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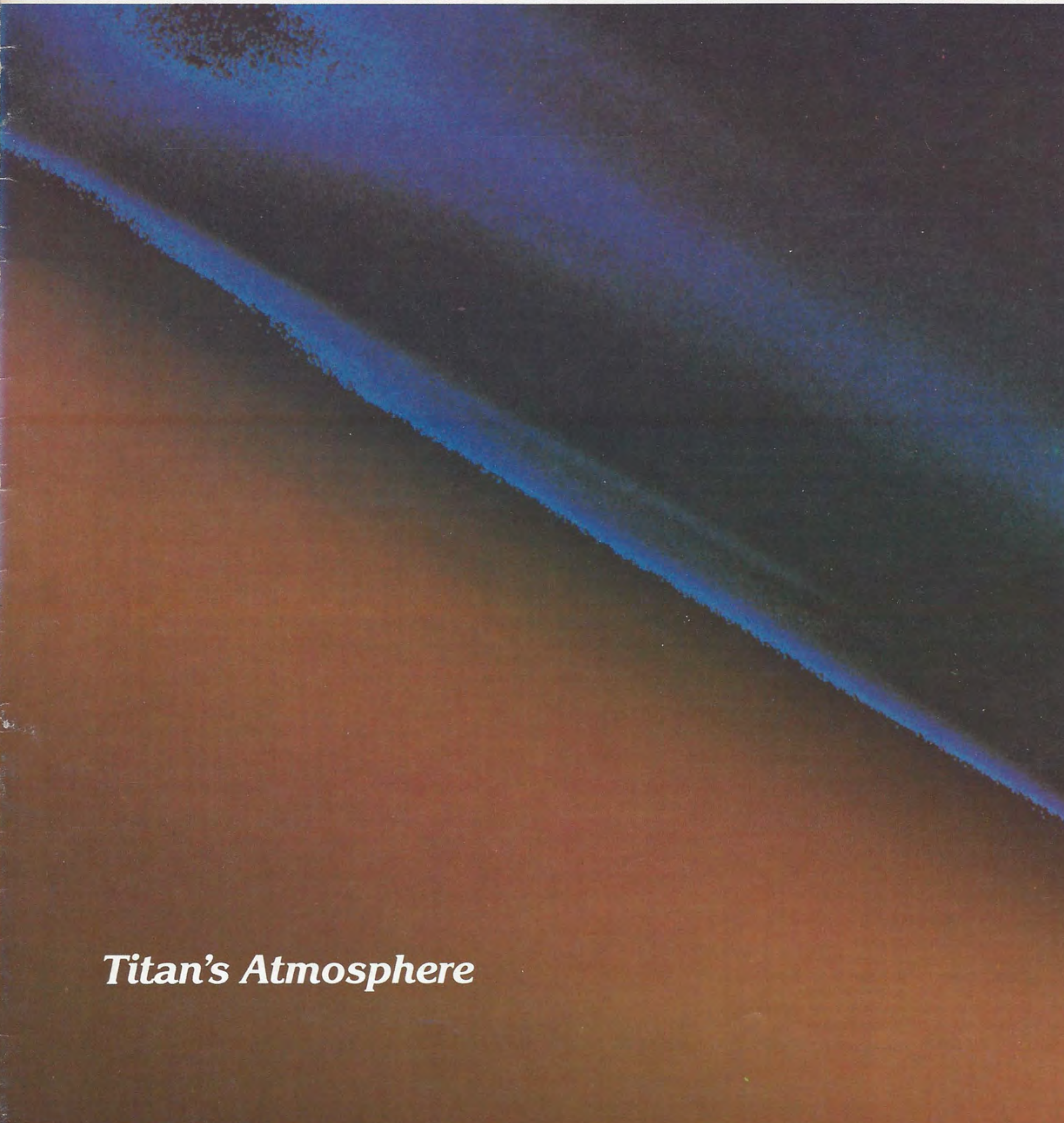

Titan's Atmosphere

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Cover photograph: The haze layers surrounding Saturn's largest moon, Titan, become brilliant blue in this false color image of the satellite's atmosphere, while the thick aerosols enveloping Titan appear orange. Several individual haze layers are visible.

PHOTO: JPL/NASA

Setting Sail for the Planets

by Carl Sagan

The *Voyager* missions of exploration and discovery are the latest in a long series that have characterized and distinguished human history. In the fifteenth and sixteenth centuries you could travel from Spain to the Azores in a few days, the same time it takes us now to cross the channel from the Earth to the Moon. It took then a few months to traverse the Atlantic Ocean and reach what was called the New World, the Americas. Today it takes a few months to cross the ocean of the inner solar system and make planet-fall on Mars or Venus, which are truly and literally new worlds awaiting us. In the seventeenth and eighteenth centuries you could travel from Holland to China in a year or two, the time it has taken *Voyager* to travel from Earth to Jupiter. The annual costs were, relatively, more then than now, but in both cases less than one percent of the appropriate Gross National Product. The *Voyager* mission cost a penny a world examined for every inhabitant of the planet Earth. Our present spaceships, with their robot crews, are the harbingers, the vanguards of future human expeditions to the planets. We have traveled this way before.

The fifteenth through seventeenth centuries represent a major turning point in our history. It then became clear that we could venture to all parts of our planet. Plucky sailing vessels from half a dozen European nations dispersed to every ocean. There were many motivations for these journeys: ambition, greed, national pride, religious fanaticism, prison pardons, scientific curiosity, the thirst for adventure and the unavailability of suitable employment in Estremadura. These voyages worked much evil as well as much good. But the net result has been to bind the Earth together, to decrease provincialism, to unify the human species and to advance powerfully our knowledge of our planet and ourselves.

Emblematic of the epoch of sailing-ship exploration and discovery is the revolutionary Dutch Republic of the seventeenth century. Having recently declared its independence from the powerful Spanish Empire, it embraced more fully than any other nation of its time the European Enlightenment. It was a rational, orderly, creative society. But because Spanish ports and vessels were closed to Dutch shipping, the economic survival of the tiny republic depended on its ability to construct, man and deploy a great fleet of commercial sailing vessels.

The Dutch East India Company, a joint governmental and private enterprise, sent ships to the far corners of the world to acquire rare commodities and resell them at a profit in Europe. Such voyages were the life blood of the Republic. Navigational charts and maps were classified as state secrets. Ships often embarked with sealed orders. Suddenly the Dutch were present all over the planet. The Barents Sea in the Arctic Ocean and Tasmania in Australia are named after Dutch sea captains. These expeditions were not merely commercial exploitations, although there was plenty of that. There were powerful elements of scientific adventure and the zest for discovery of new lands, new plants and animals, new people; the pursuit of knowledge for its own sake.

Never before or since has Holland been the world power it was then. A small country, forced to live by its wits, its foreign policy contained a strong pacifist element. Because of its tolerance for unorthodox opinions, it was a haven for intellectuals who were refugees from censorship and thought control elsewhere in Europe—much as the United States benefited enormously in the 1930's by the exodus of intellectuals from Nazi-dominated Europe. So seventeenth-century Holland was the home of the great Jewish philosopher Spinoza, whom Einstein admired; of Descartes, a pivotal figure in the history of mathematics and philosophy; and of John Locke, a political scientist who influenced a group of philosophically inclined revolutionaries named Paine, Hamilton, Adams, Franklin and Jefferson. Never before or since has Holland been graced by such a galaxy of artists and scientists, philosophers and mathematicians. This was the time of the master painters Rembrandt and Vermeer and Frans Hals; of Leeuwenhoek, the inventor of the microscope; of Grotius, the founder of international law; of Willebrord Snellius, who discovered the law of the refraction of light; and of Christian Huygens, discoverer of Titan and the first to understand the nature of the rings of Saturn.

(continued on page 14)

NASA's Lost Horizons

by Bruce Murray

For a few days in November, Americans—and indeed the rest of the world—shared in *Voyager 1*'s thrilling reconnaissance of Saturn and its intriguing rings and moons. Live television pictures of strange unknown worlds a billion miles from Earth were flashed into homes on four continents. Millions of words describing the new scientific finds poured from the typewriters of a 20-nation press corps encamped at the Jet Propulsion Laboratory in Pasadena. Remarkable color portraits of the planet and its halo of brilliant rings appeared on the covers of weekly news magazines throughout the world.

Not since the Apollo lunar landings has such excitement and widespread attention accompanied a space venture. But today, the justifiably proud citizenry of the United States must confront an incongruous fact. Following the *Voyager 2* encounter with Saturn next August, we face the longest dry spell since space exploration began. It will be at least five years before another American spacecraft reveals secrets of other worlds. By comparison, since 1963 there has never been a period longer than 12 months without the receipt of new data and images from a U.S. spacecraft studying an alien object somewhere in the solar system.

How did this dismal prospect come about? The primary answer is that the National Aeronautics and Space Administration, in deciding to develop the reusable space shuttle, regrettably allowed alternative launch-vehicles to be discontinued. This was a sharp break from the practice of the 1960s and '70s, when NASA always kept a proven system in reserve whenever it moved on to an advanced rocket mode. For example, in the early '60s, when the *Atlas-Centaur* rocket development did not come along as advertised, the less-powerful but established *Atlas-Agena* system was used instead, and that's how we first got to Mars and Venus. Similarly, the *Titan-Centaur* system, proposed in the late '60s, ran into delays. But then we fell back on the *Atlas-Centaur*, which launched *Mariner 9* to Mars, *Mariner 10* to Venus and Mercury and *Pioneer 10* past Jupiter and on its way out of the solar system. These happy results were achieved with a launch vehicle that wasn't the one we planned to use, but it was available because it had been kept in production.

The reason for our present dilemma is that the *Titan-Centaur*—so successful in launching *Vikings* to Mars and *Voyagers* to Jupiter and Saturn—was not kept in production as the space shuttle was brought into being.

We already are paying dearly for the failure to maintain a reserve of *Titan-Centaur* rockets through the current transition period from Earth to just-outside-Earth's-gravity launches. Delays and unanticipated extra costs in shuttle development have left America's planetary program very seriously disrupted.

Other NASA programs are on short rations, and great uncertainty surrounds the future of the entire civilian space effort.

The *Galileo* mission to orbit Jupiter and its satellites, begun in 1978 as the first planned use of a shuttle with new upper stages for planetary purposes, was to have been launched in January, 1982. Shuttle problems have pushed back the *Galileo* launch to 1984 and have added significantly to the total mission cost. Even further delays cannot be ruled out. Similarly, the International Solar Polar Mission to observe the sun was to be launched via shuttle in 1983; now it has been postponed to 1985.

Sadly, the burgeoning costs of the shuttle have inhibited major NASA initiatives, particularly the Venus Orbiting Imaging Radar (VOIR) mission. This might be our most important planetary mission in terms of relevancy to the geological nature of our own planet. The objective of VOIR is to reveal, by orbiting radar, the cloud-covered surface of Venus in detail similar to that obtained by orbital television cameras at Mars. Scientists are eager to learn why the twin planets, Earth and Venus, have evolved so differently and what lessons we might learn concerning the future habitability of Earth. Originally proposed for 1983, VOIR's launch date is now 1984, and may be delayed until 1986. But those exciting radar views of Venus' surface are no closer to reality now than three years ago.

This disruption of U.S. deep-space efforts for the '80s has not gone unnoticed abroad. For example, the 1-in-76-year opportunity to explore Halley's comet is coming up soon. Other than the sun and the moon, Halley's has been the most fascinating, most feared and most mysterious celestial object throughout recorded history. The 11-nation consortium that makes up the European Space Agency has decided to launch a European spacecraft to intercept Halley's comet. Japan is making its debut in deep space with a probe to reconnoiter the comet. And the Soviet Union, with France as a junior partner, plans to launch several large spacecraft in a combination mission, first to Venus and then on to an encounter with the comet.

The United States, however, with by far the best technical and scientific capability to explore Halley's comet, has no plans to send its own spacecraft, choosing instead to try to negotiate a junior partner role with the Europeans. America, first to Venus and Mars and the only nation to reach Mercury, Jupiter and Saturn successfully, now will experience a new kind of first—a back seat in someone else's spacecraft.

There is still time, however, for the United States to explore Halley's using existing spacecraft components, designs and ground systems inherited from *Voyager*. The *Voyager*-based U.S. spacecraft could fly much closer to the comet nucleus than the missions planned by other nations, taking measurements essential to answering the most important scientific questions about comets. As with *Voyager* at Saturn, an encounter with Halley's could teach us more about comets than we have learned in the whole of human history.

A mission to intercept Halley's comet must be launched no later than the summer of 1985. Spacecraft and mission costs would be modest—about $250 million. Add all the additional costs for launching and tracking, and the whole endeavor would still require only about 1.5 percent of the likely NASA budget from 1981 to 1986. That's about 30 cents a year for every American.

The world needs to realize that we are not abandoning our leadership in space exploration, nor by implication are we withdrawing from other areas of international competition. A renewed commitment now to deep space exploration—specifically the exploration of Venus by orbiting radar and a flight right into the nucleus of Halley's comet—would reignite our national self-confidence with even greater force than did our encounter with Saturn.

Bruce Murray, Vice President of The Planetary Society, is director of the Jet Propulsion Laboratory.

Titan— A World Unto Itself

As *Voyager 1* neared its November 11, 1980 encounter with Titan, scientists were disappointed in the photographs of Saturn's giant moon, and apprehensive that their wandering robot spacecraft would be unable to see through the enshrouding atmosphere of Titan. The atmosphere was known to contain methane, an elementary hydrocarbon which might be a rung on the evolutionary ladder leading to a life-supporting atmosphere. This methane had fueled speculation that of all the other objects in the solar system, Titan held the greatest possibility of supporting life. Obviously unaware of the excitement generated on Earth, Titan stubbornly remained a featureless "fuzzball" to the spacecraft's cameras.

Fortunately, the designers of *Voyager* had included an integrated payload on the spacecraft, and where imaging instruments could not penetrate, infrared, ultraviolet and radio instruments could easily see. On November 11, these instruments were trained on Titan and, "With the suddenness of a bursting balloon, the total scientific spectrum became available to us," announced Dr. A. Lyle Broadfoot of Kitt Peak National Observatory. Data from the ultraviolet spectrometer, infrared interferometer spectrometer and the radio occultation experiment came in to JPL, and soon exhilaration replaced apprehension.

Titan was revealed as a cold, icy body with a nitrogen (N_2) atmosphere. Unlike Earth's gaseous nitrogen atmosphere with liquid water clouds, the clouds on Titan would be composed of organic molecules, with water frozen within the satellite itself. The nitrogen atmosphere is probably the "result of the breakdown of ammonia (NH_3) originally frozen out on Titan during its formation," according to Dr. Edward Stone of Caltech. The heavier nitrogen molecules remained behind on Titan while the lighter hydrogen escaped from the satellite, probably contributing to the hydrogen torus surrounding Saturn.

A few characteristics of Titan's atmosphere can be seen in this true color image of the "fuzzball." There is a "hood" of dark clouds over the northern polar region and a distinct line divides the northern hemisphere from the generally brighter southern hemisphere. The origin of these features has not yet been determined.

The haze layers which enshroud Titan begin to show detail in this false color image of the satellite's northern polar region. The highest altitude layers are densest at high latitudes and thin out dramatically at latitudes only slightly more equatorial.

Early data hinted that surface temperatures might be low enough and pressure high enough for Titan to be covered with a liquid nitrogen ocean. However, as study continued, scientists raised their temperature estimates to 92°K (−181°C, −294°F) and pressure to 1.5 bars, or one and one-half times that of Earth. At these levels, surface nitrogen would exist in a gaseous state, so the "global nitrogen ocean" hypothesis shrank to the possibility of "polar puddles."

The surface temperature reading given by the radio science experiment suggests other possible scenarios, put forward by Dr. Von Eshleman of Stanford University. The triple point of methane (the temperature at which it can exist simultaneously as a gas, liquid and solid) is close to 92°K. If the amount of methane in Titan's atmosphere is greater than eight percent, methane could exist on the Saturnian moon as water does on Earth. A "methane cycle" of clouds, rain, rivers, glaciers and oceans might be shaping Titan's surface.

However, if methane composes less than eight percent of the atmosphere, but more than one percent, it could form clouds, dropping snow that evaporates before it reaches the surface. In amounts less than one percent, methane could exist only as a gas.

Other hydrocarbons were detected by *Voyager 1* in addition to methane (CH_4). Ethane (C_2H_5), acetylene (C_2H_2), ethylene (C_2H_4) and methylacetylene (CH_3CCH) are thought to be the products of photochemical reactions in Titan's atmosphere, much like those that produce Los Angeles smog.

More important was the discovery of hydrogen cyanide (HCN) in Titan's atmosphere. According to Dr. Rudolf Hanel of Goddard Space Flight Center, hydrogen cyanide is a "very significant molecule because it's the first one which deviates from the simple C-H bond and has been considered a building block of more complex organic molecules." Finding hydrogen cyanide again raised the question, "Is Titan's atmosphere evolving along the path taken by Earth's?" Dr. Hanel responded to the speculation, saying that on Titan we "may have a snapshot of atmospheric evolution which might have taken place a long time ago here on Earth. However, there is a major difference—the temperatures at Titan always have been very low, except for the accretion period. So we may find in a deep freeze the molecules which may have evolved on Earth in quite a different way."

Voyager 1 also answered questions about the physical nature of Titan. This Saturnian moon was "dethroned" as the largest satellite in the solar system; its radius was measured at 2560 kilometers, smaller than Jovian Ganymede. Titan's density is about 1.92 grams per cubic centimeter, (1.92 times that of water) suggesting a rocky core with a thick ice mantle.

"Titan is an extremely alien world," emphasized Dr. Tobias Owen of the State University of New York at Stony Brook. He speculated that a visitor to the Titanian surface would not find rocks or craters, for surface objects would be buried by accumulated aerosols raining down through the atmosphere and possible layers of methane ice and snow. If Titan has surface features cut by flowing liquid, as on Earth or Mars, they might have been carved by liquid ammonia, not water, during a possibly warm early era, although pools of liquid methane may exist there today.

Titan is a fascinating world and extremely important to knowledge of the evolution of planets and atmospheres. Even from this first brief encounter, scientists have gained information that will certainly lead to a greater understanding of the processes that create and shape planets.

—CHARLENE ANDERSON

Planetary Weather Report—The Atmosphere of Saturn

by Garry E. Hunt

Saturn is the most distant of the planets known to the ancient civilizations. Distance and subtle features hindered atmospheric studies so that little was known about its weather systems. Unlike its giant neighbor, Jupiter, Saturn revealed only the occasional cloud spot in its atmosphere. Now this has all changed as a result of the observations made by the *Voyager 1*, which climaxed during the planetary encounter on November 12, 1980.

Saturn, like Jupiter, is a banded planet; the atmospheric patterns appear as subtlely contrasting light and dark horizontal lines. High haze layers obscure the main cloud systems, whose upper layers are thought to be composed of ammonia particles. A further major difference is the effect of the majestic rings, which constantly cast a shadow on the planet, affecting the local heat balance of the equatorial region. But this "shadowing" effect does not cause rapid changes in the Saturn weather system, since the huge hydrogen atmosphere responds in a sluggish manner to radiation changes as it circulates from shadowed to sunlit areas.

At the equatorial region of Saturn, cloud systems have been found to move at a speed of more than 400 meters per second (about 800 miles per hour). These clouds are the fastest moving systems currently detected in any planetary atmosphere. They also are traveling more than four times faster than clouds in the equatorial region of Jupiter. Indeed, the whole region bounded by the latitudes of 40°N and 40°S seems to be moving rapidly in a prograde sense (the direction of the planet's rotation about its axis) on Saturn. This is quite unlike the Jovian cloud systems for this region, which seem to move along alternating prograde (easterly) and retrograde (westerly) jets.

Both Saturn and Jupiter have weather systems driven by the heat of the deep interior, with a small contribution from the weak solar energy that falls on the cold distant planets. This differs from the meteorologies of Earth, Venus, Mars and, probably, Titan, whose atmospheres are driven by the difference between the amounts of solar energy falling on the polar and equatorial regions of the planets. In spite of these differing energy input systems, weather on Jupiter (and probably Saturn) is driven by the transfer of energy from small scale atmospheric eddies into the mean zonal flow of the prevailing winds. Surprisingly, this is the same mechanism we find in the Earth's atmosphere. This result would have been quite unexpected before the *Voyager 1* encounter. Another surprising result is that the jets on Jupiter have remained unaltered for decades while the visible cloud structure has changed rapidly. This may also be true on Saturn.

The haze layers appeared more tenuous as the spacecraft neared Saturn, and red spots were seen at high latitudes in both hemispheres of the planet. The southern hemi spheric feature is more than 6000 kilometers (3700 miles) long and seems to have many of the characteristics of the Jovian spots, drawing material up from the deeper layers of the atmosphere. At the polar latitudes, the broad light and dark regions gradually reduce to less well-defined flows, which result in atmospheric wave structures and small-scale eddies.

The *Voyager 1* look at the Saturn weather system has found huge wind systems and several large cloud features shrouded by high altitude hazes. Currently it is April in the Saturn year, so important seasonal changes can be expected as the planet continues on its path around the Sun. We have found a vastly differing weather system for investigation. It will test our theories and at the same time help us to understand planetary atmospheres in our quest to understand more fully the weather and climate of Earth.

Garry E. Hunt, of the Laboratory for Planetary Atmospheres, Dept. of Physics and Astronomy, University College, London, England, is a member of the Voyager *Imaging Science Team.*

Although the colors in this photograph are "reasonably close" to the true colors of Saturn's atmosphere, the contrast has been enhanced to bring out detail. Bands, waves and spots pop out of the bland, butterscotch Saturn clouds. The two brown spots in the upper right corner (at 40° and 60° north latitude) roughly correspond to the red spot seen in Saturn's southern hemisphere.

Scientists have found it "difficult, if not impossible" to produce "color pictures of Saturn that maintain fidelity of color and still show the low-contrast color features," according to Dr. Bradford Smith, leader of the Voyager *Imaging Team. A high-altitude haze obscures the atmospheric features, forcing the scientists to use false color and enhanced contrast to gain detail. A longitudinal wave can be seen in the diagonal light blue band in this picture. In the dark brown band below, convective cloud features become prominent. An isolated convective cloud surrounded by a dark ring lies in the lower portion of the light brown band.*

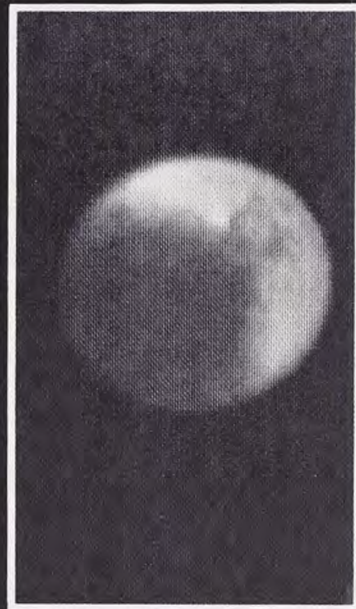
Like Jupiter, Saturn has red spots in its atmosphere. Lying at 50° to 55° south latitude, near the polar region of the planet, this red spot (center of photo) is between 10,000–12,000 kilometers long and appears to be an anticyclonic feature similar to the white ovals Voyager 1 *found in Jupiter's atmosphere. This spot feature seems to be a relatively stable feature of the Saturn atmosphere. Another red spot has been discovered in the northern hemisphere. The red spot is best seen in ultraviolet light and so, in this false color image, appears brighter than it actually is. In "real" color, the spot does have an orangish-red color.*

Gallery of Moons

While the planet Saturn was known to many ancient civilizations, the discovery of its satellites began with the work of Huygens, who discovered Titan in 1655. Within the next thirty years, Cassini discovered Iapetus (1671), Rhea (1672), Tethys (1684) and Dione (1684). A century later, in 1789, William Herschel discovered Mimas and Enceladus. It was John Herschel who suggested the names we use for these satellites, all drawn from characters in Greek mythology. Bond in the United States and Lassell in England codiscovered Hyperion in 1848. Phoebe was found by Pickering in 1898. The ground-based observation of Janus by Dollfus in 1966 was the first of a series of observations of these small satellites culminating in the *Voyager* images.

The great achievement of *Voyager 1* has been to transform these satellites from small blips of light seen in a telescope into individual worlds, each different from the other. Let's now take a closer look at these new worlds.
—DENNIS MATSON

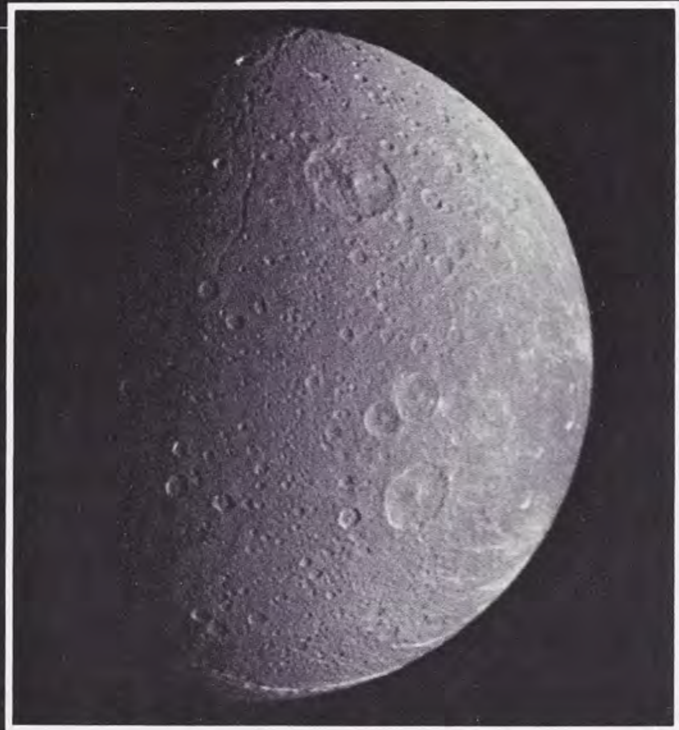
Mimas, "Eye of The Saturnian System"*—Also called, by a few wags, the "Death Star," after the Imperial battle station in "Star Wars," Mimas is distinguished from Saturn's other icy moons by the giant impact crater dominating its surface. The crater is over 100 kilometers across and covers over a quarter of the diameter of the entire satellite. Scientists estimate the depth of the crater at about nine kilometers and the height of the central peak at half that height. Mimas and its "eye" have the largest crater diameter to satellite diameter ratio known in the solar system and the impact which created the feature may have been close to the upward limit the satellite could take without being knocked to pieces. Linear features on the side opposite the crater are possibly fractures caused by the impact or debris thrown out when Mimas was hit.*



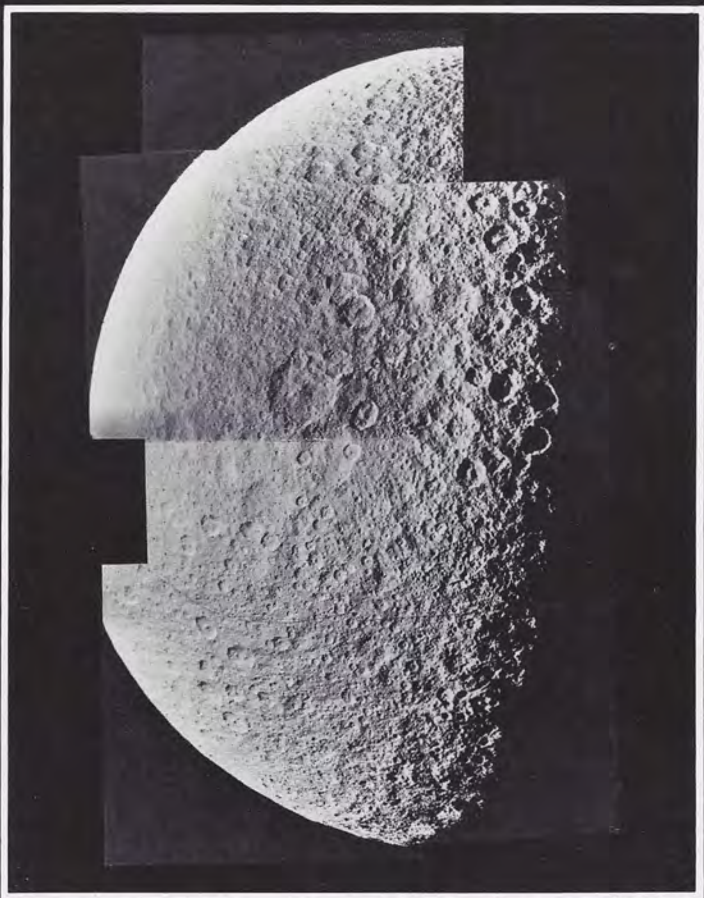
Iapetus, "An Evolved Object"*—Iapetus is a puzzle to scientists, with the leading hemisphere of the satellite many times darker than the trailing hemisphere. This brightness difference is probably due to a variation in surface material, leading scientists to speculate that this eighth large moon out from Saturn has evolved since its formation and now differs from the "standard" Saturnian moons like Mimas, Rhea and Dione. The images returned by* Voyager 1 *revealed hints of craters, including the dark circular feature near the boundary between the light and dark hemispheres. The ring may be dark material that was thrown out by an impact or that flowed into a depressed ring around the feature.* Voyager 2 *will fly three times closer to Iapetus, so in August, 1981, scientists will have a better idea of the satellite's strange markings.*

New Moons, "The Shepherding Satellites"*—*Voyager 1 *discovered three new moons of Saturn that seem to be intimately connected with the ring system. S13 and S14 (far right) were discovered on October 25, 1980, while the spacecraft was still 25 million kilometers (about 16 million miles) from Saturn. The moons travel in orbits on either side of the narrow F-ring and scientists believe they act much like sheepdogs, preventing stray particles from escaping the ring. S15 (near right) appeared in* Voyager 1*'s cameras on November 6, 1980. It orbits just 800 kilometers (500 miles) from the outer edge of the A-ring. "This little satellite, only 100 kilometers in diameter, may be controlling and bounding the outer edge of this ring system, which measures hundreds of thousands of kilometers across," according to Dr. Bradford Smith, leader of the Imaging Team.*

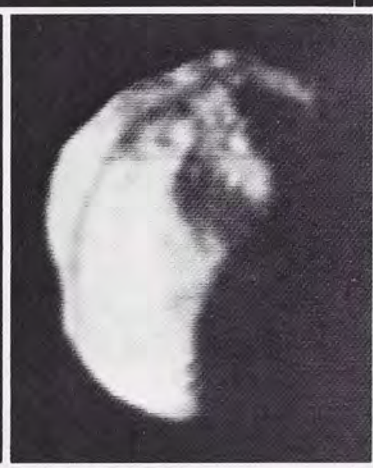
Tethys, "Body with a Complicated History,"— *The large trench winding over the heavily cratered surface of Tethys is of uncertain origin. There are no craters in the region of the trench, which is 750 kilometers long and 60 kilometers wide (about 500 by 40 miles), suggesting that the planet has evolved since the era of heavy meteorite bombardment. A large albedo feature, lying on the side opposite the trench, may be an impact crater, which has led some scientists to speculate that the trench may be a surface fracture resulting from a large impact that cracked the small (1,050 ± 20 kilometers), icy moon.*



Dione, "Looks Like the Earth's Moon"— *While the surface of Dione, the fourth large moon out from Saturn, looks suggestively like the Earth's Moon, Dione is a small (1,120 ± 20 kilometers), icy body and it is unwise to make comparisons. This Saturnian moon displays large craters with central peaks, long narrow sinuous valleys and markings of "wispy" material that may be associated with fracturing of the crust due to impacts or, perhaps, internal processes. Relatively smooth areas on the satellite's surface suggest that internal processes may have "resurfaced" heavily cratered areas after early meteorite bombardment was over.*



Rhea, "Shoulder to Shoulder Craters"— *Rhea is the most heavily cratered body in the Saturnian system and seems close to the saturation point, when new impacts will destroy as many craters as they create. Rhea's bright terrain is among the most ancient of planetary surfaces and is apparently about the same age as the highlands of the planet Mercury and the Jovian satellite Callisto. The craters of Rhea, and the other Saturnian satellites, are much less smooth and regular than those on the Earth's Moon. With the exception of Titan, Saturn's moons are much smaller and less dense than the Earth's, so gravity plays a lesser part in smoothing crater features.*



The Co-Orbital Satellites, "On a Collision Course,"— *Recent Earth-based observations of Saturn's satellite system revealed two satellites in the same orbit about the planet, on an apparent collision course. (Only one of these satellites is pictured above.)* Voyager 1 *images of these satellites showed them to be small, irregularly shaped bodies, leading some scientists to speculate that they may be halves of a small moon, cracked in two by a meteorite or comet collision larger than the one that caused the "eye" on Mimas. Researchers viewing these successive images of the trailing co-orbital satellite discovered an unexpected bonus. A narrow shadow can be seen moving across the face of the tiny moon. It is believed to be the shadow of a small, narrow ring circling Saturn a few thousand kilometers from the co-orbitals.*

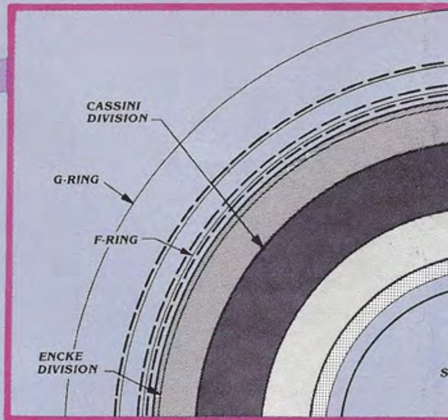
PHOTOS: JPL/NASA

Saturn's Rings
A Voyager Update

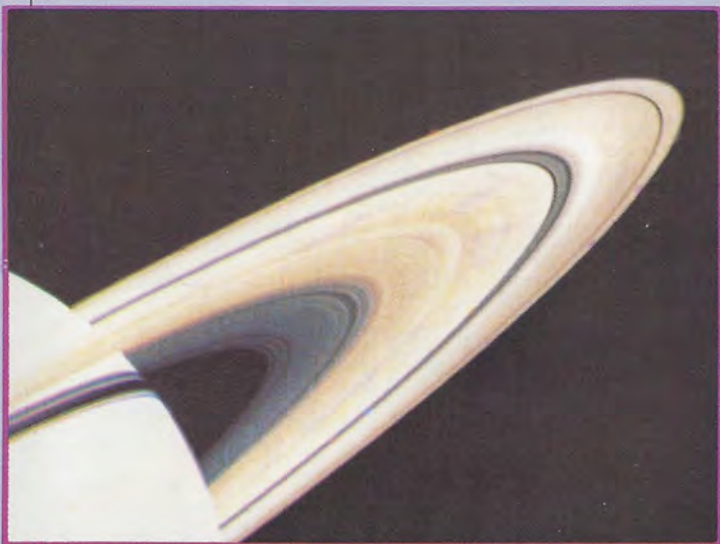
by Jeffrey Cuzzi

Saturn's rings have intrigued and attracted people for hundreds of years. The bright rings, hovering almost changelessly about giant Saturn with their sharp gaps visible on nights of good seeing, seemed to defy the laws obeyed by more familiar celestial objects such as the moons of Jupiter and Mars. It was not until 1859 that James Clerk Maxwell, who developed the first analytical treatment of electromagnetic waves, demonstrated from dynamical stability calculations that the rings could only exist as a series of individual moonlets in independent orbits.

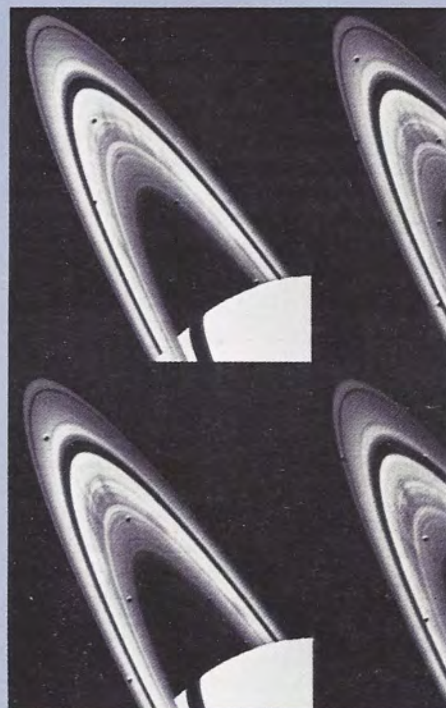
This theory was strikingly confirmed by Keeler, who, in 1895, observed that velocities in the ring system obeyed Kepler's laws–that is, the velocities corresponded to those expected for particles in elliptical orbits. From the observed red and blue shifts of spectral features in sunlight reflected off the revolving ring particles, it was obvious that the material at the inner edge of the rings, closer to the planet, had to be revolving around Saturn at a faster rate than the material at the outer edge. The variation was in exactly the same form as shown in the orbits of the planets about the sun, or the orbits



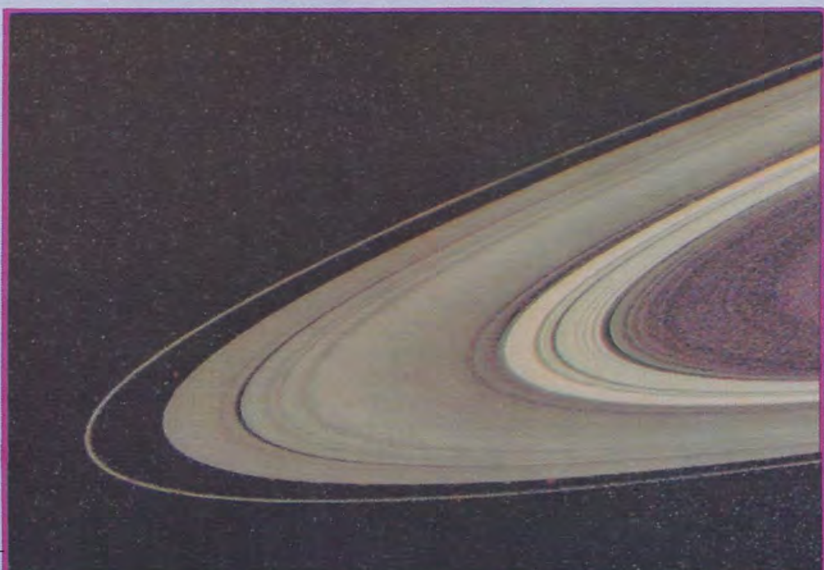
Saturn's rings and the divisions in the ring



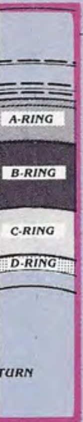
At the wavelength of visible light, Saturn's rings appear uniform in color. At invisible ultraviolet wavelengths, however, some regions are anomalously bright. In this false color image, the pale blue features (Cassini Division and C-ring) appear especially bright in ultraviolet, suggesting that they are composed of different materials than the larger, brighter A- and B-rings.



The revolving "spokes" of the B-ring can b images (from upper left to lower right) ta



Saturn's rings appear dramatically different when seen from the unilluminated side. The B-ring, which is the brightest region on the sunlit side, now appears dark (magenta in this false color image), presumably because little sunlight can pass through it. The normally dark Cassini Division is now the brightest feature of the rings. The narrow F-ring is clearly visible outside the A-ring.



ystem.

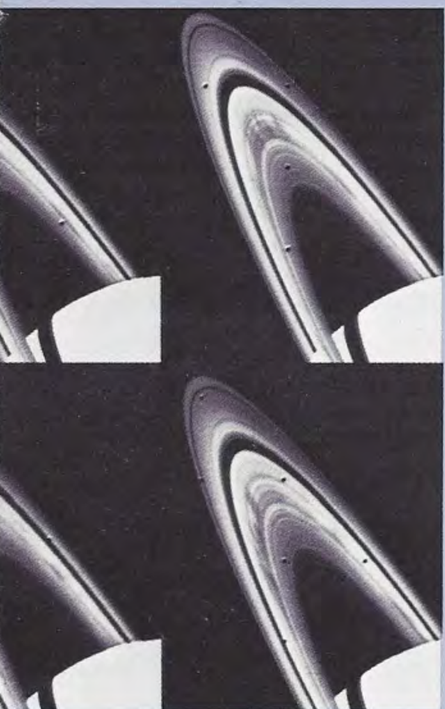
of Jupiter's Galilean satellites, thus proving that the rings were composed of countless independent satellites.

The source of all these independent moonlets has been a problem underlying all more detailed questions under study. All of the ring material lies within the "Roche limit" of Saturn, the distance from the planet's center within which the tidal forces exerted on a large moon by Saturn are so large that the moon could not hold itself together with its own gravity. This circumstance permits two possible origins of the rings: either they are the debris of an unfortunate larger moon which wandered too close and was destroyed, or they are the seeds of a moon, condensed directly in place from the early nebula from which the planets were formed and which were prevented by these same tidal forces from accreting into a sizeable, discrete moon as did their cousins more distant from the planet.

Gravity plays an equally important role in sculpturing the features of the rings. It had been realized from the turn of the century that the orbital periods in the regions of ring edges and gaps and the orbital period of Mimas, Saturn's innermost satellite known at the time, were closely related. Particles in these orbits receive an extra gravitational pull from the same direction (of Mimas) every few orbits. These locations are known as resonances. Due to this pull, the orbits become more eccentric. Particles are eventually removed from these resonating orbits by collisions with particles in neighboring non-eccentric orbits. This idea was proposed by Goldsborough in 1921 and developed extensively by Cook and Franklin in only the last few decades.

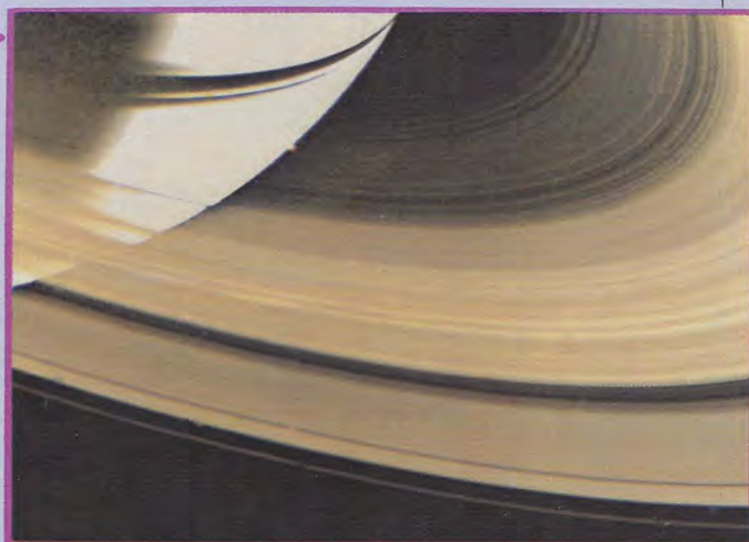
Similar concepts have been successfully applied to the Kirkwood gaps in the distribution of asteriods at various orbits strongly resonant with Jupiter. However, where the Kirkwood gaps are quite narrow compared to the width of the disk, as expected for a perturbing object of Jupiter's mass, both the Cassini and Encke Divisions in Saturn's rings are much broader than expected for a perturbing object of the mass of Mimas.

Several hypotheses have been advanced to account for the broadening of the divisions in Saturn's rings, ranging from the effects of collisions to the effect of spiral density waves, such as might account for the arms of spiral galaxies, and which is similar to ripples spreading from a stone thrown into a pond. Peter Goldreich of Caltech and Scott Tremaine of the Insti-

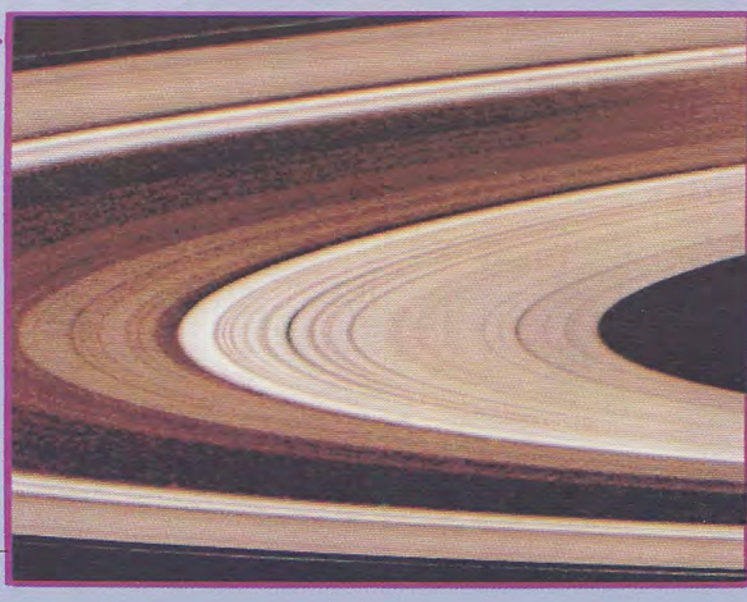


seen moving about Saturn in these six sequential
en 14.4 minutes apart.

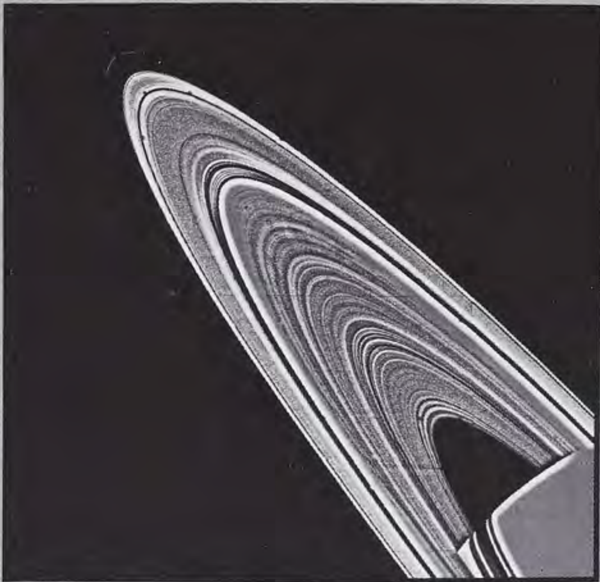
The bright crescent of Saturn is clearly seen through all but the densest region of the planet's rings, which cast a shadow on the face of Saturn. Sunlight scattered off the rings provides significant illumination on the planet's dark hemisphere.



The Cassini Division (top and bottom) and the C-ring (center), which appear dark on the sunlit side of Saturn, are the rings' brightest feature when viewed from the unilluminated side, as in this false color image. By comparing the rings' brightness under different viewing/lighting conditions, it will be possible to determine both the properties of individual particles and the density of particles within individual ring features.



PHOTOS: JPL/NASA



Approximately 95 individual concentric features are discernible in this two image mosaic of Saturn's ring system. The narrow F-ring and Saturn's fourteenth satellite (one of the "shepherding" moons) can be seen in the upper left of the mosaic.

The "braided" F-ring is one of the puzzles of the Saturnian system revealed by Voyager 1. *This structure is difficult to attribute simply to particles orbiting normally about the planet—other forces are probably at work. The gravitational effects of the "shepherding" satellites or electromagnetic interactions of the particles with Saturn's magnetic field are two possible explanations.*

tute for Advanced Study have suggested this latter idea, with the prediction that the orbital resonances (gravity interactions between moons) excite such waves.

In spite of their broad radial extent of 100,000 kilometers, Saturn's rings are known to be quite thin—less than a few kilometers in vertical extent. This high degree of flattening is due to the continuous collisions suffered by the particles, which are densely packed. In the past, the rings might have formed a fatter cloud, and the collisions would have been quite violent, possibly fracturing and grinding up the particles. However, at present, the collisions are relatively gentle, with velocities of at most a few centimeters per second and probably significantly less.

The extent to which this flattening has proceeded is still controversial. Dynamical arguments hold that the flattening proceeds until the rings are only a few particle radii in thickness, the so-called "monolayer" model. Recent studies by this author with J. Burns, R. Durisen and P. Hamill concluded that local "turbulence" associated with the few largest particles could effectively keep the rings in a layer of thickness many times the size of a typical, common particle.

Returning to the questions of the origin of the rings brings us to their practical significance. Catastrophic explanations of almost any phenomena are generally more suspect than explanations which follow naturally from processes known to be ongoing. In addition, studies of both the radio emission and the radar reflection of the rings indicate the primary particle size to be in the range of centimeters to meters, and their primary composition to be ice or water. Also, water ice has been specifically observed in the rings in the near infrared. Significantly, this size range and composition is in good agreement with what sizes and composition would be expected to result from direct condensation from Saturn's protoplanetary nebula. For these reasons, the model accounting for the formation of the ring particles in place, rather than from the break-up of a small moon, is currently preferred. Thus, the rings may contain direct evidence for conditions that existed in the protoplanetary regions of the solar system, unaffected and unmetamorphosed by incorporation into a larger body.

Regardless of their specific origin, the rings will now provide us with invaluable information on the real influence of resonances on a disk of particles. Whether resonances preferentially disperse or coalesce particles, and in what way, may now be decided observationally. Possible effects of proto-Jupiter and proto-Saturn on planets forming in the inner parts of the Solar System may be derived in the future.

The first close-up investigation of the rings was accomplished by *Pioneer 11* in September, 1980. *Pioneer 11*, a spinning spacecraft with only limited capability for targeted pointing, was highly optimized for magnetic field and charged particle studies. A new and very thin ring, the F-ring, was discovered outside the A-ring. Important information relating to the scattering properties of the ring particles, and the optical depth variations in the ring layer, was obtained, which made it possible to predict the brightness that would be seen by *Voyager* (and thus establish camera exposures) much more exactly than would have otherwise been possible. Localized thin regions, possibly very narrow gaps, even in the most opaque regions, were inferred. In addition, new and exciting information on the ring structure was obtained using very high radial resolution studies of the charged particle densities. These are quite sensitive to ring material, as had been proven in the case of *Pioneer's* observations of the Jupiter rings, but not fully understood until the *Voyager* Jupiter encounter. Such observations revealed a very interesting triple structure to the F-ring at high resolution, as well as hints of as yet unconfirmed new, possibly ring, material.

(continued on page 14)

An Alternative Hypothesis....

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WASHINGTON WATCH

by Louis Friedman

There is a lot to watch in Washington these days. Even prior to November's general election, considerable changes were in the offing. Dr. Robert A. Frosch, the NASA Administrator, announced that he was leaving the agency in January—no matter what the election results. Dr. Thomas A. (Tim) Mutch, the NASA Associate Administrator for Space Science, died in a tragic climbing accident in the Himalayas. Gus Guastaferro, the Manager of the Planetary Program at NASA, was appointed the Deputy Director of Ames Research Center in Mountain View, California. Thus, three principal positions in NASA are open.

Just prior to his defeat, President Jimmy Carter announced that the Venus Orbiting Imaging Radar (VOIR) mission (see box) would be in his proposed budget for the next fiscal year (1982). The Office of Science and Technology Policy (OSTP), popularly known as the Science Advisor's Office, supports the mission. Clouding the picture are the budget difficulties introduced by cost overruns in the space shuttle program, the Inertial Upper Stage development and the *Landsat* system, as well as pressures to reduce federal spending. The *Galileo* project will be delayed—again—by a redirection of the Inertial Upper Stage program.

The budget process in the Executive Branch, through which all NASA projects must pass, is as follows: NASA, after internal review, presents a budget to the Office of Management and Budget (OMB). This Executive Branch agency is responsible for formulating the federal budget. OMB acts on the request and puts together a budget for review by the President, his domestic policy staff and OSTP. This activity goes on, generally behind closed doors, between September and December. In late December, the President makes his final decisions and a proposed budget is presented to Congress on January 20. (As described in the last issue of *The Planetary Report*, Congress, through its Budget, Authorization and Appropriations committees, considers the budget from January to July.) Public influence on the budget is usually focused during Congressional hearings, held in February and March, and occasionally during times of critical votes. There is letter-writing to the President, the Science Advisor and Congressmen during the time of active budget consideration.

This year the Reagan Administration will amend the Carter budget and send their revisions to Congress about one month afterward (in mid- to late February). We will then learn something about the space exploration priority of the new administration.

Finally, we note major changes on the Senate side of Congress as a result of the Republicans' winning majority control. Senator Harrison H. Schmitt (R-New Mexico) is now Chairman of the Senate Science Technology and Space Subcommittee and Senator Jake Garn (R-Utah) is Chairman of the Senate Appropriations Subcommittee for HUD and Independent Agencies (which includes NASA). (The corresponding House of Representatives persons are Representative Donald Fuqua (D-Florida) of the House Science and Technology Committee and Representative Edward Boland (D-Massachusetts) of the House Appropriations Committee.) Their subcommittees will hold hearings and receive letters and testimony concerning the VOIR and Halley proposals during the months of February, March and April, 1981.

Louis Friedman, Planetary Society Executive Director, spent one year as a Congressional Fellow with the Senate Committee on Commerce, Science and Transportation.

For the fiscal year 1982 budget, the chief new exploration issues are VOIR and a Halley's comet mission:

Venus Orbiting Imaging Radar

THE VENUS ORBITING IMAGING RADAR (VOIR) is planned as a 1986 mission to map the entire Venus surface. Because Venus is veiled by clouds, conventional optical imaging techniques will not work. However, a radar instrument, using a technique known as synthetic aperture imaging, is capable of piercing the cloud cover and transmitting an image of the planet's surface back to Earth. This technique has been used on military aircraft and in the successful *Seasat* mission which produced highly detailed images of the Earth's ocean surface and geologic features.

Using these radar images, scientists hope to produce a map of Venus that would show surface detail down to 600 meters (about one-third mile) in size. VOIR will also provide information on the Venus atmosphere and electromagnetic environment.

Halley's Comet Intercept Mission

A UNITED STATES MISSION TO INTERCEPT COMET HALLEY requires a July, 1985 launch in order to encounter the comet in March, 1986, one and one-half months after the comet's perihelion (closest approach to the Sun). Science objectives of the Halley intercept are to determine the nature of the comet's nucleus and coma (atmosphere) and the interaction of the solar wind with the comet.

NASA currently favors cooperating with the European Space Agency (ESA) on their planned *Giotto* mission in lieu of doing a separate mission. However, NASA has studied an American mission as a backup to the ESA plan. This mission would use a three-axis stabilized spacecraft targeted very close to the comet's nucleus. With a highly accurate navigation system, this spacecraft would have excellent picture-taking ability. The Japanese are also planning a Halley mission, called *Planet A*, and the 1984 Soviet/French *Venera* mission will include a Halley fly-by after encountering Venus.

News & Reviews

by Clark R. Chapman

The last quarter of 1980 was an exciting time for planetary scientists, with the latest *Voyager 1* pictures of Saturn appearing on evening telecasts and in local papers. *Newsweek* ran an excellent account of the Saturn discoveries as the cover story of its November 24th issue. Amidst all the hullabaloo, however, the steady pace of planetary research continued in universities and laboratories around the country.

Just a few months ago, after more than four years of transmitting data from Mars, the last remaining *Viking* Orbiter was shut down. Some of its final pictures are printed in the November, 1980 issue of *Sky and Telescope*. Meanwhile, Martian research has entered the mature stage of detailed analysis of geophysical, geological and atmospheric processes. An ambitious portrayal of the global evolution of Mars, as synthesized from fifteen years of scrutiny by spacecraft, has been published in the August, 1980 issue of *Reviews of Geophysics and Space Physics* by Washington University geoscientists Raymond Arvidson, Kenneth Goettel and Charles Hohenberg.

The continent-sized Tharsis Plateau and the huge Olympus Mons volcano are not totally compensated isostatically; that is, they are not simply "floating" in the Martian mantle. Evidently they are supported by a thick, rigid crust, or else they respond to continuing dynamical motions within the interior of Mars. The absolute geological timescale for Mars remains uncertain, but studies of the cratering record and the thermal evolution of the planet suggest a comparatively recent epoch for the peak of volcanic activity. At the same time vulcanism was dying out on our Moon, Mars may have been most alive, with vulcanism especially prevalent on the northern hemisphere of the planet.

Despite the thin air on Mars, the *Viking* Orbiter photography shows geological evidence for abundant volatiles on or near the surface of the planet in times past. The famous channels were formed by running water. Other Martian features apparently reflect the presence of immense deposits of subsurface ice or permafrost. Arvidson and his colleagues discuss data on the isotopic composition of the Martian atmosphere. Their conclusions are tempered in the light of unexpected *Pioneer* measurements of another terrestrial planet, Venus. But they nevertheless infer the presence of voluminous reservoirs for volatiles, presumably including the polar caps and the "regolithic" surface layers of Mars. It is problematical whether or not the volatiles are periodically liberated into the atmosphere, yielding periods of more clement weather on the red planet.

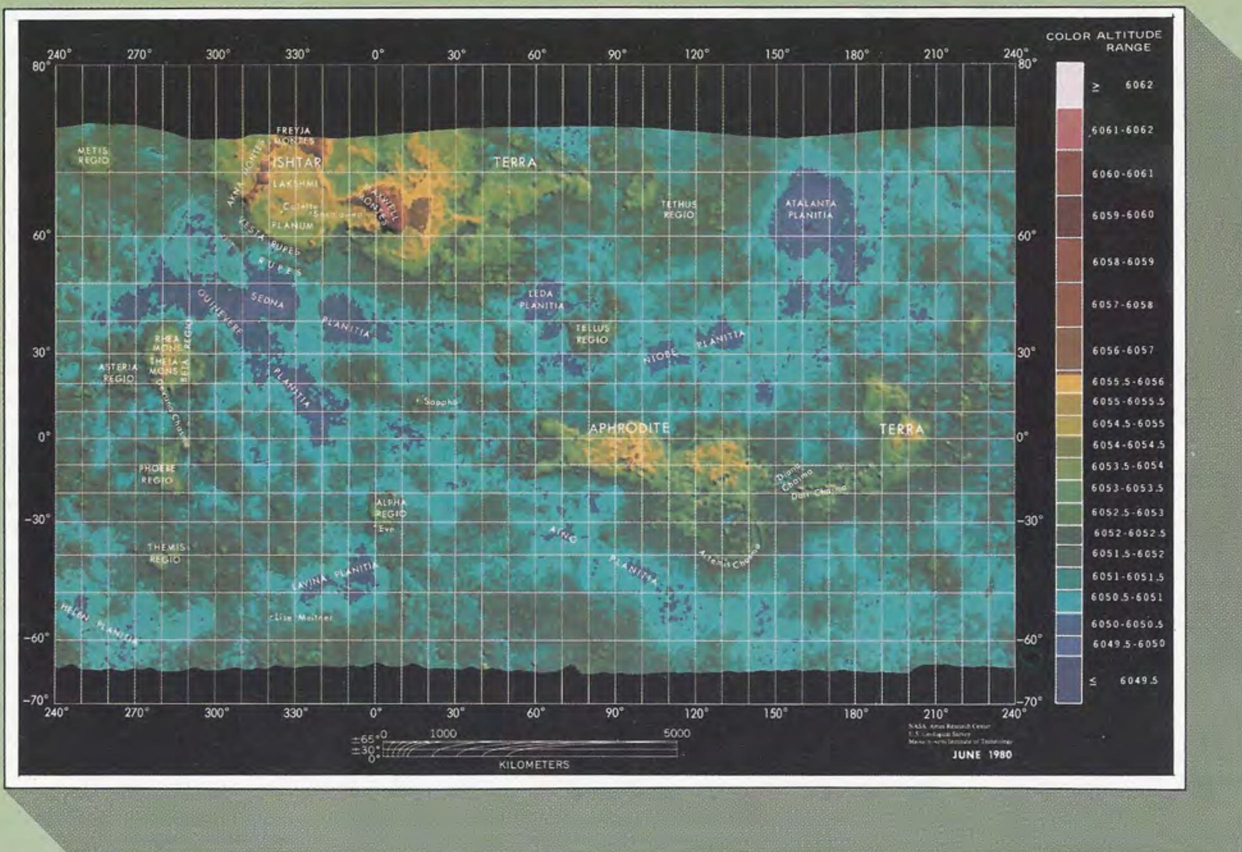
A shorter, less technical review of the geology of Mars has been written by Michael H. Carr, the leader of the *Viking* Orbiter Imaging Team. It appears in the November–December, 1980 issue of *American Scientist*.

A readable article by William Hoffer in the September–October, 1980 issue of the National Science Foundation magazine *Mosaic*, "Looking Up to Know Ourselves," carries the first good photograph of cloud patterns on distant Neptune, setting the stage for a three-and-one-half century old saga that is still unfolding. It was in the closing days of 1612 that Neptune was first observed and recorded by a human being. The observer was none other than Galileo, who had first used an astronomical telescope just three years earlier. Galileo's observation of two "fixed stars" that "seemed farther apart" the night before has recently been unearthed by Stillman Drake and Charles Kowal (*Scientific American*, December, 1980). Galileo failed to follow-up his curious observation, so the discovery of Neptune had to wait another 234 years.

Progress in learning about Neptune has been only a little more rapid in the 134 years since its discovery. It has seemed to be a faint, featureless, frigid world on the outer fringes of the solar system. Some pieces of the puzzle came together at the latest annual gathering of planetary astronomers (Division of Planetary Sciences of the American Astronomical Society meeting, Tucson, Arizona, October, 1980: see preliminary reports in the *Bulletin of the American Astronomical Society*, Vol. 12, No. 3). Infrared spectral data presented by J. Apt, *et al*, show enormous variations. Normally, Neptune is very black in the infrared due to strong atmospheric absorptions. But occasionally a bright, high haze layer forms and Neptune's spectral character changes dramatically. As wisps of haze are carried around by Neptune's axial spin, Dale Cruikshank and his collaborators have been able to refine their 1977 determination of the rotation period to about 18 hours. They now basically agree with the period determined from more subtle variations at a different wavelength that have been studied for several years at McDonald Observatory in Texas. Remaining small differences may reflect real atmospheric motions at different levels in the Neptunian atmosphere. We have not heard the last of the "elusive haze" and "weather" on Neptune! It is a prime example of research still in progress.

Clark Chapman, of the Planetary Science Institute in Tucson, Arizona, is a member of the Galileo *Project Imaging Team. His primary research interests are asteroids and small bodies.*

Global Altimetry Map of Venus



NASA AMES RESEARCH CENTER

by Stewart Nozette

Beginning in the early 1960's, Earth-based radar began to provide tantalizing glimpses of the surface of Venus, our nearest planetary neighbor. Many interesting features resembling basins, impact craters and volcanoes became visible but, due to a lack of topographic information, we could not tell whether a feature was actually a mountain, a basin or something intermediate.

The *Pioneer* Venus 1 spacecraft, which went into orbit around the planet in December, 1978, carried on board a small radar instrument capable of measuring topography and imaging portions of the surface. This experiment has been able to provide a topographic map (shown here) with a horizontal resolution of about one hundred kilometers and a vertical accuracy of about two hundred meters.

The topographic map covers 93 percent of the Venus surface and reveals a wide variety of geologic forms, including a mountainous region in the northern hemisphere containing Maxwell Montes—a peak reaching eleven kilometers (36,000 feet) above the surrounding plain; Aphrodite Terra, a continental structure half the size of Africa; a rift valley over three kilometers deep; and Beta Regio, perhaps the largest volcanic structure in the solar system.

Venus is a very smooth planet with less than 10 percent of the surface composed of highlands (yellow, brown and red areas on the map). More than 60 percent is gently rolling upland (green, turquoise and light blue). Less than 30 percent of Venus may be called a lowland, or basin (dark blue). Venus does not have surface features resembling the terrestrial ocean basins, and there is no evidence of the great trenches or global rift systems diagnostic of terrestrial plate tectonics (movement of continental plates over ocean basins). Although some features are suggestive, the *Pioneer* Venus radar mapper has not identified any feature which may be unambiguously labeled an impact crater.

The low resolution information provided by *Pioneer* Venus is still too coarse to answer many questions about the types of geological processes and structures present on Venus. The largest features—Ishtar Terra, Aphrodite Terra and Beta Regio—are all extremely complex, and as yet we can only glimpse their rough outlines. Are there impact craters on Venus? What are the processes which shape the surface? Is there evidence for recent vulcanism?

To answer some of these questions and pose many others will require high resolution radar images covering the entire planet. NASA is currently planning a mission called the Venus Orbiting Imaging Radar (VOIR) for launch later in this decade. The VOIR mission will provide a grand leap in our knowledge of Venus and the origin and evolution of planets in general.

Stewart Nozette is a graduate student in the Department of Earth and Planetary Science at the Massachusetts Institute of Technology, Cambridge, Massachusetts. The Pioneer *Venus project is managed by NASA Ames Research Center and the topographic maps are produced by the United States Geological Survey in Flagstaff, Arizona, under the direction of Harold Masursky. The radar data reduction and analysis is carried out by the Department of Earth and Planetary Sciences at MIT, under the direction of Gordon Pettengill.*

Setting Sail for the Planets

(continued from page 2)

The connection between Holland as an exploratory power and Holland as an intellectual and cultural center was very strong. The improvement of sailing ships encouraged technology of all kinds. People enjoyed working with their hands. Inventions were prized. Technological advance required the freest possible pursuit of knowledge, so Holland became the leading publisher and bookseller in Europe, translating works written in other languages and permitting the publication of works proscribed elsewhere. Adventures into exotic lands and encounters with strange societies shook complacency, challenged thinkers to reconsider the prevailing wisdom and showed that ideas that had been accepted for thousands of years—for example, on geography—were fundamentally in error. In a time when kings and emperors ruled much of the world, the Dutch Republic was governed, more than any other nation, by the people. The openness of the society and its encouragement of the life of the mind, its material well-being and its commitment to the exploration and utilization of new worlds generated a joyful confidence in the human enterprise. Those benefits of an exploratory society can be ours as well.

This continuity of the human exploratory tradition is why The Planetary Society's logo displays a sailing ship, bound from the Earth to the planets and the stars.

Carl Sagan, President of The Planetary Society, is David Duncan Professor of Astronomy and Space Sciences at Cornell University.

Excerpted in part from *Cosmos* (New York: Random House, 1980).

EDITOR'S NOTE:

Today this tradition of curiosity and discovery at far frontiers is flourishing in the Netherlands. With cloudy skies and no high mountains, Dutch astronomers turned to the radio realm, and with strong government support, quickly built the Westerbork Synthesis Telescope, an array of antennas that has given unique pictures of celestial radio sources. Space science publishing is active in Holland, and the country hosts the European Space Agency's main scientific and technological development center near Noordwijk. Dutch involvement in recent space missions has included the Astronomical Netherlands Satellite (ANS), a pioneering X-ray observatory, and participation in the Infrared Astronomical Satellite (IRAS) intended to make an infrared all-sky survey, beginning in 1982. Thus a small nation, with relatively modest resources but a long and strong intellectual tradition, recognizes the importance of being in the forefront of some carefully chosen fields as this new age of discovery begins.

—James D. Burke

Saturn's Rings—

(continued from page 10)

For a large number of the *Voyager 1* photos of the rings, a resolution of 10 to 100 kilometers was obtained. Of equal importance, was the wide range of Sun-ring-spacecraft geometry obtained during these observations of scattered and reflected light from the lit and unlit faces of the rings. These data permit us to distinguish very effectively between particles with different angular scattering properties (primarily related to particle size) and particles with different intrinsic brightnesses (primarily related to composition). Furthermore, the high resolution will now allow us to study the real properties of resonances and ring structure as never before possible.

As of this writing, many spectacular photos have been obtained, and many significant discoveries, both clarifying and baffling, have been made from the images. The three main rings (A, B and C) have been shown to be unique in their properties. The A-ring is almost as classically expected; smooth overall, and punctuated with narrow gaps which lie near locations predicted from the orbits of known satellites. The B-ring is quite "busy" and chaotic, with fine structure extending all the way down to the limits of *Voyager* resolution. This ring is the location of the puzzling "spokes"—irregular, blotchy contrast features in the ring which appear extended in the approximately radial direction. The "spokes" are sporadic and transient, and are believed at the time of this writing to be in some way related to relatively greater or lesser proportions of fine, micron-sized particles in a background of larger particles. The mechanism for enhancement or transport of these particles is not obvious at present, although several hypotheses are under consideration.

The C-ring is distinct from both the A- and B-rings in general properties, with a structure more regular than the B-ring but less classically "resonant" than that seen in the A-ring. The Cassini Division itself is revealed to contain more structure than previously known in the entire ring system! Its borders seem to correlate in position with classically predicted resonances with known satellites but the structure in between is unlike resonant structure and is similar to the C-ring in appearance.

The question of confinement of ring systems has received sizeable new input with the discovery of S13, S14, and S15, small satellites of several hundred kilometers diameter, near the outside edge of the rings. S13 and S14 straddle the thin F-ring and appear to confirm another hypothesis of Goldreich and Tremaine that the "sheepdog" effect of small moons may confine the narrow rings of Uranus. Close-up, the F-ring reveals an exotic asymmetrical structure with intersecting or overlapping components, the so-called "braided" structure which may be transient. In a similar way to the shepherding effects of S13 and S14, S15 seems to confine the outer edge of the A-ring. So some, at least, of our pre-*Voyager* questions have been answered.

Several other questions will be answered using other *Voyager* data. For instance, radio and visual observations will determine directly the predominant particle size range in the rings. This method shows C-ring particles to be on the order of a meter in size, and further study of the data is underway. The radio scattering experiment will be the only direct, explicit measurement of particle size. We all look forward to final analysis of these data.

The enormous wealth of data provided to current and future workers in the field is truly a worthy legacy to a superbly designed and managed *Voyager* mission, and to the vision of the planners who conceived it over ten years ago. It is also a credit to the important preparatory work of *Pioneer 11*, whose initial results facilitated optimal use of *Voyager*, and to the hundreds of earthbound observers dating back to Galileo who endured cold nights and bleary eyes to catch a fleeting glimpse through our wavering atmosphere of the magnificent structure that we are now fortunate to see up close. We should enjoy it for their sake as well as for our own.

Dr. Jeffrey Cuzzi, of Ames Research Center, is the "ring-leader" of the Voyager *Imaging Team.*

Society Notes

by Louis Friedman

The *Voyager 1* Saturn encounter reaffirmed popular interest in planetary exploration. Cover stories in *Time* and *Newsweek*, features on national television and extensive newspaper coverage were noteworthy. The Planetary Society's formation was often mentioned, sometimes with the irony that after the great discoveries of new worlds by *Voyager*, we face the longest gap in planetary encounters since the beginning of the space age.

The national attention paid to the Society provides a basis for optimism, even as budgetary threats are leveled at the planetary exploration program. Our membership, now over 20,000, is growing at a remarkable pace, and I hope that Society activities will attract more attention to our newly focused constituency.

In this issue of *The Planetary Report*, we announce the availability of pictures from the *Voyager 1* Saturn encounter. This service for members will be expanded to include posters, books and additional materials. We also are beginning a nationwide "*Voyager* on Tour" series of lectures and discussions of the *Voyager* project results and other aspects of planetary exploration. Announcements in this magazine and special mailings will keep you informed.

Several people have written to us about the possibility of The Planetary Society's cooperating with other space interest groups. We are doing so, on an ad-hoc but regular basis. We meet and share information with the National Space Institute, the L-5 Society, the Aerospace Industries Association, the American Institute of Aeronautics and Astronautics, the American Astronautical Society and the Space Studies Institute. We also are keeping a liaison with the Viking Fund, the World Space Foundation and the Space Foundation. Duplication of effort is not a problem and The Planetary Society's attempt to organize the great public interest in deep-space exploration is supported and welcomed by all.

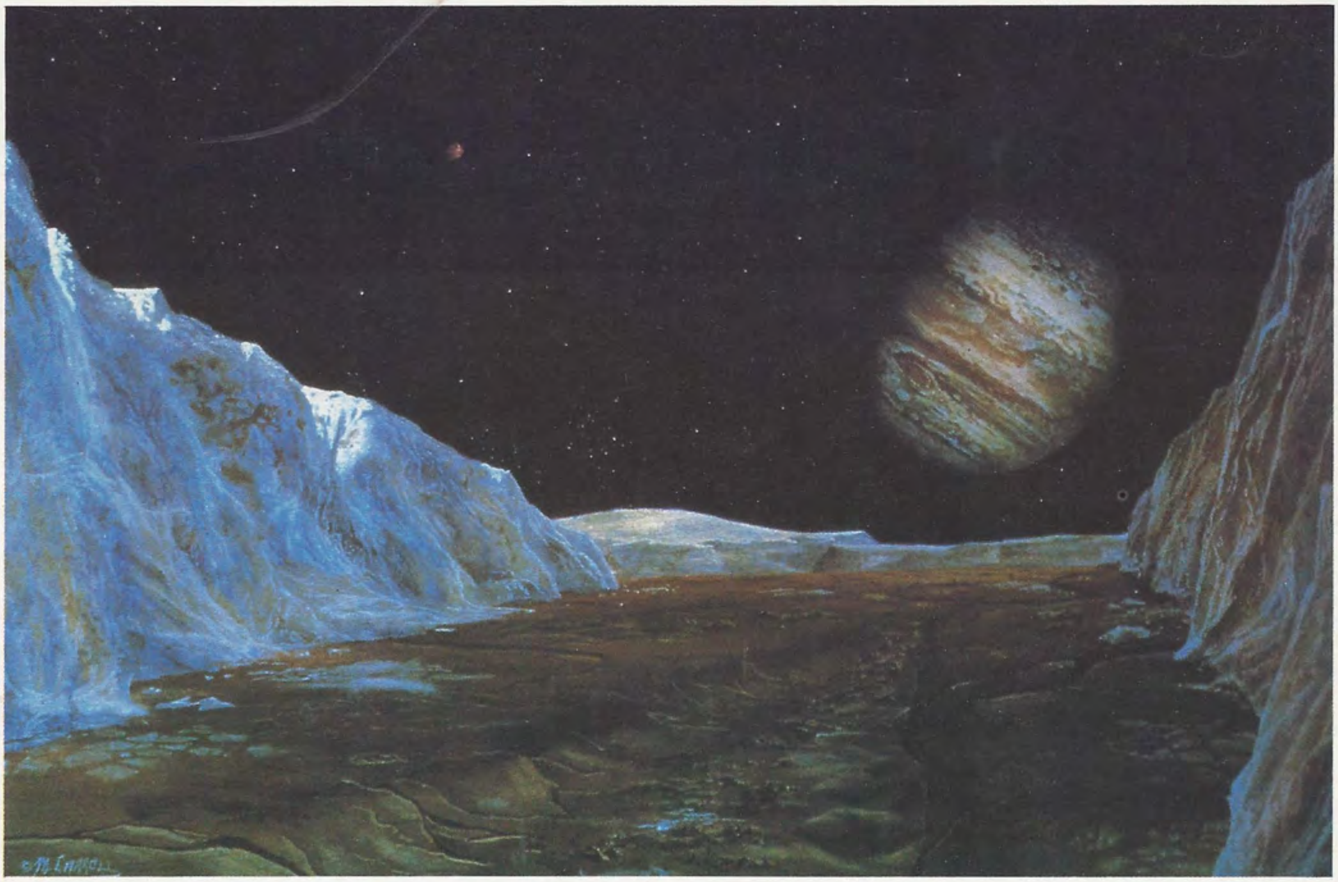
We welcome to our Board of Advisors Professor Jacques Blamont, Chief Scientist of the Centre National d'Études Spatiales (the French space agency) and Dr. Hans Mark, former United States Secretary of the Air Force.

Announcement: Space Science Symposium

On March 23 and the morning of March 24, the National Air and Space Museum, Washington, D.C. will present "Space Science Comes of Age: Perspectives in the History of the Space Sciences." The symposium, bringing together distinguished scientists and historians, is free and open to the public. Speakers will include James Van Allen and Robert Jastrow.

In conjunction with the symposium, the Museum is publishing a book of papers by the participants, upon which the talks will be based. The book will be available at the symposium, through the Smithsonian Institution or at your local bookstore.

For further information, contact the Space Science and Exploration Department, National Air and Space Museum, Smithsonian Institution, Washington, D.C. 20560.



THE ICY CORRIDORS OF EUROPA—In the Voyager *photographs of Europa, the second Galilean moon out from Jupiter, it appeared as a smooth, icy body covered with crisscrossing patterns of dark lines. These lines may be shallow cracks in the surface of the satellite, as artist Michael Carroll projects in this painting of Europa as it might be seen by an observer sitting between the icy ridges. Here Jupiter dominates the Europan sky, dwarfing Io in the left center of the painting.*

Michael Carroll is a freelance artist living in San Diego, California. He is currently at work on the largest astronomical mural in the United States for San Diego's Fleet Space Theater.

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