to have the space scientists decide by consensus what the program ought to be.

**Sagan:** So glad I gave you an opportunity to get that off your chest.

**Goldin:** I'm a little intense on the subject.

**Sagan:** But isn't there an excluded middle here? Surely there are many good missions that can be done by taking some risks. You can do that if you have other missions in the pipeline, so that on average you do well. In the progression of scientific exploration, there are circumstances in which the obvious next step requires something more elaborate than what preceded it. Look at the exploration of Jupiter. It starts with *Pioneers 10* and *11*—spacecraft like your quick Pluto mission—then *Voyagers 1* and 2. And now *Galileo*, which is not a flyby but an orbiter. That's a logical sequence. If NASA were *really* strapped, then the conclusion would be don't go to the outer solar system. Just go nearby. Were you to exclude *Galileo*, which weighs about 3 tons, we'd be closing lots of options.

*While we reach for the planets and the stars, we will transfer technology into the American economy.*

—Daniel Goldin

**Goldin:** In this course in creative thinking I teach, I ask people to put six lines on a piece of paper. Then I say, take those lines and arrange them into four equal-sized equilateral triangles. Most people will draw a square with two lines across it, but the sides of those triangles are 1:1:square root of 2. A few people will realize the answer is a tetrahedron. What's the lesson? I tricked them. I asked them to think in two dimensions. Very few people, when asked to think in two dimensions, start thinking in three.

There's a belief in the space community that you have to have "big" to accomplish what needs to be accomplished. I believe deeply that if we start thinking in three dimensions, we'll find that in three out of four cases we could do it small. One of the reasons I grabbed onto the Pluto mission is that I believe you should take the geniuses out here at JPL and unleash them. It's been a decade since we put technology into NASA programs. While we reach for the planets and the stars, we will transfer technology into the American economy to create new industries and new jobs. This also meets our new president's political agenda.

**Sagan:** The perfect example of what you just said is in monitoring Earth with regard to global environmental issues from Earth orbit. Flying lots of small missions makes perfect sense. Then you can design each mission from what you found in the previous mission. You have quick turnaround so you can take advantage of improvements in technology. You can be responsive to presidential needs on budgets. But the farther away from Earth you get, the less true that is.

**Goldin:** This gets back to my main message, that the space program has been run for the benefit of NASA. Mission to Planet Earth started as six Battlestar Galacticas. An enormous battle went on to try to make them smaller. Finally we went from full-blown Battlestar Galacticas to half-sized Battlestar Galacticas. That's where we are now, and God help anyone who wants to change that train as it gathers speed going down the tracks.

Let me switch the subject and say that we've now had four town-hall meetings. They've been standing-room only. In Los Angeles, at Cal State Dominguez Hills, we had an auditorium for 500 people. We had an overflow room with a video screen for 200 people. It filled up. We added a second overflow room for another 200 people, and that filled up and we had to send people away. There was a tremendous swell of opinion that we had to get back to the days of *Apollo*. They wanted to get humans to Mars as fast as possible. How do we get there? How does NASA balance science versus economics, so we don't get swallowed up in another large program? Space is more than just science. What is your sense, Carl, of how we might get to Mars, and when? What ought the balance be between human and robotic space probes? And what reasons would be behind it in this new world we live in?

**Sagan:** First, we ought to acknowledge that if you cannot provide a coherent justification to the taxpayer and Congress for spending the amount of money in question, then you have no right to ask for it. Clearly, a mission that takes half a trillion dollars and 30 years to send a few people to Mars is very difficult to justify.

Arguments for going include science, although the argument that you need humans to do the science is certainly not compellingly made.

My advice would be to vigorously pursue robotic exploration, especially of Mars. There are key questions about Mars that attract public interest: the reason for its past massive climate change; the search for past, or—who knows?—present life; the question of possible future human habitability. And it would clearly be prudent to examine the safety of long-duration spaceflight, including the effects of radiation in space on humans. This seems to me to be the only conceivable justification for a space station.

If enthusiasm develops, if the discretionary federal budget permits, if a president wishes to make a gesture that will ensure his or her place in history, then we can well imagine that we will go to Mars. But in the present situation, it's politically unrealistic to urge endorsement, especially on a specific timetable for sending humans to Mars.

**Goldin:** You're on the right track. One thing I'd like to add: 500 years ago, each individual country explored for itself, planting its flag separately for its own people. This gave rise to the most horrendous wars. Think about the possibilities of bringing nations together on a very difficult venture, under one flag planted for all humankind. I think that's a very, very positive reason for going.

**Sagan:** That's an argument I fervently pushed in the closing years of the Cold War: the United States and the Soviet Union working together on behalf of the human species using that same rocket technology that had put everybody on Earth at risk. Now, with the Soviet Union in utter collapse, the argument seems less pressing. But Russia, the United States, Japan, the Europeans and China, say, going to Mars together still has a profound symbolism. Whether that's a compelling argument for people who don't have enough to eat is another question.

***Goldin:*** This is a fundamental issue as NASA establishes balance in its program. Clearly I agree with your statement. You cannot send humans to Mars until you can understand how they could live and work in the hostile space environment. The interaction of cosmic rays with human tissue is yet to be resolved. We could write a book about what we don't know about humans in zero gravity.

***Sagan:*** *Mir* [the Russian space station] is the way to do that. It's operational, although only intermittently used. Residual Cold War attitudes are decaying very slowly, and that's all that prevents us from using *Mir* to start to answer questions about long-duration spaceflight. A few Russian cosmonauts have already lived in Earth orbit for around a year, which is roughly the time it takes to get to Mars.

***Goldin:*** The problem is twofold—technical and political. In the technical domain, one of the best-kept secrets has been the fact that American and Russian physicians have been working together for the last 10 years, but there's a real problem with in situ measurements because of *Mir*'s limited power and instrumentation capacity. Actually, Russia's and America's strengths are complementary. They're very sophisticated in their mechanical engineering, their propulsion and their metallurgy. We're very sophisticated in electronics, simulations and computers.

***Sagan:*** It's a marriage made in heaven, but one surprisingly difficult to consummate.

***Goldin:*** Which gets me to the political aspect—we've only had five months to work together. There's tremendous instability in Russia, and there's a reluctance in the United States to put its program in series with the Russians. So we've decided to do some confidence-building tasks first. We'll have a cosmonaut fly in the shuttle. We'll have an astronaut fly up in the *Soyuz* capsule to *Mir*. And finally, we'll have a shuttle rendezvous with *Mir*. And we're considering changing the space station's orbit. What if we put a space station in the same orbit with *Mir*? It would be simpler going from station to station. Think about the possibilities if our shuttle wasn't available, or vice versa. Think about lifeboats.

***Sagan:*** Doesn't that put off still further the day when we finish the long-term low-gravity and radiation-biology studies and so on? Does that indicate that we're not going to be sending humans to Mars in the next decade or two?

***Goldin:*** I don't think we can in the next decade or two anyhow. For low-gravity studies, I challenge the employees at NASA Langley and NASA Johnson—and anyone in this audience—to come up with a faster, better, cheaper human centrifuge for hundreds of millions instead of billions. It can be done. I have my own design. They say I'm off base again. "Goldin, you're out of your mind."

***Sagan:*** I like the idea of a NASA administrator designing spacecraft.

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***Members of the audience then came forward and asked questions. The first question was addressed to Goldin.***

**Question:** *Mr. Goldin, you've been to the Soviet Union three or four times in the last year and a half. Is it realistic, given what appears to be an economic black hole over there, for the United States to expect to have an equal partner in such a project?*

***Goldin:*** Is it risky? You bet. Will there be people who criticize it? You bet. Can we afford not to do it? We cannot. The Russians are committed to their space program. It'll be one of the last things to go. It's a matter of national pride. Could there be another coup? Yes. But how can we afford not to reach out?

**Question:** *Dr. Sagan, what is the single most important challenge to our space program, and how would you face it?*

***Sagan:*** NASA does not, in my view, do a good job of explaining why it does what it does, or even what it does. The average person's sense of what NASA is about is that every few months, a few people crowd into a tin can, go up into low Earth orbit, launch a satellite that could just as well have been launched by an unmanned booster, do some experiments the significance of which we never hear about afterward—the tomatoes didn't grow, or something—and then they come down again. And at the same time, NASA is doing fantastic science that gets very little attention. By attention, I don't mean an occasional article in the Tuesday [Science] section of *The New York Times*. I mean two or three minutes on the evening news, with wonderful visuals prepared by the nonexistent computer-animation laboratory devoted to public education at NASA headquarters.

Some people have the sense that the American public is simply too stupid to understand science. But that's not the case. I think it's important for NASA to pound on the doors of the media gatekeepers to present the argument for science and exploration.

> ***Some people have the sense that the American public is simply too stupid to understand science. But that's not the case.***
>
> —Carl Sagan

***Goldin:*** That was one of the major comments at the town-hall meetings. The public is telling us we don't communicate, especially to schoolchildren. People talked about documents and pamphlets written in language no one understands. I agree wholeheartedly. No one's responsible for publication at NASA. It's dispersed throughout the organization, which gets back to my basic point that there must be responsibility and accountability—one task, one human being. But I do want to take issue with you relative to tomato seeds on the shuttle.

**Sagan:** I thought you would.

**Goldin:** Part of the problem is that the life sciences have been woefully underfunded relative to physics and astronomy. Yet we are doing some very sound life science and microgravity science on shuttle flights.

**Sagan:** If we talk about physics and astronomy, we can answer absolutely fundamental questions from space—issues like the validity of general relativity, or whether the universe will expand forever. What is fundamental to biology

> **I would like to see, in my lifetime, international expeditions to Mars and to nearby asteroids.**
>
> **—Daniel Goldin**

is the genetic code and the evolutionary process, and you don't examine them in orbit. The only compelling argument, I believe, for life science in Earth orbit is to prepare for human missions to the planets. If we're not going to the planets, then there's no necessity for life science on a shuttle or space station.

**Goldin:** All I'm saying is we have to have a robust life science program if we're to understand how humans can live and work in space.

**Sagan:** But no tomatoes.

**Goldin:** Maybe just a few.

**Question:** *Mr. Goldin, I'm a student majoring in materials engineering. There doesn't seem to be any mechanism for NASA and JPL to handle the good ideas you get in college. What kind of proposal process would you implement for NASA to get diverse ideas for new technologies?*

**Goldin:** Thank you for the softball. About four weeks ago, I announced a new organization at NASA—the Advanced Concepts and Technology Office. I was terribly concerned by all the people who beat a path to my door saying NASA was resistant to new ideas. Greg Reck is the acting associate administrator. He's now traveling around the country soliciting opinions from universities and industry, professors and students. Send him a letter. He will respond.

**Question:** *It's amazing how many Americans couldn't care less about the space program because they don't know anything about it. They don't believe that we could possibly gain anything in daily life from space exploration. What can NASA and The Planetary Society do to educate the American public?*

**Goldin:** The single biggest problem may not be the lack of computer-animation capability at NASA headquarters. There's a more fundamental problem. Scientists and engineers do not write in plain English. I've spent hours in meetings at NASA trying to force people to speak English. The problem has gotten so bad that we've hired science writers to sit with the engineers and scientists and translate.

**Sagan:** I think The Planetary Society is doing a very good job. We do write in English. By the way, one of the advantages of computer animation is that you don't have to translate. It's visual. That's why no amount of talking heads would get on the evening news, but animation will.

**Goldin:** The American public is very sophisticated, in spite of what people think. They love science. They want to hear about science. We shouldn't demean them by saying they won't understand it.

**Question:** *This idea of the evening news bringing scientific information to us is a joke. The evening news does not treat us as intelligent beings. It's a show. It's little videos that stuff us with information—not even information, just blood and guts. I don't really feel that's the avenue to be learning about what NASA and the astronomical community are doing.*

**Sagan:** Of course you're right. The reason is the cut-throat competition between the networks, in which a single ratings point is worth umpty-ump million dollars. What you want is specials—in fact, series. There's even empirical evidence that this works.

**Question:** *Hearkening back to your Columbus analogy—aside from wiping out most of the native populations with disease, he brought on this incredible economic boom. One might expect that might happen again as a result of space exploration. For those of us interested in investing, are you considering means to fund planetary exploration—such as NASA bonds or democratized funding programs—such that we could, say, choose to finance planetary exploration versus military satellites that burn houses here on Earth?*

**Goldin:** First, let me say that we are not involved in direct military applications. We are working to find a separation, but things don't happen overnight. We have had the last military flight on board a shuttle. I *do* believe it's necessary for NASA and the military to work together on infrastructure, because we both can't go out and build launch vehicles, and we can't have separate communications and signal-processing infrastructure. But mixing missions creates a problem.

With regard to the other part of your question, it would be lovely if one could commercialize scientific missions. In the long run, by reaching out to the planets and the stars, there will be commercial activities in space.

**Question:** *Mr. Goldin, what three missions would you want, if you could have them?*

**Goldin:** In the planetary area, for the next 10 or 20 years, I'd like to see us darken the skies with small, low-cost, high-performance spacecraft to be pilot pigeons if you will. I do agree with Carl that we should be sending a significant number of these spacecraft to Mars. Second, I think we ought to do all those things necessary to get us to Mars, like understanding how human beings could live and work in a hostile space environment, and getting the systems engineering right. If we devoted 10 to 20 percent of NASA's budget, we could do these things in a reasonable amount of time.

Then, I would like to see, in my lifetime, international expeditions to Mars and to nearby asteroids (an idea Carl suggested in a phone conversation a month or so ago), and an international research station on the Moon—like the one at the South Pole—where we'll be able to image nearby stars and search for terrestrial-sized planets. That will change our view of who we are, and what we are, in the most significant manner, as would finding life, or fossilized life, on Mars.

**Question:** *Do you want to be there?*

***Goldin:*** Of course.

**Question:** *How sympathetic do you think the new administration is going to be to your projects?*

***Goldin:*** They're not my projects. They're America's projects. It's very important to understand that. I believe the new administration is very positive about the space program, because it recognizes the criticality of cutting-edge technology to America's future. Vice President Gore has been intimately involved with the space program. However, there are enormous issues facing our nation and it would be presumptive of me to say where the administration must place the space program on its priority list. I've seen a survey that shows that some 60 percent of the American people think that the NASA budget is about the size of the defense budget. It is not. We are a very small fraction of that, and I think we return a tremendous value. If you believe deeply that space exploration is important, speak out. Write letters. Pick up the phone.

**Question:** *What if a Moon base is established, and you find other planets around other star systems? Isn't it disturbing to think that in order to travel to them, you would have to hand the project down several generations? The originator would never see the outcome.*

***Goldin:*** I'd love to have that frustration. To deprive ourselves of the knowledge that there might be a blue planet around another star, I think, would be the highest-level crime. Maybe we'll start working full speed to develop warp drive. That's hokey, but…

***Sagan:*** I agree. That's a frustration I would look forward to. But it's by no means clear that the only, or the best—certainly not the most cost-effective—way of finding terrestrial planets around other stars is by establishing an extremely expensive human base on the Moon. There are other ways to do it. For example, there is a reasonably compelling case that radio astronomers have already found two planets of roughly terrestrial mass orbiting a pulsar.

**Question:** *I've never been able to see the importance of space exploration, as beautiful and fascinating as it is. Maybe you can leave me with something that I could understand.*

***Goldin:*** Society, since the earliest time, has wrestled with the question of how much do we put into the present to survive, and what fraction do we use to plant the seeds for the future. Do we take the money from the space program to solve the homeless problem? As a society, we spend our money in three different areas. We pay for our debts of the past. We have a national debt that's beyond belief, because my generation has chosen to steal from the future to live in the present. Second, we have responsibilities in the present to make sure that people have proper education, nutrition and health. And third, we have to invest in the future. I believe we have no right, as a society, to say that because we have problems in the present, we will walk away from the future. But I would weep for our nation if we didn't have a space program.

***Sagan:*** There's a range of justifications. Let me talk a little about space in general, not just NASA programs. Communications satellites link up the planet. Meteorological satellites predict the weather, saving many billions of dollars worth of crops every year. Military-reconnaissance and treaty-verification satellites make the planet more secure. Satellites, especially those that are coming along, monitor the health of the global environment, and check out the greenhouse effect, the depletion of the ozone layer, and new dangers we haven't even thought about yet. All of those are immensely practical and cost-effective.

Then there's the issue of exploration. Humans for 99 percent of our history were hunter-gatherers. We wandered. We followed the game. Exploration is built into us. And just at the moment when the planet is all explored, save perhaps for under the ocean, the planets open up as a goal for exploration.

Then there are the deep questions that each society, one way or another, asks—the origin of life; the origin of our planet; the origin, nature and fate of the universe. I think you'd have to be made out of wood not to wonder, at least a little, about those questions. Through folklore, religion, superstition or science, every human culture has invested some of its resources in trying to answer those questions. So it is reasonable for us who can, for the first time, actually find out some of the answers to make this investment as well.

If you mix those three together—the directly practical, the zest for exploration and the answering of profound questions of origins—I think you'll catch a sense of what motivates a lot of people about space. And one last thing—the vision of the future that's offered up to young people in our society is almost universally dismal—something like guys with automatic weapons on bombed-out post-nuclear-war highways. What aspect of our society, in the natural course of doing business, offers a hopeful vision of the future? It's the space program. It's new worlds, new exploration. It's something that young people can be motivated by, that can help guide their lives, make them work hard and study science. That's worth a whole lot. I think NASA, despite all of its problems and its ossified bureaucracy, is a fantastic bargain. And I'd like to wrap up this evening's discussion by saying that, after listening carefully to Dan's answers to this wide variety of questions, I think that NASA headquarters finally has got a breath of fresh air. □

***Just at the moment when this planet is all explored . . . other planets open up as a goal for exploration.***

**—Carl Sagan**

# A Planetary Readers' Service

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## To a Rocky Moon: A Geologist's History of Lunar Exploration

By Don E. Wilhelms;
University of Arizona Press, Tucson, 1993, 477 pages, illustrated.
Retail price: $29.95
Member price: $24.00

In December 1972, Don Wilhelms reminds us in his memoir, *To a Rocky Moon*, human beings took their last steps on the Moon for what may turn out to be a very long time. Having proved it could be done, and having made sure the whole Earth saw it, the United States turned its attention elsewhere.

We abandoned the Moon, our imaginations sated by television pictures of astronauts clumsily coping with low gravity. A few more *Apollo* trips and we could, at least, have made something of a geologic survey. But the way Wilhelms sees it, the cup is more than half full.

*Apollo 17* marked the end of 14 years of what psychologists call displacement activities. Rather than compete here on Earth, Soviets and Americans moved the playing field into space. After 1957 and the startling appearance of *Sputnik*, the two mightiest nations on Earth launched 41 rockets toward the Moon. The purpose was display, a high-stakes public relations gambit.

What they would find there was unknown when the flights were proposed. Wilhelms, a geologist at the US Geological Survey—the primary organization studying the Moon in the 1960s—was involved from the start. From his Menlo Park, California, office, he helped figure out what the surface of the Moon would be like, mapped the Moon, helped select the landing sites for *Apollo* and, perhaps most interesting of all, helped train the test-pilot astronauts as field geologists.

Wilhelms' story is highly personal, generous even to those he doesn't admire, and a pleasure to read. He has heroes, like Gene Shoemaker, but seems to hold no grudge against those NASA officials who never disguised their disdain for science. They scarcely bothered to debrief the astronauts about the geological aspects of the Moon walks. But thanks to *Apollo*, we now know the Moon's age and its topography, and we can make a good guess as to its origin.

Wilhelms recounts the Moon race mission by mission, providing an excellent history of lunar theory in the 20th century. He notes grimly that the real turning point in the US–Soviet race may have occurred in January 1966. Then the death of Sergei Korolev, the chief designer of the Russian program, pretty much took the Soviets out of the competition.

Taking us back to the early sixties, Wilhelms recalls that sending cameras to take pictures was not part of the original plan. Wilhelms credits Carl Sagan with understanding that images would be crucial to space scientists, that they could supply important scientific data as well as captivating the public.

Were the missions worth the billions of dollars they cost? Wilhelms answers a resounding yes. Adventure and technological expertise notwithstanding, they left two important legacies. The first is the view of Earth from space, reminding us that Earth is the only haven for life we know of in space, in contrast to the barren Moon. The second is an awareness of the danger of asteroid impacts like those that scarred the face of the Moon, a reminder of a violent past and a potentially violent future, a threat now taken seriously by policymakers.

Because of *Apollo*, Wilhelms explains, the Moon no longer belongs to astronomers; they now study distant reaches where human beings have not yet gone. It has been inherited by astrogeologists, who work with chisel, hammer and microscope. Perhaps in the next century astronomers will cede the entire solar system to their colleagues who leave footprints where they work.
*—Reviewed by Bettyann Kevles*

***Still Available:***

**Angle of Attack: Harrison Storms and the Race to the Moon,**
*by Mike Gray. Relive the tragedy and triumph of the* Apollo *program, in a tensely written tale focusing on one of the unsung heroes of the space program. (Reviewed January/February 1993.)*
*Retail price: $22.95*
*Member price: $19.95*

**Conversing With the Planets: How Science and Myth Invented the Cosmos,** *by Anthony Aveni. This provocative look at human planetary observations shows how lights in the sky were seen by astronomers before the rise of science. (Reviewed May/June 1993.)*
*Retail price: $21.00*
*Member price: $18.50*

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# WORLD WATCH

BY LOUIS D. FRIEDMAN

**WASHINGTON, DC**—The letters *TBD,* "To Be Determined," have become a code for a sea change at NASA. The Clinton administration submitted its proposed fiscal year 1994 budget (which provides funds for the agency from October 1993 to September 1994) to Congress in mid-April. The budget contains these line items:

- Space Station.........................$TBD
- New Technology Investments...$TBD
- Subtotal.....................$2,300 million

The category "New Technology Investments" includes technology research institutes, automation and robotics technology, increases in aeronautics and—of special interest to Planetary Society members—small spacecraft development for the Mars Environmental Survey (MESUR) Pathfinder, Near-Earth Asteroid Rendezvous (NEAR), small lunar orbiters and Earth probes for global monitoring.

This novel way of submitting the budget, with final amounts to be determined later, pits the current space station against the major new initiatives in technology and small robotic missions desired by NASA Administrator Dan Goldin and the Clinton administration. It represents an enormous political success for Goldin, who has been attempting both to redirect NASA toward smaller missions with more frequent accomplishments and to restore the agency's vitality.

The TBDs indicate that the design for space station *Freedom* will be reviewed to find a lower-cost approach for the United States to use to meet its objectives. Among the redesign guidelines are increasing international participation (including the Russians), meeting materials and life sciences research goals, reducing on-orbit assembly and achieving operation by 1997.

As soon as this redesign review was announced, three major camps began political infighting: those supporting the redesign, those trying to preserve the status quo and those who are content to kill the station outright and reduce NASA's budget accordingly. The Planetary Society is—and always has been—in the first camp.

The Society twice testified to Congress in favor of a reduced space station, one that could better meet science needs but not be so large as to squeeze out other programs. We have urged more reliance on crew-tended experiments, rather than supporting the "permanently manned" objective, and on joint experiments and operations with the Russians in their *Mir* program. These suggestions were included in the guidelines for the redesign.

Overall, the proposed NASA budget includes an increase of 6.5 percent, some $900 million. Such an increase by the new administration wasn't expected. Clearly, Goldin had sold the "New Technology Investments" as part of the administration's goal for revitalizing US science and technology—an investment contingent upon the successful paring down of the station. Similarly, the new starts for small planetary missions like MESUR Pathfinder and NEAR are also contingent on the station revision. The Pluto Fast Flyby mission, often mentioned by Goldin, is in the plan for a new start in fiscal year 1995, and requires only advanced research and development funds this year.

The largest area by far in the NASA budget is the more than $5 billion that must go to shuttle operations. The sea change at NASA now being attempted is to prevent the space station from eating up all other aspects of space exploration, as the shuttle did in the late '70s and early '80s.

One item missing from the proposed budget is the Bush administration's Space Exploration Initiative (SEI) for human missions to the Moon and Mars. The initiative had never gathered any political support. The press reported the elimination of SEI as indicative of the present administration's disinterest in human spaceflight. But administration officials and Goldin both say the action is more in the spirit of putting first things first. The immediate goal is to restore NASA's credibility and build up popular support, and to do that with nearer-term, lower-cost accomplishments to set us on the road to human planetary exploration. This includes the robotic missions proposed, as well as the lower-cost, earlier-operating, more international space station.

In addition to the new technology proposals, the budget includes support for the *Cassini* mission to Saturn ($266 million), the Advanced X-ray Astrophysics Facility ($260 million), American participation in the Russian *Mars '94* mission ($3.5 million), SETI (now called the High-Resolution Microwave Survey) and Mission to Planet Earth ($1,074 million).

As we go to press, we do not know the outcome of the space station redesign effort, or the fate of the new technology investments. If the space station can be constrained, its cost lowered and its overall size and complexity reduced, and if use can be made of the Russians' considerable space station capability, then these new technology programs have a chance.

The Society has been making a major effort, through its members, to let Congress know it supports the redesign of the station, new technology programs and planetary missions in the budget.

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

# News & Reviews

**by Clark R. Chapman**

One of the most important discoveries in astronomy will be the totally unambiguous detection of a planet around a star other than our Sun. During the past decade, many false alarms have been trumpeted in newspaper headlines. Generally, overoptimism and/or inadequate skepticism have been the culprits, although a few such reports did reflect discoveries of some kind of real object, or real phenomenon, that may be related to extrasolar planetary systems. So far, however, no clear case has been made for the existence of an Earth, or even a Jupiter, orbiting another Sun-like star.

Most astronomers have thought it likely that other planetary systems exist. But until one is discovered, it remains *possible* that we are alone—the product of some extraordinary coincidence or unique circumstance. The history of astronomy over the past centuries has increasingly taught us that Earth is not the center of the universe and that our Sun is an unexceptional star among a near-infinity of similar objects in the firmament. But until it can be proven that some other star possesses a roughly Earth-like planet, it could be that our Sun is indeed unique.

The April issue of *Physics Today* features an article by Anneila Sargent and Steven Beckwith entitled "The Search for Forming Planetary Systems." Written at roughly a *Scientific American* level, the essay should appeal to *Planetary Report* readers with a scientific bent. The authors, who are observational astronomers, argue that "the evidence is that planetary systems are abundant." I'm not so sure. It's not that I doubt that they may be abundant, and recent observations provide ample food for thought. But I believe the proof is not yet in hand.

## Long-Wavelength Planetary Searches

Sargent and Beckwith have been using advanced instrumental technology to study the long-wavelength radiation from stars. They observe not in the visible wavelengths that our eyes are tuned to, but in the infrared and millimeter wavelengths detected by such devices as infrared Earth-orbiting satellites and arrays of millimeter-wavelength radio telescopes on Earth. (The latter can be used as interferometers, which "sharpen" pictures of the stars that would ordinarily be increasingly blurry at longer wavelengths.)

The advantage of observing at longer wavelengths is that planets, asteroids and interplanetary dust radiate their modest heat in the infrared, unlike the Sun and other stars, which are much hotter and thus radiate chiefly in the visible. (Presumably, our eyes are tuned to visible wavelengths because visible sunlight is so bright.) Since reflected visible light from planets is very faint (just try to see Jupiter in daylight!), hypothetical planets would be "lost in the glare" of distant stars observed with normal telescopes. The glare is much reduced at longer wavelengths, so it is understandable that Sargent and Beckwith are excited by the new observations, which show extended cool "nebulas" around many stars.

The authors say that studies of planet formation have mostly been the domain of theoreticians until recently. They argue that searching for planets in visible light is fraught with difficulty—and so it has been, although progress is being made. Sargent and Beckwith extol their infrared and millimeter-wave techniques, saying they offer us "a very good look at young planetary systems." But most of their story relies on theory and inadequate data, and they admit that the resolution requirements needed to confirm the theoretical model they present "are still difficult to achieve."

## Can the Observations Supplant Theory?

Halfway through their piece, Sargent and Beckwith make a bold assumption: "We assume that the physical properties of forming planetary systems are comparable to those of the present solar system." If they were hunting for Earth-like planets, they should make such an assumption. But, instead, they are finding extended dust clouds near some stars. Using theory, they infer that asteroids (or comets, planetesimals or what have you) must exist near those stars. But who knows if the properties of the modern asteroid belt and zodiacal dust resemble those in the forming solar system, let alone in another planetary system? And, as struggling cosmogonists have realized, it is no simple matter to derive Jupiters or even Earths from swarms of smaller bodies.

The infrared and radio data make pretty pictures, and they indicate that cooler material accompanies many stars, including both young stars and evolved stars. But it is too early to say that real planets exist around these stars. I bet they do, but I'm still waiting for proof.

*Physics Today* is a monthly magazine published by the American Institute of Physics. It is available very cheaply to physicists ($2.00 per year). It is very expensive for anyone else ($130.00 per year), but it can be found in many libraries. *Physics Today* prints news about physicists, reports on the Washington politics affecting the physical sciences, and reviews of technical scientific books.

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*Clark R. Chapman edits* The Journal of Geophysical Research—Planets, *which recently won the Association of American Publishers' award for "Best Single Issue of a Journal" for its special issue on the* Magellan *mission to Venus.*

# SOCIETY *Notes*

## PAINE AWARD NOMINATIONS SOUGHT

The Planetary Society is now seeking nominees for the first annual Thomas O. Paine Memorial Award for the Advancement of Human Exploration of Mars. The award will go to the group or individual who has done the most to advance the long-range human exploration of the Red Planet.

For the official award rules and entry form, contact Society headquarters. The deadline for all entries is September 1, 1993.

*—Charlene M. Anderson, Director of Publications*

## THE SEARCH FOR INTELLIGENT LIFE CONTINUES

"We've been searching for intelligent life in the universe. If you're out there, please call 1-800-969-6277." So reads the slogan in the Society's new advertisement, appearing in publications like *Astronomy* and *Final Frontier.*

The advertisement was designed by one of our members from New York, Eric Essig. We are grateful to him for this work, which he donated to the Society, and we thank him for the new members who are joining us because of it.

We encourage all our members to use this ad to recruit new faces for the Society. Post the ad on bulletin boards, distribute it at meetings with other Society information or simply pass it along to people you think might be interested in joining the Society.

If you would like a copy of the advertisement, brochures or other information, please contact Department A at Society headquarters.

*—Louis D. Friedman, Executive Director*

## BIOASTRONOMY NEWS REFOCUSES ITS SEARCH

The Society is making some changes in the way it produces *Bioastronomy News,* the newsletter that covers the Search for Extraterrestrial Intelligence (SETI).

The Winter 1993 issue was the last issue edited by Michael D. Papagiannis, a professor in Boston University's Department of Astronomy. We owe him generous thanks for the work he has done with the newsletter over the past five years.

With the Spring issue, Guillermo Andres Lemarchand began work as the new editor of this quarterly newsletter. Lemarchand is a physicist at the University of Buenos Aires and has been a member of the SETI group of the Argentine Institute for Radio Astronomy since 1986.

If you have article ideas or other suggestions, contact Lemarchand at C.C.8-Suc. 25, 1425-Buenos Aires, Argentina; fax, 54-1-786-8114; e-mail, lemar@ seti.edu.ar.

For *Bioastronomy News* subscription information, please contact Society headquarters. *—CMA*

## SOCIETY WELCOMES SPACE COMMAND HEAD AS NEW ADVISOR

The Society is pleased to welcome retired Air Force General Donald J. Kutyna to its roster of Advisors. Kutyna brings to his new role a wealth of experience in space science, exploration and policy.

A graduate of West Point and the Massachusetts Institute of Technology, Kutyna is a former commander in chief of the North American Aerospace Defense Command and the United States Space Command. After the *Challenger* disaster, he was appointed to the presidential commission investigating the accident. In 1992, he was appointed to the US Space Council Advisory Board.

In 1987, the National Geographic Society gave Kutyna its General Thomas D. White US Air Force Space Trophy for his contributions to the nation's progress in space. Retired from the Air Force since 1992, Kutyna is now corporate vice president for advanced space systems at Loral Corporation. *—LDF*

## SOCIETY MEMBERS SUPPORT EDUCATION

We thank Society members for their support of the MarsLink project. Generous donations from Society members made it possible to distribute the MarsLink preview packet to 11,000 schools. MarsLink will bring *Mars Observer* information to middle- and high-school students from September 1993 through May 1996.

For more information on how you can support this international education project, contact the Society's education office. *—Carol J. Stadum, MarsLink Project Director*

## MEMBER TOURS IN 1994

The Planetary Society is cooperating with Grouptrav National to offer members a chance to experience a total solar eclipse in Paraguay. The tour runs from October 26 to November 5, 1994, and includes several days in Buenos Aires and a visit to the nearby Argentine Institute of Radio Astronomy, site of the Society's SETI search of the southern sky. The tour also features noted SETI scientist Woody Sullivan. For information, call Grouptrav at (800) 877-3703.

The Society is also investigating the possibility of a tour to Russia in mid-October of 1994 for the launch of the *Mars '94* spacecraft. If you are interested in receiving *Mars '94* tour information as it becomes available, write to *Mars '94* Tour, in care of The Planetary Society, or call (818) 793-5100. *—Susan Lendroth, Manager of Events and Communications*

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# Questions & Answers

***How do scientists determine, from such great distances, when intergalactic material is a gas and when it is a dust?***
**—W. S. Greathead,**
**Saratoga, California**

To determine the makeup of interstellar or intergalactic material, one needs to know a great deal about atomic and solid-state physics. Astronomers measure the light that comes from a particular region of the sky and must dissect this radiation to understand the properties of the matter in that region.

Interstellar gas and dust are thoroughly mixed together, and interstellar dust is never found without a great deal of interstellar gas. (In the most dust-rich clouds, the dust comprises only 1 percent of the mass of the cloud.) The gas produces very narrow spectral signatures (emission or absorption lines) characteristic of atomic or molecular processes. The dust produces much broader emission or absorption bands associated with matter in the solid state.

In cold clouds of gas and dust, the gas is in either atomic or molecular form, and we can determine its form by looking for characteristic spectral emissions from atomic hydrogen or certain trace molecules, like carbon monoxide. These emissions are studied by radio astronomers.

Interstellar dust is mixed with this cold gas and emits radiation in the thermal infrared portion of the electromagnetic spectrum. We are familiar with this infrared radiation as heat radiation, the energy emitted by a body when it gets warm. Even very cold bodies, such as interstellar dust at temperatures of

## FACTINOS

Astronomers have discovered a train of at least 17 very bright objects near Jupiter that they believe are pieces of a single comet that broke up last summer in a close encounter with the giant planet. They said the new find resembles "pearls on a string," but with a wispy tail. (See top picture on next page.)

The new discovery is named comet Shoemaker-Levy after United States Geological Survey scientist Eugene Shoemaker; his wife Carolyn; and colleague David Levy. They were the first to spot it, using the 46-centimeter (18-inch) telescope atop California's Palomar Mountain in March. They did so, they said, despite the fact that they were economizing by using damaged film, and they were fighting rain, snow and fog.

The next day, during better weather, Jim Scotti of the University of Arizona observed the comet from Arizona's Kitt Peak. Where the Shoemakers had seen five pieces, Scotti counted 11. Then Jane Luu of the University of California, Berkeley, and David Jewitt of the University of Hawaii used the 2.2-meter (88-inch) telescope atop Hawaii's Mauna Kea to resolve 17 separate "subnuclei" of ice.

The comet's identity before it shattered is not known, but from now on, Shoemaker said, "it will be one of the best observed comets ever," if it stays bright enough. "We rarely get to see the long-term behavior of freshly broken-up cometary surface. This is really a whole new experiment."
—from Kathy Sawyer in the *Washington Post*

❖

When the European-American spacecraft *Ulysses* flew by Jupiter in February 1992, the huge planet appeared to be blowing puffs of dust in the face of the passing craft. Six times *Ulysses* recorded bursts of tiny dust grains striking it. The bursts came at remarkably regular intervals of about 28 days. They came in narrowly focused streams from the direction of the planet, suggesting a jovian origin.

It defied common sense, the puzzled scientists said, that any material, much less the finest of dust, should be escaping the gravity of the most massive planet in the solar system.

The discovery was reported in an April issue of *Nature* by an international team of scientists led by Eberhard Grün of the Max Planck Institute for Nuclear Physics in Heidelberg, Germany. In a separate article, Joseph A. Burns of Cornell University assessed the findings and suggested likely solutions to the mystery. The scientists said the dust is presumably coming from the faint rings around Jupiter or the volcanoes of Io, one of its inner moons.
—from John Noble Wilford in *The New York Times*

❖

For the second time in seven months, David Jewitt and Jane Luu have captured an image of a body that lies outside the orbit of Neptune (see bottom picture at right). They suggest that the object belongs to a primordial storehouse of comets known as the Kuiper belt, which astronomers have long believed to exist in that region of the solar system.

The mysterious body, known as 1993FW, lies too far away—and researchers have made too few measurements—to determine whether it is indeed a comet, says Jewitt. It is 250 kilometers (about 155 miles) across, and it is roughly 46 times as far from the Sun as Earth. That distance, says Jewitt, corresponds to the inner reaches of the proposed Kuiper belt. But he adds that many more measurements are needed to determine if 1993FW has the circular orbit required of a Kuiper belt resident. If instead it has a highly elliptical orbit, he noted, it might eventually reach the inner solar system and therefore could not be a member of the reservoir.
—from R. Cowen in *Science News*

about 15 degrees above absolute zero (15 degrees Kelvin or minus 258 degrees Celsius or minus 432 degrees Fahrenheit), emit such radiation. This infrared radiation is absorbed by the air.

For astronomers to observe this radiation from very cold clouds requires telescopes carried in airplanes, balloons or satellites above most or all of Earth's atmosphere.

If a star is close to a cloud of cold gas and dust it can produce what is called a reflection nebula—that is, we see light that was emitted by the star and scattered or reflected toward Earth by the dust in the gas cloud. This light basically has the properties of the star that first produced it, but is altered by scattering off the dust. There are two prominent effects of this scattering process. The light becomes highly polarized (a state in which rays of light display different properties in different directions, as when they are reflected off glass in a particular way or like the glare off a sunlit sea). It also becomes bluer—that is, the blue light from the star is more efficiently scattered by the dust than is the red light, so the reflection nebulas appear bluish compared to the color of the star.

Hotter gas becomes ionized (electrons are stripped off its atoms) and produces radiation that is characteristic of atoms and ions in a thermal plasma (a gas of positive ions and electrons). The hottest thermal plasmas known to astronomers have temperatures of several million degrees and can only be observed via their X-ray emission. This requires X-ray telescopes carried above the atmosphere on satellites.

Interstellar dust mixed with this hot gas is usually at a temperature of several hundred degrees above absolute zero (200 to 300 degrees Kelvin, minus 70 to 30 degrees Celsius or minus 94 to 86 degrees Fahrenheit), and emits strong continuous radiation in the thermal infrared. Specific spectral features emitted by the dust allow astronomers to distinguish between its various constituent parts (such as silicates similar to the silicate mineral olivine that we know on Earth, graphite, silicon carbide and carbonaceous materials such as polycyclic aromatic hydrocarbons, et cetera).

One other way of determining the composition of interstellar matter involves using a background star as a light source and studying the absorption spectrum of the star's light as it passes through an interstellar cloud en route to Earth. In this way a variety of constituents of interstellar dust and gas have been found, including interstellar ices; this was also the method used in the first detection of gas excited by the cosmic background radiation.

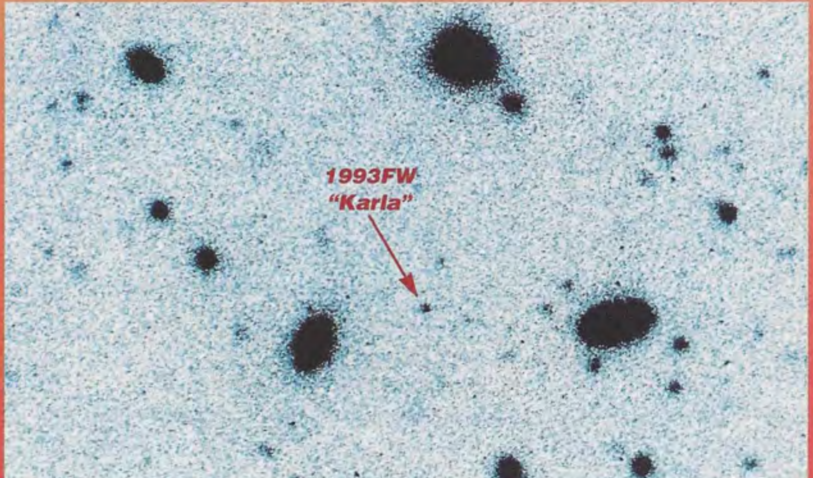
It is the cold, tenuous gas and dust in interstellar clouds that collapse to form new stars and planetary systems.

—TOM SOIFER, *California Institute of Technology*

*This "necklace in the sky" is comet Shoemaker-Levy as it looked when David Jewitt and Jane Luu captured it on film this past March. Seventeen separate nuclei appeared in the original charge-coupled device image, but the faintest ones were lost during photographic reproduction. Each nucleus has its own gas coma and tail.*

*Over three nights of observation, the researchers saw no changes in the shattered comet's appearance. However, they expect to see changes over longer time scales, and this will provide many clues as to how comet nuclei actually split apart.*

*Image: David Jewitt and Jane Luu*




*On the night of March 28, 1993, David Jewitt and Jane Luu used the University of Hawaii's 2.2-meter (88-inch) telescope to capture this image of 1993FW (also known as "Karla"). This is the second object the pair have discovered orbiting the outskirts of our solar system. (They found the first one, 1992QB1, or "Smiley," last August.) While Neptune and Pluto orbit the Sun at about 30 astronomical units (AU), these bodies reside at 42 AU.*

*The Kuiper belt is believed to consist of the outer remnants of the disk from which the solar system accreted. Therefore Karla and Smiley give us a direct look at the most primitive planetary bodies.*

*Image: David Jewitt and Jane Luu*

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# the Universe This Summer!

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