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The Rings of Uranus from *Voyager 2*

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COVER: The black rings of Uranus reveal subtle color differences in this computer-enhanced, false-color image generated from data returned by Voyager 2 during its January 1986 encounter with the planet. The bright epsilon ring appears as the neutrally colored line at the top. Moving down, toward Uranus, are the delta, gamma and eta rings, here seen as bluish-green, with the beta and alpha rings in lighter tones. Below them are rings 4, 5 and 6 in pinkish shades. The faint pastel lines between the more defined rings may be traces of new rings discovered by Voyager 2. ***Image: JPL/NASA***

CHALLENGER

THE DISASTER OF THE SPACE SHUTTLE *Challenger* was heartbreaking. The Planetary Society mourns the loss of seven brave explorers. They were two women and five men; their families came from Asia, Russia, West Africa, Europe; they represented at least four of the world's great religions. Their loss is not just for the United States, but for the planet.

After the 1967 fire that killed astronauts Grissom, White and Chaffee, the *Apollo* program went on to its greatest triumphs, and we believe that in the long run the human venture into space will experience, because of *Challenger*, only a brief detour on the eve of historic accomplishments. The Planetary Society intends to play an important role in the key discussions and decisions on the future of space exploration to be made in the coming year. — CARL SAGAN

THE THREE TRAGEDIES OF *CHALLENGER*

THE TRAGEDY OF JANUARY 28 has touched the American soul more deeply than anything since the John F. Kennedy assassination — Why? Why should there be such a tremendous grief and outpouring over the death of seven of us when death is such a common occurrence in all walks of life?

The reason is that we have all identified so deeply with those attractive and adventuresome individuals who are our surrogates in space. They represented all of us reaching out to push back the frontiers of adventure and exploration.

For that reason, their deaths will not and should not be in vain — we should continue to send out representatives to explore space on our behalf. We should continue to send them in a public and visible way so that, indeed, all of us may participate vicariously. We should continue to fly the space shuttle for that purpose as soon as the cause of the explosion has been identified and corrected.

However, there is a second tragedy unfolding, not nearly so visible to the American people but just as profound in its implications. The shuttle had been designed not only to carry humans to and from Earth orbit, but it also incorporated a new and unproven concept in space flight. The shuttle was to carry automated payloads intended for distant orbits, to service the military, to launch commercial communication satellites and to carry out the diverse activities of scientists.

As a consequence, NASA has eliminated all expendable launch vehicles which have traditionally been the means of launching automated (and usually expendable) payloads. Now that the shuttle fleet is grounded, all US space activities are likewise grounded.

The implications are disheartening.

Not only is the orderly continuation of military surveillance and other functions disrupted, not only is our ability to ferry commercial communications satellites suspended, but our dwindling planetary exploration effort has been dealt a stupendous blow with a year or more further delay of our principal new planetary mission — the *Galileo* orbiter and probe to the planet Jupiter.

The third tragedy — yet to happen — looms when the budgetary implications of these delays and reprogramming efforts for both the manned and unmanned programs go to Congress for approval.

The timing couldn't be worse. The Gramm-Rudman (deficit control) bill represents an abdication by both the Administration and the Congress from making judicious adjustments in various federal programs, as now needed because of the *Challenger* tragedy.

Somehow we must collectively find the political wisdom and capability to respond to the *Challenger* setback. We must provide timely, efficient and flexible transport to orbit for the full range of automated activities which are essential to both our present and future.

And we must look beyond the shuttle and even the space station to where the manned endeavor of exploration truly leads.

The President can and should set the goal of Americans (we hope in collaboration with others) reaching the surface of Mars sometime after the turn of the century as a culmination of our steps into space and as the final tribute to the seven *Challenger* crew members. — BRUCE C. MURRAY

Questions & Answers

***Why does our Moon present only one side to Earth, and is this phenomenon common among other moons in our solar system?* — Donn Bigelow, Connell, Washington.**

The phenomenon of synchronous, or "locked" rotation and revolution, is common among the moons in our solar system. For example, the four large moons of Jupiter, the Galilean satellites, are all in this state.

If a moon is rotating (spinning) faster than its period of revolution about its governing planet, tides in the moon raised by the planet's gravity will dissipate spin energy by kneading the moon's material until eventually the moon turns only one face toward the planet. The effect is mutual: In the absence of outside disturbances such as large impacts, our Earth and Moon will, in the far-distant future, end up facing each other. Earth's day and month will then be the same.

— JAMES D. BURKE, *Jet Propulsion Laboratory*

***How does Halley's Comet, a "dirty snowball," retain ice over so many millennia?* — David W. Caird, Tucson, Arizona**

Ice in space behaves a bit differently than you might expect. At any given distance from the Sun, the amount of ice lost depends on the amount of solar energy falling on it. In a vacuum, the ice sublimes, changing directly from solid to gas, just as carbon dioxide (dry ice) does on Earth's surface. So much energy goes into this "change of state" from solid to gas that the ice doesn't warm up much, probably never reaching its freezing point even when closest to the Sun.

Since Halley's Comet travels in a very elongated ellipse, it spends most of its time far from the Sun where it loses no ice at all. The comet is significantly active for only about one year out of the 76 years of its orbital period. Using its current rate of mass loss of about one hundred million tons per orbit, we calculate it loses less than two meters in radius in each swing through the inner solar system. Halley's Comet has been in its present orbit since *at least* 14,000 BC, or about 210 revolutions around the Sun. The loss of ice would have reduced its radius by less than half a kilometer. (We estimate its current radius at three kilometers.)

So, many millennia ago, Halley's Comet was not greatly larger than it is now. It should be with us for some time to come.

— RAY L. NEWBURN, *Jet Propulsion Laboratory*

***What orbit does Halley's Comet travel, does it go out beyond our solar system, and what is its speed?* — Robert T. Ruffin, Snoqualmie, Washington.**

The orbit of Halley's Comet has a cigar-like shape (it's an eccentric ellipse) that reaches its farthest point from the Sun (aphelion) between the orbits of Neptune and Pluto

HALLEY'S COMET, 1986. PHOTOGRAPH: ELINOR HELIN/JPL

and its closest point (perihelion) just inside the orbit of Venus. At perihelion, the comet's orbital velocity reaches its maximum — 196,300 kilometers per hour — while at aphelion, it reaches its minimum — a much more leisurely 3,200 kilometers per hour.

Because the distance between the comet and a particular planet is constantly changing, the gravitational force between them can differ substantially from one return to the next. Thus, the orbital period of Halley's Comet has been as long as 79.3 years between the successive returns to perihelion in June 451 and September 530 A.D. and as short as 74.4 years between November 1835 and April 1910. This latter record will be broken when the comet takes only 72.7 years between perihelia in July 2061 and March 2134.

— DONALD K. YEOMANS, *Jet Propulsion Laboratory*

What can I do about the Challenger disaster?

Many members have called or written us in the month since the *Challenger* disaster. Some wanted only to express their sorrow, some donated money in memory of the crew, and many asked "What can I do?"

Around the United States, many people suggested memorials such as scholarship funds in the crew's memory and trusts for their children. Another suggestion was to name seven of the newly discovered moons of Uranus for the crew of *Challenger*; we brought this idea to the attention of the *Voyager* Imaging Team. (The naming of celestial bodies follows slow international conventions, so we must wait to see what will happen.) The Soviets proposed, as did many American planetary scientists, that we remember the *Challenger* crew, as we have other space heroes, by naming surface features on other planets after them.

Some hastily conceived proposals, such as public subscription to build a replacement shuttle, were made by several people and groups.

As Drs. Sagan and Murray express on the opposite page, we in The Planetary Society have dedicated ourselves to the future. Great pressures are now being put on America's space program. The Society's role has become increasingly important.

To our members who ask, "What can I do?", we can say, "Keep your eye on the future. Stay with us and help increase the Society's strength as we work for continued US exploration of the solar system and the search for extraterrestrial life."

Later this year we will be writing you about new Planetary Society programs and our drive to build an even larger world-wide membership base to demonstrate public interest in the great enterprise of space exploration. You will be asked to support these efforts.

Let us hope that the legacy of 1986 will be our exploration of Uranus and Halley's Comet, and that the tragedy of *Challenger* will be only a brief interruption in humanity's journey to the planets.

— LOUIS D. FRIEDMAN

JAPAN

A NEW FACTOR IN SPACE

BY STEVE BURGESS

Something is different about the Japanese space program. The realization could hit you at any time. It could be while taking off your shoes before entering Tanegashima Space Center. It could be while being shown satellites named after flowers, and how the strap-on boosters resemble an opening flower as they tumble away from the N-II launch vehicle. It could be when you notice that the characteristic dissent heard in most American institutions is absent here.

This singleness of mind is partly responsible for the phenomenal success of Japanese industry, and the parallel growth of the Japanese space program. The attitude seems to have aided the perfection of technology in many fields. The world market speaks for the results. And these relative newcomers to space have established themselves in that field as well.

The Japanese space program has become a world-scale institution in only 20 years. As in many fields where government funding has helped a seed project blossom into a burgeoning industry, so has this space program grown. In the last few years, Japan has entered the stage of international cooperation and competition in space research and applications.

The seeds were planted in 1964 at the University of Tokyo. A few months after the first satellite-televised Olympic Games, held in Tokyo, the university announced its plans to produce scientific satellites. In 1969, the National Space Development Agency of Japan (NASDA) was formed, with the assigned function of making practical use of space technology.

Japan launched its first satellite in 1970 from the University's Kagoshima Space Center just two months before China put up its first. The entire annual space budget at this time was $59 million. During the next five years, while the United States was in the midst of a recession and NASA's budget dropped by 15 percent (about 50 percent in "real" dollars), the Japanese budget grew over 500 percent and brought the 1975 launch by NASDA of the first N-I vehicle, capable of putting a 270-pound payload into geosynchronous orbit.

In 1981, upon the successful return of the first US space shuttle, the Institute of Space and Astronautical Science (ISAS) was established outside of the University of Tokyo as a joint research institute for space science. ISAS has launched numerous small scientific satellites, while NASDA has put up 15 engineering, communications and meteorological craft.

Growing Budget

Although Japan's budget for space activities has grown dramatically — by 1850 percent — over the past 15 years and it enjoys a written-in percentage (0.2 percent) of the gross national product, the government contribution is nonetheless limited — to $533 million in 1984, for example. It is being augmented in ever-greater amounts by private industry. Over 15 percent of NASDA's 1984 budget came from corporate members of Keidanren, a nonprofit advisory organization made up of some 60 large Japanese companies.

The budget for ISAS, on the other hand, has remained relatively fixed for the past few years. Yet the scale of ISAS' projects has grown considerably. It is the agency responsible for the first Japanese interplanetary probes, *Sakigake* (formerly MS-T5) and *Suisei* (formerly *Planet-A*; see the July/August 1985 *Planetary Report*), scheduled to encounter Halley's Comet early in March, 1986. ISAS' minimal funding has brought it to develop its own technology and vehicles in-house.

ISAS has a great advantage over most governmentally funded programs in that it is largely responsible for its own policy under the direction of Dr. Minoru Oda. The institute uses many graduate students and visiting professors to augment its paid staff and does not actually have to produce specific results to justify its funding. Thus some of the country's most creative minds are allowed greater freedom to produce timely and remarkable results.

ISAS comes under the auspices of the Japanese Ministry of Education, while NASDA is under the Science and Technology Agency. Both organizations are advised by the Space Activities Commission (SAC), which determines the general outline of Japanese space policy.

Appreciating Aesthetics

Nearly wherever you go, from NASDA headquarters in Tokyo to Tanegashima Space Center 1000 kilometers to the south, the aesthetic qualities of Japanese space hardware are among the first things mentioned by those in the program, and remain prominent in conversation thereafter. Attention is given to the red and silver design of ISAS' launch vehicles and to the fine lines of NASDA's stark white ones. At Tanegashima, launch gantries seem to be tucked into the recesses above semi-tropical caves on the island. And at Masuda tracking station there, nearly every photograph of a satellite dish was dramatically composed, with the stars behind and colored arc lamps before.

In publicity releases, photographs of NASDA's satellites are superimposed upon the flowers for which they are named: *Yuri/Lily* (broadcasting), *Kiku/Chrysanthemum* (engineering), *Himawari/Sunflower* (meteorology); *Sakura/Cherry Blossom* (communications). And while watching a launch of the N-II, there's an anticipatory silence and a request to stop and watch before the strap-on boosters begin to tumble away in an expanding circle.

Although many people everywhere appreciate the beauty inherent in technology, this obvious attention to aesthetics seems to be almost foremost in Japanese thoughts.

This appreciation of beauty seems to be second only to the all-pervading drive toward production and installation of domestically produced technology. Most test facilities at Tsukuba Space Center,

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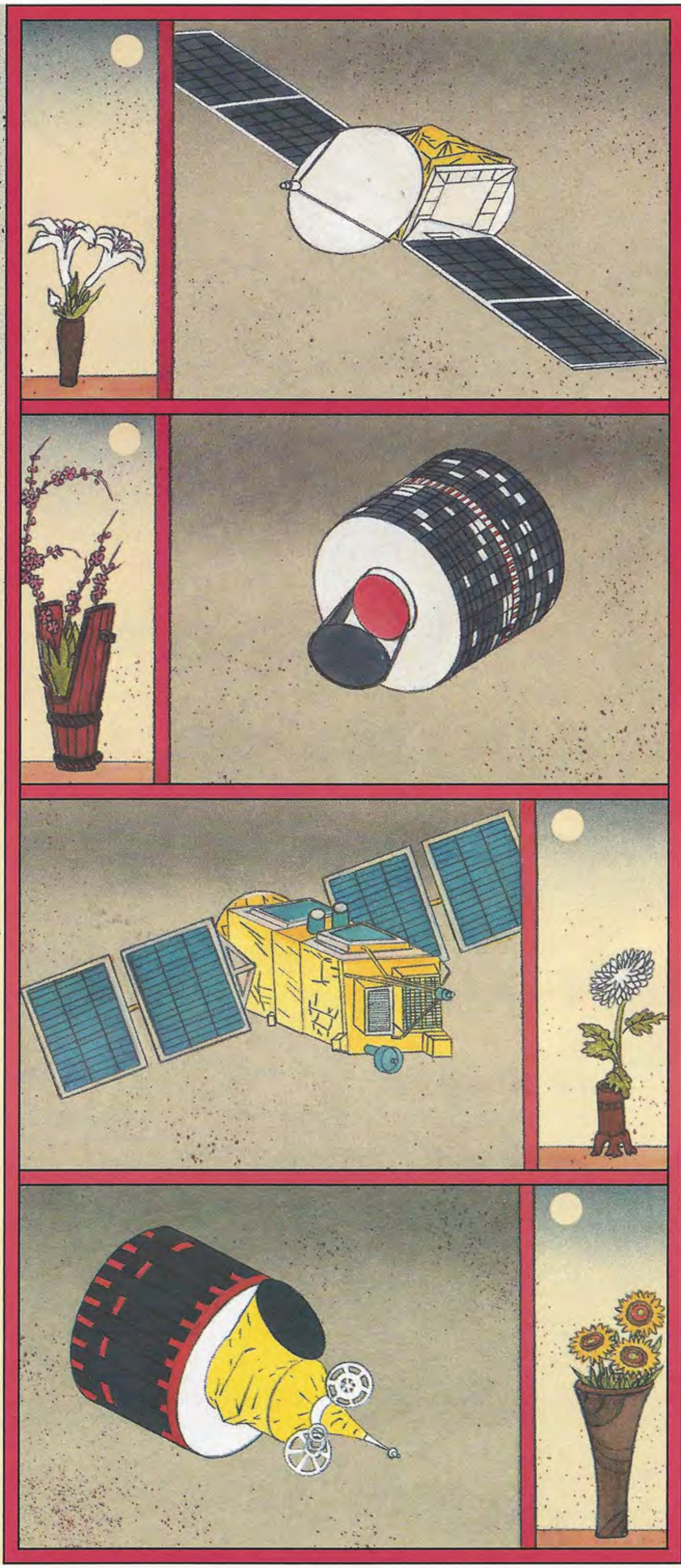

Top to bottom: Yuri/Lily; Sakura/Cherry Blossom; Kiku/Chrysanthemum; Himawari/Sunflower

Illustrations: S.A. Smith

N-II rocket is launched from Tanegashima Space Center in Japan.

Photograph courtesy of NASDA

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about 64 kilometers north of Tokyo, now perform quality control on component systems originated in Japan. At Tanegashima Space Center, banks of McDonnell-Douglas and Hewlett-Packard computers are steadily being replaced by new NEC (Nippon Electric Company) machines. Discussion with Tanegashima's Deputy Director, Kunihiko Okugawa, reveals that domestically originated fuels, engines and other equipment are being scheduled for production upon the conclusion of licensing agreements with western companies.

Whatever the effect of this drive and appreciation, the results again are the proof of the pudding. Out of launches scheduled five and ten years earlier, only one missed its fiscal year window, and that apparently because the new N-II launch vehicle was completed ahead of schedule so a more advanced satellite was launched first. I have seen evidence of only one unsuccessful orbital placement (a 1979 *Ayame* satellite) and one partial failure of a satellite (two channels of a 1984 *Sakura*).

Japanese national space policy is created on a yearly basis, with consideration of previous results and changing demand. In 1967, the goal of the policy was largely to achieve levels of success recognizable by western nations. Japan quickly achieved its goal.

Continuing Successes

With its continuing successes and growing independence of foreign technology, Japan can now afford to help other countries in their own development. To that end, Japan offers assistance to many Asian and Pacific nations, including Australia, China, Indonesia, the Philippines, Taiwan and Korea. The image promoted by NASDA's International Affairs Department is that of an older, more experienced brother helping his less-advanced siblings with marine and geodesy observation data, or with their fledgling space programs.

On a larger scale, Japan cooperates with NASA and the European Space Agency (ESA) research programs. Every two years, an international group of space scientists meet in Tokyo to consider the current level of world development in their field. NASDA has a staff exchange program with ESA and is beginning one with NASA. ISAS participates with NASA and ESA in the International Solar-Terrestrial Physics Program.

Japan is planning an active future in space. This year, *Sakigake* and *Suisei* have encountered Halley's Comet. A Japanese payload specialist is scheduled to fly on board a 1988 space shuttle for their first materials processing test, containing 34 experiments in physics, alloys, genetics and exotic semiconductors. The early 1990's promise a launch vehicle able to put two tons into geosynchronous orbit. Japan is buying at least two modules from an American company to use on the proposed US space platform.

Plans through the end of the century include permanent facilities in space. There are also hopes for missions to Jupiter and Mars, to be done in cooperation with other spacefaring nations.

Many of these plans were outlined 18 years ago. The drive of Japanese space scientists has produced results at the scheduled times. The most delayed experiment was a particle-accelerator test that had to wait until the US space shuttle was ready. The growing Japanese confidence in their space program has fueled them to greater efforts and greater sharing of the fruits of those efforts.

Future Possibilities

The possibility of a Japanese presence in space has become fact. The future of a manned Japanese presence in space is a surety. Japan's role in the international development of space is uncertain.

Hirokuki Osawa, President of NASDA, gives us a glimpse of the possibilities: "Looking to the twenty-first century, there are many problems which must be resolved if humankind is to flourish. NASDA seeks to contribute to the solution of the problems by its space-development activities, building up technological skills which can then form the basis of international cooperation."

The drive behind the Japanese program has yielded dramatic results. The aesthetic appreciation suggests a softening of the image of hard science as it is perceived by many today. The program's quality control has produced a unique ability to perform and to achieve while reducing duplication, cost and time necessary for completion.

The active inclusion of the Japanese in an internationally cooperative space effort can only be good news to exploration and development. The difference in the Japanese approach could make a difference in humankind's successful exploration of space.

Steve Burgess is a freelance writer specializing in space sciences.

WE ARE LISTENING

As our metal eyes wake
to absolute night,
where whispers fly
from the beginning of time,
we cup our ears to the heavens.
Avid, we are listening

on the volcanic lips of Flagstaff,
and in the fields beyond Boston,
in a great array that blooms
like coral from the desert floor,
on highwire webs patrolled
by computer spiders in Puerto Rico.

We are listening for a sound
beyond us, beyond sound,

searching for a lighthouse
in the breakwaters of our uncertainty,
an electronic murmur,
a bright, fragile *I am.*

Small as tree frogs
staking out one end
of an endless swamp,
we are listening
through the longest night
we imagine, which dawns
between the life and times of stars.

Our voice trembles
with its own electric,
we who mood like iguanas,
we who breathe sleep
for a third of our lives,
we who heat food
to the steaminess of fresh prey,
then feast with such baroque
good manners it grows cold.

In mind gardens
and on real verandas
we are listening,
rapt among the persian lilacs
and the crickets,
while radio telescopes
roll their heads, as if in anguish.

With our scurrying minds
and our lidless will
and our lank, floppy bodies
and our galloping yens
and our deep, cosmic loneliness
and our starboard hearts
where love careens,
we are listening,
the small bipeds
with the giant dreams.

— Diane Ackerman

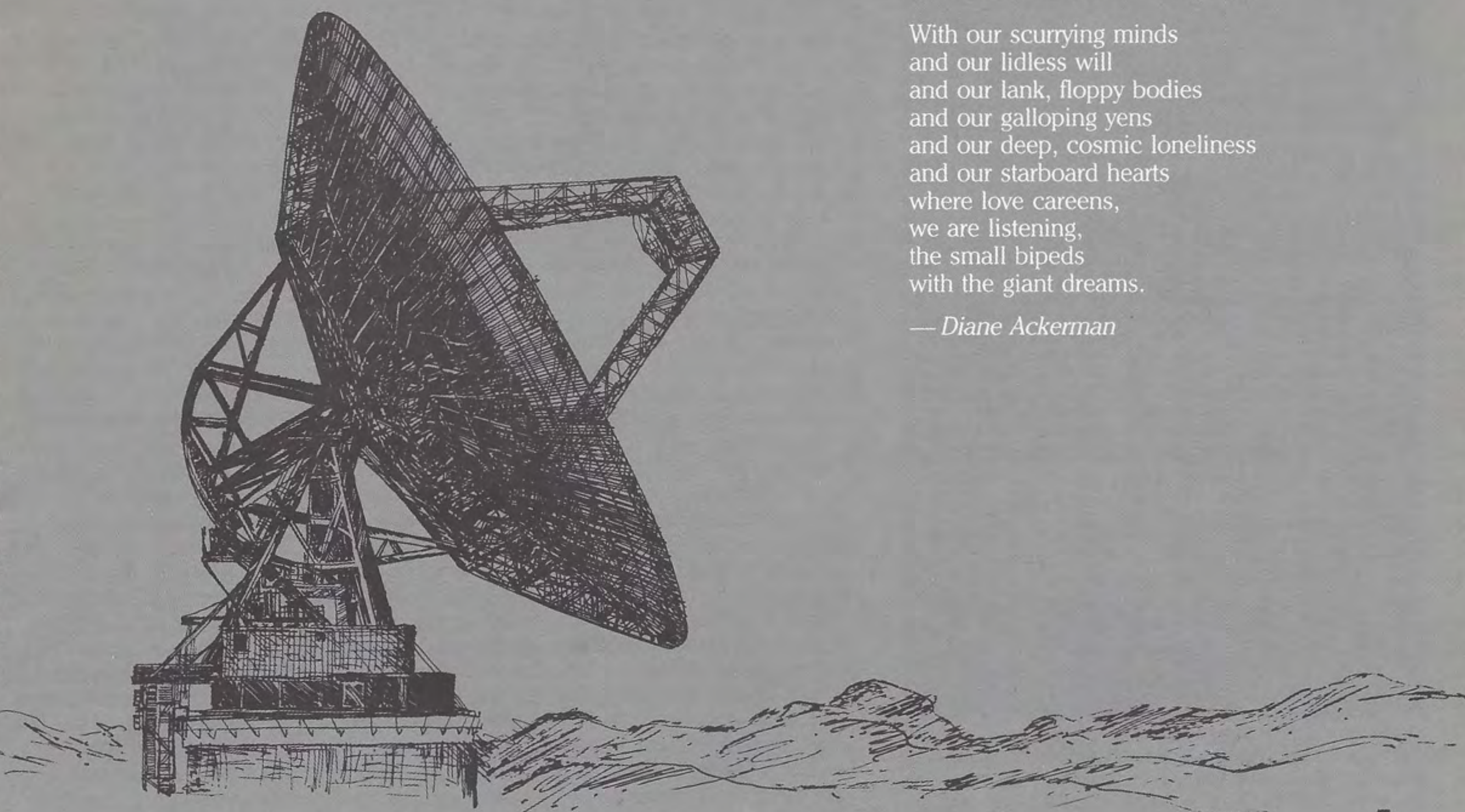
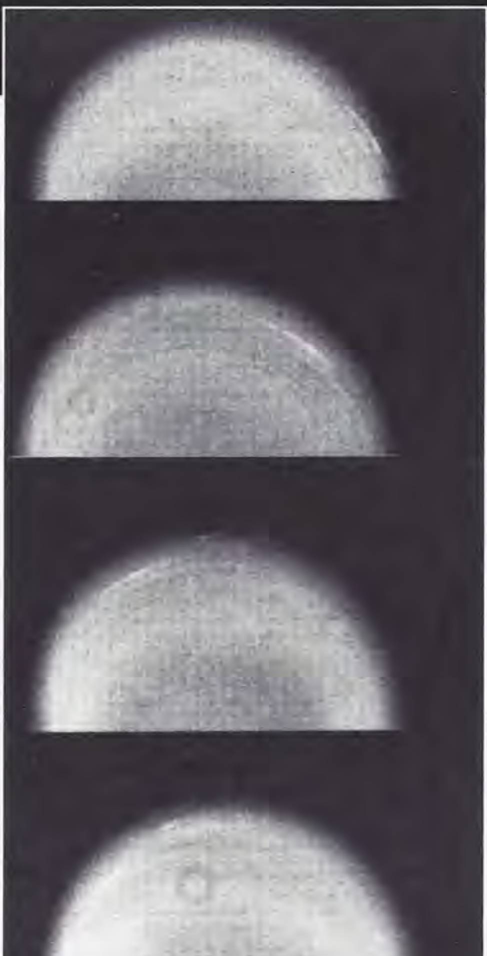


ILLUSTRATION: BARBARA SMITH

ENCOUNTER!

Voyager 2 Explores the Uranian System

by Clark R. Chapman



As Voyager 2 approached Uranus, atmospheric features remained hard to detect, but finally, some features were found. In these time-lapse images, two small, streak-like clouds move counterclockwise around the planet. The larger cloud moved around the planet in about 16.2 hours; the smaller cloud (seen faintly in the three lower images) rotated in 16.9 hours. The rotation period of Uranus' interior was measured at about 17 hours. Commented Brad Smith, "The atmosphere is rotating differentially with respect to the deep interior of the planet — in other words, there are winds there."

On Wednesday, January 22, I drove west from my Tucson home toward Pasadena's Jet Propulsion Laboratory, to witness the first flyby of one of the last unvisited worlds in our solar system. Near Marana, Arizona, I noticed traffic veering to the shoulder of Interstate 10, and people getting out to gaze skyward. I stopped, too, and saw the space shuttle *Columbia* gliding piggyback toward a refueling stop, enroute to Cape Canaveral from its recent desert landing. It was my first view ever of a space shuttle, and it seemed an exhilarating beginning to a week celebrating *Voyager's* fifth planetary encounter. Hardly could I have imagined that *Voyager* week would be cut short by the tragedy of a nation having its last look at the noble spaceship *Challenger*.

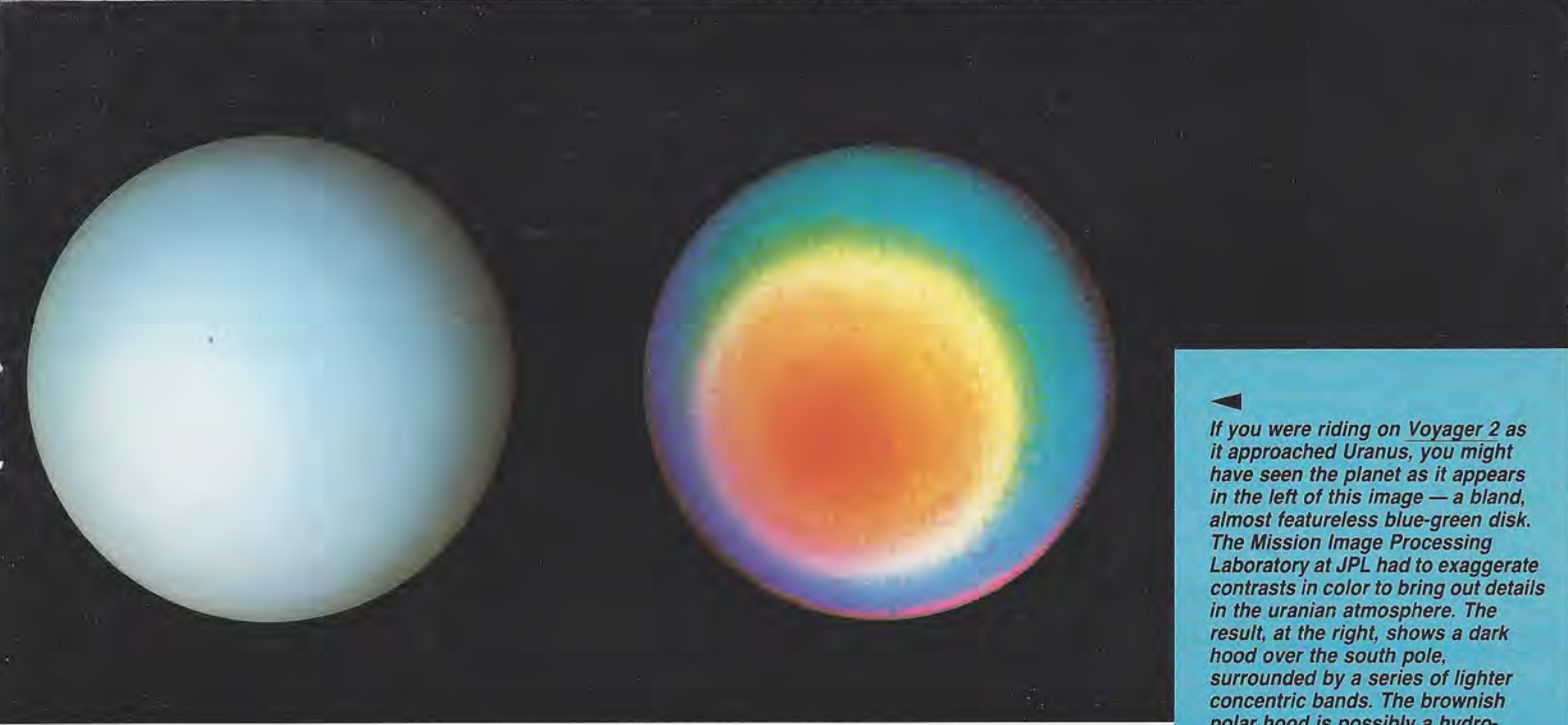
The *Voyager* spacecraft was never planned to survive an eight-plus year trip to Uranus. Dreams of a "Grand Tour" of the outer solar system had faded in the post-*Apollo* blues. A fallback *Mariner* Jupiter-Uranus mission was also squeezed from the budget as the space agency pursued shuttle development and purposefully phased out the well-tested *Titan-Centaur* launch system. *Voyager*, designed only to probe Jupiter and Saturn, suffered serious malfunction soon after launch and could hardly have been expected to last past Saturn.

Brilliant engineering feats back on Earth, however, more than made up for *Voyager's* weaknesses; its inherent soundness was destined to carry it past Uranus early this year. Not only did engineers overcome the almost inevitable degradation of performance expected at Uranus, but there is optimism that *Voyager* will be alive and well when it passes Neptune in 1989. That the pared-back *Voyager* could be carrying out the forsaken Grand Tour is a little-engine-that-could story testifying to the versatility of robotic space probes guided by dedicated teams of human beings two billion miles back on Earth.

A spacecraft encounter is more than a mark on a mission timeline. It is the culmination of many months of incremental approach to a distant world . . . an accelerating magnification in the final weeks . . . and then a torrent of incredible new data in just a few days' time. An encounter is also a human event, a celebration, as space junkies from around the world converge on Pasadena to experience the joyous rush of never-before-seen images tickling their brains.

The festivities were many and varied. Bruce Murray, a founder and leader of the nation's golden age of planetary exploration, was feted at a lavish banquet and fundraiser for The Planetary Society in Beverly Hills. At the California Institute of Technology, teachers and planetarians converged on the grand Beckman Auditorium for a *Voyager* Educators' Conference. VIP's, ranging from movie stars and politicians to Nobel prizewinners, toured JPL the day after encounter. So great was the interest in Uranus, that JPL bureaucracy had to turn away journalists and science writers by the dozens, simply because there was no more room in the seven packed meeting halls at the Lab.

On encounter night under a full Moon, an overflow crowd queued up in front of Caltech's Beckman and Ramo Auditoriums to attend a Planetary Society symposium featuring *Voyager* chief scientist Edward Stone, Society President Carl Sagan, Cambridge historian Michael Hoskin, Society Vice President Bruce Murray and Princeton physicist Freeman Dyson. Dyson startled everyone with his hummingbird version of future Uranus exploration. "Think small,



If you were riding on Voyager 2 as it approached Uranus, you might have seen the planet as it appears in the left of this image — a bland, almost featureless blue-green disk. The Mission Image Processing Laboratory at JPL had to exaggerate contrasts in color to bring out details in the uranian atmosphere. The result, at the right, shows a dark hood over the south pole, surrounded by a series of lighter concentric bands. The brownish polar hood is possibly a hydrocarbon smog produced by sunlight acting on the atmosphere, much like the more famous smogs of Los Angeles. (The doughnut-shaped objects are dust in the camera.)

think quick," Dyson told the audience, "and we can go and graze on the rings of Uranus." Dyson thinks genetic engineering advances promise that future generations of spacecraft will be "grown rather than built."

As Dyson spoke of future uranian adventures, a fantastic but true story was already taking shape in the minds of *Voyager* scientists, based on the steady stream of radio data from Uranus. And enigmatic Miranda's miraculous face was already magnetically encoded within *Voyager's* tape recorder for next-day broadcast to Earth, even as the spacecraft hurtled hundreds of thousands of kilometers beyond, toward Neptune and the stars.

* * *

In the autumn of 1985, Earth-based astronomers were vying to beat *Voyager* to a few key secrets of the tipped-over planet. International Ultraviolet Explorer satellite data hinted at a uranian aurora. The published satellite masses were questioned. And JPL's Glenn Orton ventured out on a limb to suggest that some noisy infrared data meant nearly half the planet might be composed of helium, much more than the 10 percent values for Jupiter, Saturn and the Sun. Meanwhile *Voyager's* instruments were beginning to magnify the planet's disarmingly blank disk and show hints of narrow encircling rings. At radio wavelengths the planet remained unexpectedly mute.

In a December visit to JPL, my attention was attracted to a display terminal showing a bull's-eye disk. Evidently a data analyst, using computer processing magic, had transformed the featureless images into a fuzzy, flickering globe with a dark, just-off-center polar hood. The data-bits from dozens of images had been piled on top of each other and stretched to their limit so that the faintest differences in grey shades now appeared dark grey and white. The bulls-eye image gave the first indication that Uranus' clouds circulated around the planet in concentric zones. The planet's bizzare axial tilt — long known from the skewed satellite orbits — had been thought likely to affect the atmospheric circulation. To first appearances, though, distant Uranus looked as Jupiter might from far above its pole.

A week and a half before encounter, I visited the *Voyager* Imaging Team's cramped quarters on the third floor of JPL's Building 264. Already, separate rooms were set aside for interactive computer work in the three major science topics: rings, atmosphere and satellites. Each tiny room was crammed with chairs, a table or two, and a couple of display monitors and computer terminals. What would be happening here, I wondered, by the following weekend? Now that half a dozen new moons had been discovered, would there be multitudes more? Would Uranus remain atmospherically and magnetically blank? What were the bulk densities of Uranus' larger moons? There was a sense of excitement in the air: At this stage in *Voyager's* previous planetary encounters, nearly all its amazing discoveries were yet to come.

In a hallway, I talked with Reta Beebe, a *Voyager* atmospheric specialist who has been charting Jupiter's whirling cloud motions for years. She spoke about a high-latitude spot that had finally been detected on Uranus: It seemed to circulate around the pole about every 14 hours. But her excitement was tempered by the continuing bland appearance of this bloated, blue ping-pong ball. Without the wind-marker spots Beebe wanted to measure, this tipped-over planet's meteorology would remain a mystery. Reta

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On its way to Neptune, Voyager 2 looked back at Uranus and imaged the sunlit crescent of the planet. Methane in Uranus' atmosphere absorbs red light, giving the planet its blue-green color.

ALL IMAGES: JPL/NASA

▼*All nine rings known before encounter are recorded in this image taken the day before closest approach from about 1.12 million kilometers (690,000 miles). From top to bottom, they are epsilon, delta, gamma, eta, beta, alpha, 4, 5 and 6. A newly discovered ring, called 1986U1R after International Astronomical Union conventions, is barely visible here about halfway between the epsilon and delta rings. Like Jupiter's and Saturn's rings before them, Uranus' rings held surprises for the Voyager scientists, particularly in the size of their component particles. "I don't know anyone who suggested that we would find rings that were mainly meter-sized and larger particles, when at Saturn all the rings were mainly centimeter- and smaller sized," said Edward Stone, Voyager Project Scientist. Their narrow structure also distinguishes the uranian rings from Saturn's. Shepherding satellites — Voyager discovered several — probably account for this structure.*

(continued from page 9)
Beebe's transient spot had already faded from view and she was getting pessimistic about having much to measure during the weeks and months following encounter.

A time-lapse movie sequence released to the press the day before encounter was more encouraging. While the planet's cloud deck was seemingly immersed in a thick haze layer, some clouds poked high enough into the uranian stratosphere for Reta Beebe to measure, before they were shredded into streamers by the super-rotating high-altitude winds. Several spots revealed a nearly one-hour difference in rotation period, due to wind shear, over less than 15 degrees of latitude. Finally, three days after encounter, a preliminary estimate for Uranus' bulk-body rotation period was reported — from cyclical radio emission — that was slower than most of the atmosphere. Combined with unexpected temperature measurements (it seems that Uranus' dark pole is warmer than the sunlit pole!), this result confused the atmospheric team. As *Voyager* Week came to a close, it appeared that Uranus' meteorology was more complex than expected.

* * *

In my last visit to the Imaging Team quarters before encounter week, I walked through the door labelled "Satellites" and found Bob Brown happily occupying a chair in front of the interactive terminal. His doctoral thesis at the University of Hawaii had provided most of our pre-*Voyager* knowledge about the uranian moons, based on painstaking telescopic observations of the starlike points of light. He was already feeling relieved that his thesis work was vindicated, to within the reported errors of his inexact techniques. Although the pictures were still very blurry, Bob and others were beginning to learn the personalities of the five largest satellites.

Twenty-four hours before closest approach, JPL's Von Karman Auditorium was filled with reporters. Project Scientist Ed Stone strode to the podium at precisely 10 a.m. and announced a discovery: Uranus has a magnetic field! The media people seemed underwhelmed. After all, the evidence is indirect, the discovery hardly unexpected, and it is difficult for people to relate to charged particles, radio bursts and magnetopauses. Questions dealt mainly with confusions about the terminology of Uranus' peculiar axial tilt. How can the bull's-eye pole we've been looking at be called the "south pole" when the "right-hand rule" (familiar to any freshman physics student) defines this pole as "north"?

Imaging Team Leader Brad Smith, who spoke after Stone, seemed low-key. He is the usual star of the press conferences, due to his personal showmanship and the easy-to-grasp pictures it is his duty to report. He showed a few fuzzy moon shots and one false-color view of the familiar uranian bull's-eye, dominated by a bright crescent of pink, which Smith then dismissed as an artifact.

The "Satellites" room was the scene of frenzied activity when I visited it the day before encounter. Live pictures were being computer-processed in real time as geologists crowded around the screen to scrutinize fuzzy hints of geology never before known to humankind. The pictures would be much sharper in just twenty hours, but already it was clear that the moons did not all have the Callisto-like, heavily cratered surfaces most scientists had intuitively expected. (Jupiter's outer Galilean moon, Callisto, is interesting enough, but it had been upstaged by the exciting tectonics of Ganymede, by the active sulfurous volcanism of Io, and even by the lineated flatlands of Europa.) Dark Umbriel — befitting its name — might be another Callisto-like world, but personality differences hinted at the existence of more exciting, complex internal geological forces operating within these frigid, small bodies.

With encounter day nearly upon us, a veteran science reporter privately opined that Uranus might be a dud. Indeed, the hints of excitement I had detected in Building 264 on Thursday were still absent from the press briefing that began just two minutes after Uranus closest approach. Brad Smith balked at interpreting the still fuzzy satellite pictures, and most discussion centered on a preview of things still to come.

I had learned over breakfast, from a *Voyager* scientist also staying in my inn, that Glenn Orton's vision of a helium-rich Uranus had already been ruled out. But scientists hesitated in "going public" with speculation about data that would become definitive in just another day. Journalists

▼*As Voyager 2 swung into the shadow of Uranus and turned to look back at the rings, it took this 96-second exposure of the system. An Image Motion Compensation maneuver smeared the background stars while holding the camera steadily on the rings, and revealing lanes of fine, faint dust among the narrow rings. The Voyager radio science team determined that the uranian rings are made up mainly of boulder-sized particles, but this image demonstrated that fine dust is also present.*

▲ *Dark Umbriel, orbiting between Ariel and Titania, displays probably the oldest surface in the uranian system. Heavily cratered by meteorite or comet bombardment, Umbriel seems to have experienced little of the geologic activity that might have reworked its surface. The strangest feature on this medium-sized (1,200 kilometers, 750 miles, in diameter) moon is a bright ring (top) about 140 kilometers (90 miles) across, which may be associated with an impact crater.*

ABOVE: Valleys and fault scarps crisscross the pitted face of Ariel, the moon orbiting Uranus between Miranda and Umbriel. Voyager scientists speculate that expansion and stretching of Ariel's crust caused this faulting. Some features appear to have been partly filled with younger deposits, in which sinuous scarps and valleys have also formed. "Some sort of fluid flow," said Larry Soderblom, Deputy Imaging Team Leader, may have carved these features in Ariel's surface. ABOVE RIGHT: The largest satellite in the uranian system (almost 1,600 kilometers, 1,000 miles, in diameter), Titania is marked by fault valleys and impact craters. In this image, the sunward-facing walls of some valleys appear very bright. The lighting angle contributes to this effect, but this brightness also suggests that something light, possibly frost, lies in these valleys.

▲ *Several large impact craters, surrounded by bright rays reminiscent of those on Jupiter's moon, Callisto, are the most prominent features on Oberon, Uranus' outermost moon. Near the center of the disk lies a large, peaked crater whose floor is partly covered by dark material. Larry Soderblom suggests that this could be icy, carbon-rich material erupted onto the surface sometime after the crater formed.*

ALL IMAGES: JPL/NASA

were reminded that the most important discoveries might not be available for two or three days, partly because of the deliberate pace of radioing back the recorded data from a faraway spacecraft. But it was beginning to seem that this would be an atypically ho-hum encounter for *Voyager.*

And then, on Saturday, there was Miranda! And Ariel! And Titania did pretty well, too. I visited the Imaging Team area as the first close-ups came in. There, computer processed, magnified images were displayed to the amazement of the scientists, but the raw images broadcast over the NASA satellite feed were spectacular enough for watchers around the country. "Who would have thought that Miranda would turn out to be so damn interesting?" Bob Brown posed the question to Carl Sagan, who uncharacteristically had no immediate response. This little world is the size of some asteroids, those long-neglected bodies not yet visited by a spacecraft. Returning from his press briefing, Deputy Imaging Team Leader Larry Soderblom, a geologist, took a look at a processed Miranda image and exclaimed, "Holy Moly! Good God! Is this for real?" At a Sunday press conference, Soderblom would show the Miranda close-up frames and explain that this small satellite, which G.P. Kuiper discovered just a few decades ago, apparently contains provinces reminiscent of Mercury, Mars, Jupiter's Ganymede, and Saturn's Enceladus and Mimas — as diverse a group of planetary surfaces as have been studied by planetary spacecraft — all rolled into one!

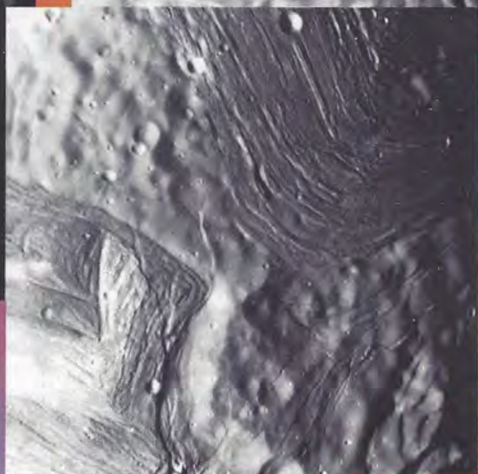
The satellites are remarkably different from each other. Only Umbriel is unremarkable, strangely spared by the powerful forces that affected other uranian moons. As for the rest of them, Soderblom was temporarily at a loss to explain "the ferocity in the way these bodies have been tectonically shuffled, in a catastrophic fashion." The *Voyager* satellite scientists began to count the craters on the various satellites, and found a mixture of different populations. Titania's torn surface seemed to have had impacts from debris revolving about Uranus, very different from the cometary craters saturating the surface of the adjacent Umbriel. And what could be made of the flow-like (perhaps even river-valley-like) features on Ariel, a bitterly cold world made of ices? Understanding the geology of bodies so cold that even ammonia ice is like solid rock must await months and years of detailed measurements of the pictures, combined with patient laboratory work.

* * *

It is a tribute to the power of Earth-based astronomy that right up to encounter day, there was little if anything that *Voyager* could add to our knowledge of the unique system of narrow uranian rings. This didn't dampen the interests of ring scientists, huddled around their display terminal in Building 264. French astronomer Andre Brahic looked at the screen and then moved his closed fingers away from his face in a magnificent, graceful gesture. "Rings are the perfume of astronomy," he proclaimed, meaning that there is great beauty in such a small amount of finely disseminated material.

Voyager had a roller-coaster ride prepared for the ring scientists. Only a single new ring was discovered before encounter, but there were high hopes of seeing more rings (and the known rings more clearly) by looking back at them, in the direction of the Sun. But the first of these "high phase angle" pictures barely showed the rings at all: Evidently, unlike the rings of Saturn and Jupiter, uranian rings are lacking in micron-sized dust. Analysis of *Voyager's* radio signals scattered through the rings as the spacecraft passed behind the planet revealed not only the absence of dust, but the absence of pebbles and rocks, as well. Evidently these concentric, spider-web-like rings are composed almost exclusively of huge boulders many meters in size! Saving its best for last, *Voyager's* highest phase angle picture of all came in Sunday evening. A gleaming halo of dozens of Saturn-like rings could be seen poised next to the crescent of Uranus! Evidently there is a bit

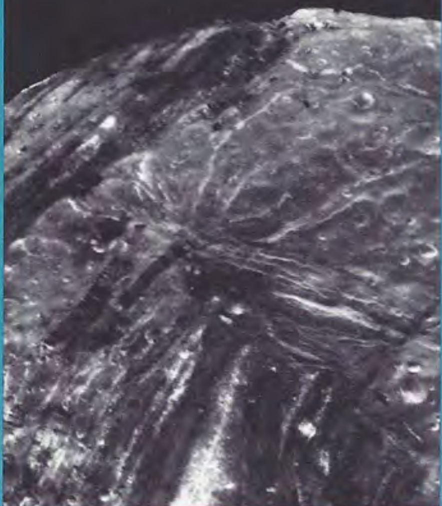
MIRANDA — Star of the Show



▲ *Old cratered terrain is cut by younger, striated terrain and huge scarps, marking the complex surface of Miranda. On this small moon, some scarps reach five kilometers (about three miles) in height — higher than the walls of the Grand Canyon on Earth. The diversity and strangeness of the geological features on Miranda both surprised and excited Voyager scientists. "We had the same conservative terrestrial view at Jupiter, at Saturn, at Uranus," said Larry Soderblom, "I wonder if we'll learn by the time we get to Neptune."*

◄ *Voyager 2 imaged the "chevron" region of Miranda when it was only 42,000 kilometers (26,000 miles) from the small moon. The bright chevron (lower left) is bounded by linear fault systems and separated from another fault system by older and smoother terrain.*

▲ *TOP LEFT: "Miranda is a bizarre hybrid . . . of valleys and layered deposits on Mars, combined with the grooved terrains of Ganymede, matched with (what some have called) compression faults on Mercury. So if you can imagine taking all the bizarre geologic forms in the solar system and putting them on one object, you've got it in front of you." Thus did Larry Soderblom introduce Miranda, the innermost and smallest of the main moons of Uranus. Although it is only 500 kilometers (300 miles) in diameter, Miranda displays some of the strangest geology yet seen in the solar system. Embedded in cracked crust and surrounded by gently cratered, rolling hills, a chevron-shaped feature dominates the center of this mosaic. The two concentric ringed features (top right and bottom left) resemble racetracks and were whimsically dubbed the "Circae Maximae" by the Voyager Imaging Team.*



◄ *Stepped terraces jut up into space along the limb of Miranda, marking the edge of one of the concentric "racetrack" features. Images such as this led Larry Soderblom to imagine what it might be like to hike across this moon's surface: "It would be like walking down the Grand Canyon and, instead of having the canyon at the end of the next bend, you'd just have stars . . . ."*

of "perfume" between the boulder-rings, after all.

Excitement was rampant at JPL through the weekend and as the new week began. Perhaps it should have been expected that the surprises would be even greater from a planet so distant, and difficult to observe, from Earth. But we were all fooled by the blandness of the early data. Then the surprises came thick and fast. Imagine the immense uranian magnetic field, sweeping obliquely through space due to the totally unexpected 55 degree offset between the magnetic and rotational axes. It's as though the Earth's north magnetic pole were located in Dallas! The satellites were stunning in their diversity. Even the atmospheric people had more puzzles to work out than they had bargained for. And the spacecraft had worked flawlessly, including the spectacular aiming and clarity of the Miranda mosaic. Even the rain in Spain — which has been known to knock out receipt of data at the Madrid station — kept away.

As reporters readied themselves for the Tuesday briefing and *Voyager* receded beyond 5 million kilometers from Uranus, there was nothing but awestruck wonder at the technical perfection of this NASA mission. Somewhere out there, Neptune, even more distant and obscure than Uranus, was beckoning to *Voyager* in the faint illumination of a distant Sun.

Then, way back in the inner solar system, there was a mighty roar from the third planet out as yet another team of seven adventurers accelerated starwards to share the adventure of space with schoolchildren around the world, and to study the famous comet streaking behind the Sun. In one fiery second the enterprise of American manned spaceflight turned topsy-turvy. And *Galileo*, the next outer-planet robotic spacecraft already in Florida waiting to be launched by a remaining Shuttle, awaits its fate.

Planetary scientist Clark Chapman will resume his regular "News & Reviews" column with our next issue. We will continue our coverage of Uranus with a special issue later this year.

World Watch

by Louis D. Friedman

NEW YORK — This month we are witnessing four close fly bys of Halley's Comet — by the Soviet *Vegas 1* and *2*, the European *Giotto* and the Japanese *Suisei* (*Planet-A*). Before the *Challenger* tragedy the United States was planning to launch three space science missions this year: *Galileo* to investigate the Jupiter system, the European *Ulysses* to study the Sun and the Hubble Space Telescope to scan deep space. These three missions were initiated and approved back in the 1970's *before* the Halley's Comet missions were even conceived. They were delayed by the US decision to abandon its expendable launch vehicles while it developed the space shuttle system. The original schedule called for all three missions to be launched by 1983.

After the shuttle disaster, serious questions are now being raised about US space policy. This would have happened anyway, with the publication of the National Commission on Space report (available soon in bookstores, published by Bantam Books), the lowering of NASA's budget and consequent delay of a space station, and the space science successes of the Soviet Union, the European Space Agency and Japan. On January 7, noting the juxtaposition of *Voyager 2's* encounter with Uranus and the oft-delayed shuttle flight of Congressman Bill Nelson, *The New York Times* commented:

"As for NASA, it seems to have lost its sense of direction. There would be no need to buy influence with senators and representatives if it had a space program that aroused genuine enthusiasm. Congress would willingly fund a plan of exploration that stretched imagination and technology . . . .

"Unmanned missions should be a principal effort, not an orphan activity. Still, there may be a role for humans as well. Many supporters of a vigorous space program believe a human presence is desirable, and not just to engender public enthusiasm. One suggestion is to send people to Mars, perhaps in cooperation with the Soviet Union."

Following the *Challenger* disaster, the *Times* published two more editorials emphasizing the need to reconsider the goals of US space activity — and again the paper suggested American and Soviet cooperation in the exploration of Mars.

These editorial comments were remarkable because, although they could be interpreted as against human space flight, they cited the advantages of adopting the goal of human exploration of Mars — a goal The Planetary Society has strongly advocated. The need for such a goal to pace our space activities transcends the issue of the "manned vs. unmanned" debate; it is the real issue that needs attention from our national decision makers.

Planetary Society officers Carl Sagan and Bruce Murray have actively advocated the goal of putting humans on Mars as an international effort by all spacefaring nations. Last month both published articles on this subject: Dr. Murray's appeared in the prestigious policy journal, *Issues*, published by the National Academy of Sciences; Dr. Sagan's article ran in the largest-circulation magazine in the United States, *Parade*, which featured the Mars story on its cover.

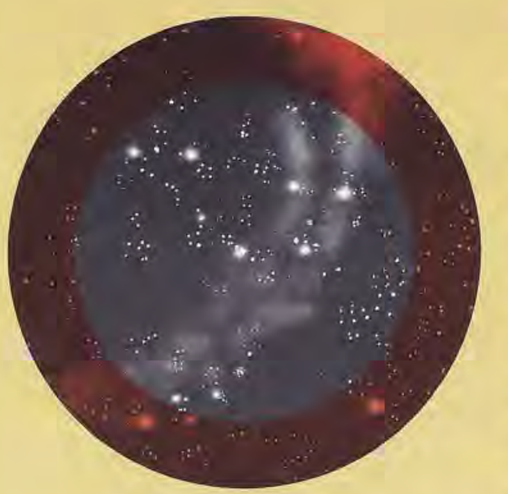
NEW YORK — The United Nations Association of the United States (UNA-USA), a nonprofit organization with chapters throughout the US, has launched a study of international cooperation in the exploration and development of space. From January through May, 1986, community panels organized by UNA chapters around the US will examine questions facing humanity on the space frontier: What are the prospects for international cooperation? How and by whom should space resources be used? Who is to decide? The UNA will gather the recommendations of these panels into a single consensus report to be released in October, 1986.

Because of The Planetary Society's leadership in promoting international cooperation in space exploration, the UNA-USA has invited our members to participate in the study. We have agreed to cosponsor the study to further the cause of international cooperation in space.

Members who wish to contribute to the study should read the briefing book, *Developing the Final Frontier: International Cooperation in the Peaceful Uses of Outer Space.* This book provides background information on human activity in space, international law governing these activities and the current status of national and private space programs. Four policy areas are emphasized: cooperation among industrialized countries, particularly in the proposed space station; US-USSR cooperation; and the possible impact of military programs on civilian activities.

For information on how to participate in the study, contact Ann Florini, Studies Director, UNA-USA, 300 East 42nd Street, New York, NY 10017. Copies of the briefing book are available for $5.00 from the UNA-USA Publications Office.

Louis Friedman is Executive Director of The Planetary Society.



META's Megasearch Begins

Since its ceremonious switch-on last fall at Harvard University's Oak Ridge Observatory, the Megachannel Extraterrestrial Assay (META) has been vigilantly scanning the sky in search of a radio signal from an extraterrestrial civilization. Except for a microprocessor failure which brought operations to a halt for three days, the eight-million channel receiver has been running nonstop.

META is now searching the "magic" frequency of 1420 megahertz. Many researchers regard this frequency of neutral hydrogen to be a "natural" for interstellar communication because hydrogen is the most abundant element in the universe, and the universe is relatively quiet at this frequency. At the time we went to press, the telescope had covered the sky from −30 to +5 degrees. META is able to store much of the information it receives — an advantage over its predecessor, Project Sentinel. This enables scientists to study the data for signals in retrospect.

But, according to META's originator, Harvard professor Paul Horowitz, the search for extraterrestrial intelligence is not fraught with excitement. So far, all the big signals received have turned out to be radio interference. In the meantime, Horowitz is busy refining META's software so it can search for supernovas in the galaxy — a function, he believes, that can easily be carried out alongside META's regular duties. A good thing is about to become better!

SOCIETY NOTES

TELEVISION SHOW A SUCCESS

"Comet Halley," The Planetary Society's television special, aired on the Public Broadcasting System during the week of November 26. An estimated 8 million viewers across the United States watched the show, and PBS is considering rerunning it later this year. In Houston, New York and the Los Angeles area, Society members were treated to previews of the show a few days before its air date. The Houston preview, held in conjuction with the Houston Museum of Natural Science, attracted a full house of 800. At the New York Academy of Sciences, three sittings were needed to accommodate all those who wished to see the show and hear Dr. Tobias Owen of the State University of New York at Stony Brook. KCET, the Los Angeles PBS affiliate station, hosted a press preview of "Comet Halley" where show producer John Wilhelm, Society Executive Director Louis Friedman, and University of Washington scientist Donald Brownlee answered questions from the audience. After a showing at the Jet Propulsion Laboratory in Pasadena, viewers cheered the closing credit for "Members of The Planetary Society."

FROM COMET HALLEY TO MARS

November 19 was an especially busy night for The Planetary Society; we held three events in three different cities. While "Comet Halley" was being previewed in Los Angeles and New York, the Society and Space Age Publishing held a symposium on Mars in San Francisco. The symposium was scheduled to coincide with the San Francisco meeting of the National Commission on Space. At the commission meeting, Society President Carl Sagan testified on behalf of the Society.

Dr. Sagan also chaired the Mars symposium, where the principal address was by Dr. Michael Carr of the United States Geological Survey. Commission members Drs. Kathryn Sullivan, George Field and Laurel Wilkening participated in a panel discussion.

PLANETARY SOCIETY SCHOLARSHIPS

The New Millennium Committee of The Planetary Society has announced its second annual scholarship contest. In 1986, a total of $5,000 will be awarded to college-bound students. To be eligible for a scholarship, a student must be a member of the Society or the nominee of a member, and in the final year of secondary school.

Awards will be made on the basis of SAT or ACT scores, scholastic achievement, letters of recommendation, accomplishments demonstrating leadership and creativity, a written essay, and plans for a career in space or planetary science.

The deadline for completed applications is May 15, 1986. A panel of three distinguished scientists will determine the scholarship winners by June 6, 1986. To receive an application form, write to The Planetary Society, Dept. ED, 65 North Catalina Avenue, Pasadena, CA 91106, or call 818/793-5100.

The New Millennium Committee was formed to support education programs and research projects extending into the next millennium. For information about joining the committee, or to donate to the scholarship fund, contact Lyn McAfee at the above number.

VENUS MAPPER NAMED

At last we have a name for the Venus Radar Mapper! NASA has selected *Magellan* as the name for the mission, scheduled for launch in 1988. The name was chosen from more than 500 entries from Society members in the "Name a Spacecraft" contest announced in the November/December 1983 *Planetary Report.*

The naming of a spacecraft or space project involves many considerations and sensitivities. Names for the Venus mission were solicited from within NASA, primarily from the project itself, as well as from Planetary Society members. NASA officials and the project people liked *Magellan* and selected it for the spacecraft. But the wheels of bureaucracy grind slowly. It took over two years to propose, consider and review a naming policy for all of NASA before *Magellan* could be officially chosen.

And who won the contest? Fourteen Society members submitted the name *Magellan.* The entry with the earliest postmark came from Nicholas Cognito of Braddock, Pennsylvania. Mr. Cognito won an all-expense-paid trip to JPL for the *Voyager* encounter with Uranus last January. (He chose *Voyager's* encounter with Uranus over *Magellan's* encounter with Venus because he didn't want to wait until 1988.)

The runners-up, who will each receive a copy of *Comet* by Carl Sagan and Ann Druyan, are (in order of postmark): David Vacco, Arizona; Fred Mendenhall, Indiana; J.F. Gallo, Maryland; Robert Schiffer, New Mexico; James Likkle, Ohio; T.M. Hennig, Texas; James A. Peterson, Iowa; David Spann, Florida; Steve Bonner, Maryland; Gregory Zentz, Florida; Leonard A. Russ, Virginia; Nikolai Daskalov, Virginia; Michael Sarno, Connecticut; Michael Jacks, Ohio; Mike Evans, California.

Using radar imaging techniques, *Magellan* will map over 90 percent of Venus' cloud-shrouded surface as it orbits the planet. The Soviet Union used similar techniques on the *Venera 15* and *16* missions, which mapped Venus' northern hemisphere. *Magellan* will extend the mapping to the southern hemisphere and provide greater detail over the whole planet.

SPACE UPDATE: 1986

The Planetary Society will cosponsor a conference on space and geoscience exploration on May 15-17, 1986 in Burnaby, British Columbia. Many interesting topics on planetary science and space exploration will be discussed at "Space Update: 1986," which is being organized by the British Columbia Science Teachers' Association. Planetary Society members are invited to attend a community space update on May 15, and update sessions and a banquet on May 16. For more information, contact Anand Atal at (604) 438-3351 or Susan Slater at (604) 522-0651.

The Solar System in Pictures and Books

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For a written description of each item, see back issues of THE PLANETARY REPORT or write to The Planetary Society.

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VOYAGER OVER MIRANDA — *Artist Michael Carroll here imagines Voyager 2 flying by Miranda, the uranian moon that "stole the show" during the spacecraft's recent encounter with the planet. This strange little moon displays some of the most bizarre geological forms yet seen in the solar system.*

Michael Carroll is a freelance artist living and working in San Diego, California.

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