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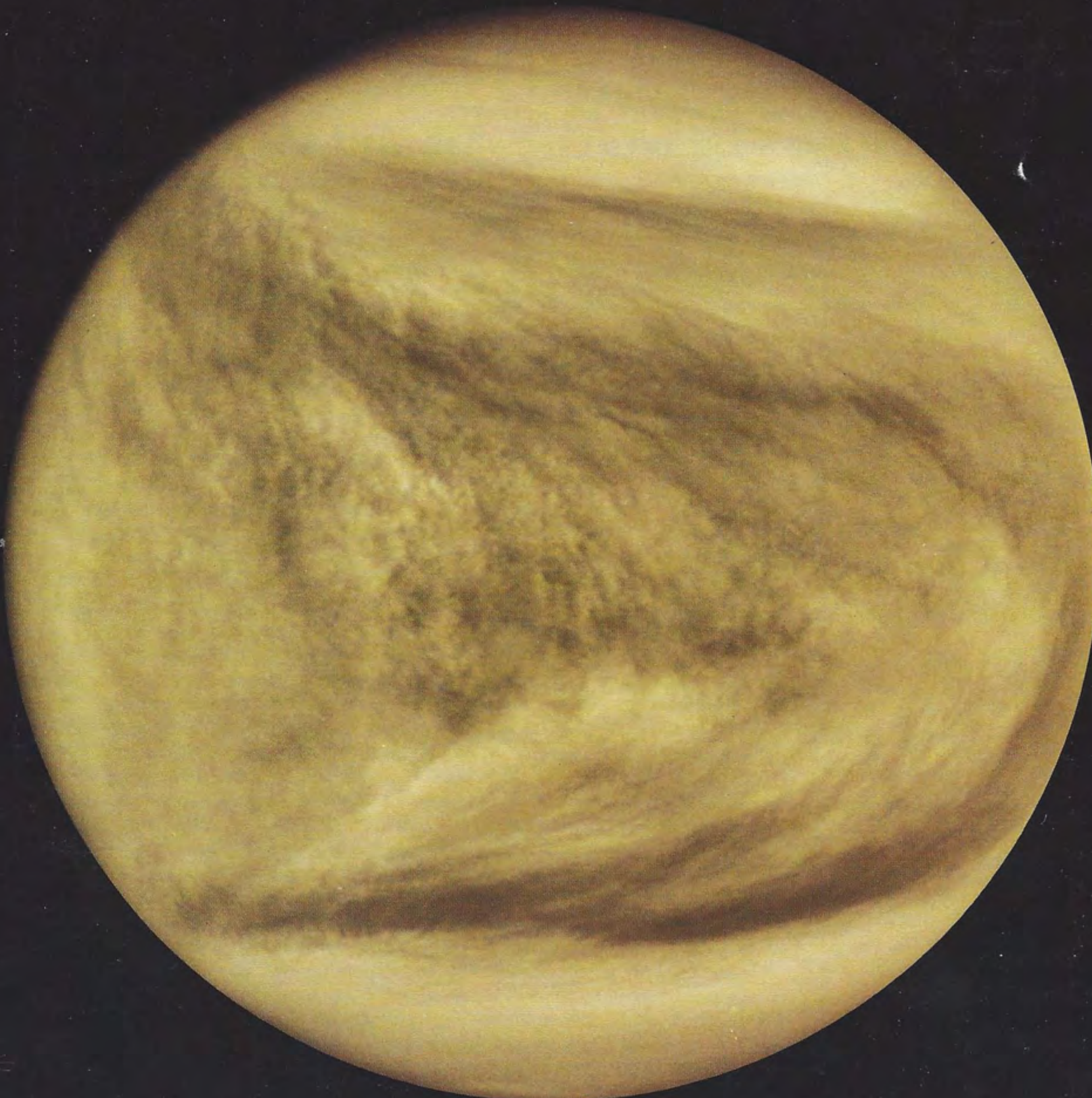

Exploring Venus

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Editor, CHARLENE M. ANDERSON; *Technical Editor,* JAMES D. BURKE; *Associate Editor,* LYNDINE McAFEE; *Assistant Editor,* DONNA STEVENS; *Art Director,* BARBARA SMITH

COVER: Thick sulfuric acid clouds completely enshroud Venus, hiding the surface and making the nearest planet very difficult to study. Our knowledge of Venus has been obtained only with great ingenuity. If seen by the human eye, the face of Venus would be almost featureless; the cloud patterns in this false color image appeared when seen by Pioneer Venus in ultraviolet light. The recent Vega mission used an old technology in a new way when it released balloons to study the atmosphere of Venus. ***Image: NASA***

Ballooning Around Venus

On September 19, 1783 a sheep, a rooster and a duck went aloft — the first passengers in a balloon. Their trip was made possible by the finding of French scientists Joseph and Etienne Montgolfier that a fabric bag filled with hot air would rise. Shortly after their discovery the Montgolfiers launched an unmanned balloon which, to the astonishment of all, flew for 1.5 miles. In November 1783 the first manned flight took place when a balloon carrying two passengers traveled 5.5 miles in 23 minutes. The advancement of science had its protesters in that era, too; when scientists ballooning from Paris landed in a small rural village, they were attacked by peasants terrified by the arrival of beings from outer space.

The Montgolfiers came to their epic invention by observing that smoke flowed upward from fire and deducing that smoke had some mysterious property that they called "levity." The term seems fairly appropriate to describe ballooning, even though it now has a long tradition of scientific exploration and, sadly but inevitably, military applications. Ballooning conjures visions of a leisurely sightseer, whereas a spacecraft presents an image of a single-minded workaholic. Thus, the arrival of two balloons in the atmosphere of Venus strikes one not only as a scientific landmark but also as a delightful adventure. It seems appropriate that a visit to our nearest planetary neighbor, often only a mere 26 million miles away, was accomplished by a meandering balloon.

The proposal that a balloon could be used to explore the atmosphere of Venus was the idea of Jacques Blamont of France, who then enlisted the support of Soviet, French and American scientists in a fine example of international cooperation. This cooperation was sustained and intimate as plans evolved from a focused mission to Venus alone to the final alternative of releasing a balloon from each of two Vega spacecraft on their way to Comet Halley. Moreover, the tracking of the balloons across Venus required the dedicated teamwork of scientists and engineers at radio observatories in 10 different nations: Australia, Brazil, Canada, Great Britain, West Germany, South Africa, the Soviet Union, Spain, Sweden and the United States.

This research is designed largely to satisfy curiosity about Venus, a planet almost the size of Earth but nearer the Sun. Venus, like Uranus, rotates differently from the other planets. As in most basic research, there is a serendipitous and practical side in addition to the gathering of pure data. Although Venus rotates on its axis at about one-hundredth the rate of Earth, its atmosphere rotates far more rapidly. The greenhouse effect of Venus and the velocity of rotation of its atmosphere are significantly different from those of Earth. Since it is not easy to create meteorological experiments in a test tube, the prospect of testing ideas about meteorological behavior on Venus is attractive. In California, a state with an atmosphere as close to heaven as is conceivable, there can be some hellish weather. But warnings from meteorologists armed continuously with information from space-based satellites keep the loss of life very low. Weather prediction is still an imperfect art, but information from distant Venus may one day provide meteorological theory that will benefit earthbound nonballooners.

It is intriguing to speculate that a model for international cooperation was also developed by the teamwork of scientists from the Soviet Union, France and the United States. Discovering common goals is easier in science than in world politics, but the search for enterprises that transcend international frictions cannot abate. Otherwise, the atmosphere of Earth may resemble that of Venus. — DANIEL E. KOSHLAND, Editor, *Science*

Exploring Venus by Balloon

by Jacques Blamont

Planetary Society Advisor Jacques Blamont is a leader in international planetary exploration, known for his creative contributions to the European, Soviet and American space programs. With Soviet colleagues he conceived the Vega balloon mission to Venus, as well as the American-Soviet-French tracking network. In this article Professor Blamont reports on the results of the Vega experiment.

In a future issue, Professor Blamont will present his innovative and exciting concept for exploring Mars by balloon.

It's time to look at new methods for exploring the terrestrial planets. Until 1985, little emphasis was placed on mobile vehicles. The probes that landed on Venus and Mars — the numerous Soviet *Veneras* and the American *Vikings* — were all fixed stations that stayed where they landed. In the hostile atmosphere of Venus, with a surface temperature of 475 degrees Celsius, the *Veneras* survived for an average of one hour. In the more friendly martian atmosphere, the *Vikings* worked for several years.

But to stay in a single spot is a strange strategy for exploring a new world. As part of the Soviet-led international *Vega* mission to Venus and Halley's Comet, in June, 1985 we took another approach when two instrumented balloons were placed in the atmosphere of Venus.

In 1981, the balloon experiment was officially included in the *Vega* payload, with the Soviet Union developing the flight hardware. The experiment was formally organized as a cooperative effort of Intercosmos, the Soviet organization responsible for international space experiments, and the Centre National d'Etudes Spatiales (CNES), the French space agency, with NASA assisting CNES. One of CNES's main responsibilities was to organize an international network of radio telescopes to track the motion of the balloons.

The *Vega* mission consisted of two identical and independent space probes that were launched from Baykonur in the Soviet Union on December 15 and 21, 1984. On June 11 and 15, 1985, the spacecraft reached Venus, where they each separated into two modules — two probes into Venus and two spacecraft that continued on their way to meet Halley's Comet in March, 1986.

Each Venus entry module then separated into two parts — a descent probe similar to the previous *Venera* landers and a canister containing a balloon. During the descent, the balloons inflated with helium from tanks that were jettisoned at an altitude of about 50 kilometers.

The 3.54-meter-diameter balloons each supported a mass of 21 kilograms (46 pounds), including a 6.9 kilogram (15 pound) gondola. They floated in a region of convective clouds at an initial altitude of 53.6 kilometers, with a pressure of 535 millibars (one millibar equals one one-thousandth of a bar — the pressure of Earth's atmosphere at sea level), and a temperature of 32 degrees Celsius. We chose this altitude partly because of its relatively benign temperature and pressure. At the surface, pressures can reach almost 90 bars, and temperatures can soar to 475 degrees — hot enough to melt lead.

Both balloons entered the atmosphere on its nightside, near the local midnight, at a longitude of about 180 degrees. The *Vega 1* balloon entered seven degrees north of the equator, the *Vega 2* balloon seven degrees south of the equator. They drifted westward with the predominant zonal (east-west) wind and we expected them to follow closely a parallel of latitude.

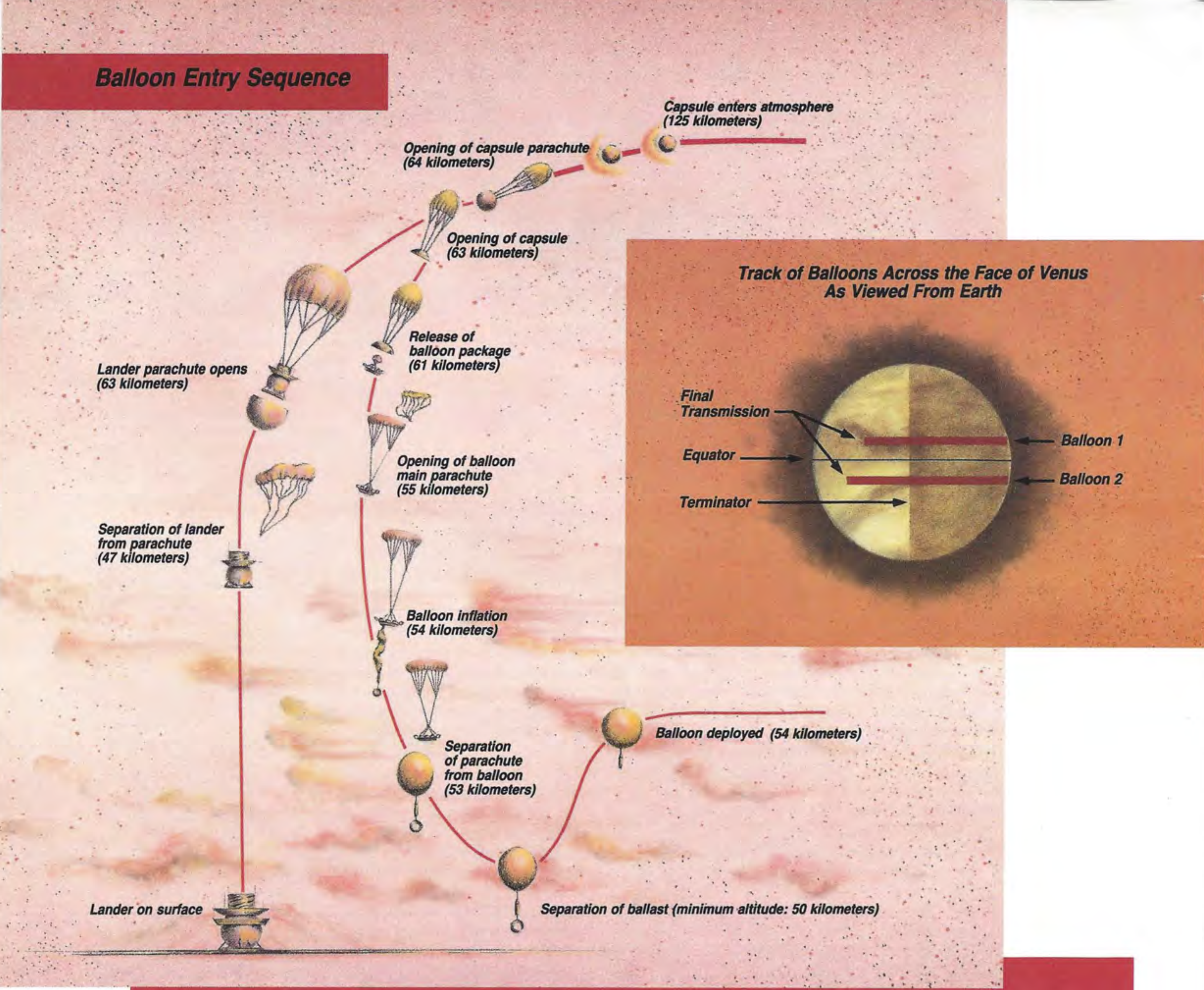
We tracked the balloons over more than 11,000 kilometers. They encountered dawn about 33 hours (8,000 kilometers) after deployment, and then penetrated far into the dayside hemisphere. We assumed that they continued to float after they stopped transmitting — when their batteries ran out. The batteries' capacity restricted the earthward radio signal to two to four watts, depending on the position of the balloon. As a consequence, we had to use exceptionally sensitive receiving stations in the Earth-based tracking network.

Our primary objective in the balloon mission was to gather information about the atmospheric motions, structure and clouds at the float altitude. We expected to gain new insight into such phenomena as turbulence, eddy motions, waves, meridional (north-south) flow, and heat and momentum transport. We planned two types of measurements: measurements taken by the spacecraft and transmitted to Earth, and tracking of balloon motion by antennas on Earth. Both types of measurements were provided by signals transmitted directly from the balloons to Earth.

Because of Earth's rotation, to receive telemetry continuously we had to use antennas widely distributed around our planet. Therefore, the tracking network consisted of 20 antennas spread over the globe. These stations were organized in two separate but coordinated networks: a Soviet network of six existing antennas on Soviet territory and a new 70-meter antenna at Ussurisk, built for this experiment; and an international network, coordinated by CNES, composed of the three sensitive 64-meter dishes of NASA's Deep Space Network and 11 radio astronomy observatories.

All instruments operated properly and the network retrieved data with amazing efficiency. The balloons provided the first opportunity to obtain meteorological measurements for an extended time from within Venus' atmosphere. Pressure, temperature and wind velocity were determined with great accuracy during the intermittent data transmissions, which occupied 25.5 hours of the balloons' 46.5-hour active lifetimes.

The many new results give us completely new insights into Venus' meteorology. For example, the balloons discovered downdrafts 10 times larger than expected, as strong as those found, to our knowledge, only in storms on Earth. And, on Venus, they occur planetwide. We were astounded by the behavior of the *Vega 2* balloon as it passed over Aphrodite, one of the highest regions on Venus. It seems that this 5-kilometer-high mountain



ABOVE: Vega's deployment of the balloons and landers at Venus required many steps that were performed at specific altitudes to prepare the probes for their missions. INSET: The Vega balloons entered Venus' atmosphere on the nightside and floated across the terminator (the boundary between day and night) well into the dayside. Illustrations: S.A. Smith

created atmospheric waves above and downstream from it, and these waves propagated all the way to the 55-kilometer altitude of the balloon. Strong waves buffeted the balloon and caused large deviations in its trajectory.

The balloons also gave us the first observations of weather on Venus: During their lifetimes, each stayed in air masses whose temperatures varied by 6.5 degrees Celsius. This indicates that eddies as large or larger than those we see on weather maps of Earth affect Venus' atmosphere.

When all the data are finally analyzed, we expect to uncover major clues to understanding the atmosphere of Venus, a noxious place of crushing pressures, searing temperatures and sulfuric acid clouds, which rotates 60 times faster than the solid body beneath it. It is a world very different from Earth, but by better comprehending how it works, we may come to better understand our own planet.

We obtained these important results with a science package weighing only about one kilogram (two pounds), showing that Venus' atmosphere should be explored with floating systems. It is easy to imagine vehicles working at practically all altitudes down to 15 kilometers — solar-heated montgolfieres, kites, balloons with valves and ballast to ascend and descend over a wide range of altitudes. We can even create a scenario for the return of samples from the ground, using existing techniques.

However, the interest of the various space agencies in exploring Venus seems to be waning. Only NASA's radar-mapping *Magellan* mission is now planned. But when the agencies decide to resume ambitious exploration of Venus, larger and more powerful systems will float for many days or weeks in the so-called hostile atmosphere.

The *Vega* mission has not only provided a rich scientific harvest, it has also been a model of international cooperation among scientists from the Soviet Union, France and the United States. We are working now toward extending this cooperation to *Phobos*, the next Soviet mission to Mars and its moons. It is an uphill fight! □

Questions & Answers

We are listening, but are we sending? I've heard a lot of talk about listening at the "magic" frequency, but nothing has been said about transmitting at this frequency. If we do not transmit, why should we expect other intelligent life to be transmitting?
— Mark Heyse, Memphis, Tennessee

Most SETI scientists agree that we should begin by searching for transmissions from older civilizations more advanced than we are in the art of interstellar communication. If we transmit, we would have to wait decades or more for our signal to reach them, and for their response to travel across space at the speed of light. And that could only happen if we guess the correct transmission frequency and direction. By limiting our initial experiments to reception, we hope to take advantage of "their" technological lead to save us time and costs.

If we truly are the new kids on the space-age block, it may also be prudent to listen a while. Eventually, our ability to communicate over interstellar distances will mature and we may then decide to transmit. That decision could be made sooner rather than later, if signals are detected by SETI experiments.

— MICHAEL J. KLEIN, *SETI Project Manager, Jet Propulsion Laboratory*

Why is space dark when the Sun is shining?
— Leah Cote, Quakertown, Pennsylvania

We see things either by direct or reflected light. A lightbulb, or the Sun, appears bright because it gives off light which then travels directly to our eyes. We see a book, or the Moon, by light that it reflects to our eyes. With the Moon, we see light from the Sun that is reflected off the Moon's surface.

When we look at a blue sky, we are actually seeing light from the Sun that has been reflected, or "scattered," by the molecules and dust in Earth's atmosphere. (When we see a beam of light come through a window, we are seeing the light reflected from dust particles in the air.)

In all cases, the light either comes to our eyes directly from its sources or it is reflected to our eyes by some object. Space is dark, even though stars are shining, because nothing there reflects enough light to our eyes.

But space is not empty: Astronomers have long recognized clouds of dust and gas between the stars. These clouds are so tenuous, and are often far from any star, that the light they reflect is just not enough to register on our eyes. We need large telescopes to see these clouds of dust, and even then they are recognized more often by what they obscure than by reflected light.

— LEE SAMUEL FINN, *California Institute of Technology*

What is Earth's position and velocity in the universe?
— Julian I. Adams, Berkeley, California

There is no way to determine our position in the universe, although it looks to us, as it would to observers anywhere, as though we are at the center. In the 1920s Edwin Hubble and Milton Humason established the expansion of the universe by observing that the more distant a galaxy is, the faster it is moving away from us. The universe appears to be expanding uniformly in all directions, so observers at any points in the universe would see all other objects as expanding away from them at speeds that are proportional to their distances. Of course, if we could see the edge of the universe, we would know more, but not only can we see no edge, we don't even know if the universe has an edge!

However, mass comes in clumps (such as galaxies, clusters and superclusters of galaxies) and gravitational pulls between clumps produce local motions slightly different from the uniform mean expansion. Careful observations by groups at the University of California at Berkeley and Princeton University show that our Sun is moving relative to the local average expansion (not the universe as a whole) at about 370 kilometers per second. Our galaxy, the Milky Way, is falling into the local supercluster of galaxies at about 610 kilometers per second.

— CHARLES R. LAWRENCE, *California Institute of Technology*

Why does the Moon appear larger when very low on the horizon and smaller when very high in the sky?
— Keith Hansen, Waukegan, Illinois

The larger Moon on the horizon is an ancient and much-discussed illusion that results, apparently, from the tendency of the eye and brain to compare objects in the visual field. You can prove that the Moon's angular diameter doesn't change appreciably by looking at it through a pipe or a hole in a piece of paper, and tracking its size as it moves across the sky. In fact, the Moon is a trifle larger when it is overhead, because you are closer to it by the radius of Earth — about 6,400 kilometers.

— JAMES D. BURKE, *Jet Propulsion Laboratory*

Because of the tidal forces induced in Earth by the Moon, the rotation of Earth is slowing. To conserve angular momentum in the Earth-Moon system, the Moon is receding from Earth. What forces act on the Moon so that it moves away from Earth?
— Barry A. Bodhaine, Boulder, Colorado

One oversimplified way to visualize the force on the Moon is to look at this diagram: As Earth rapidly rotates, friction drags the oceans' tidal bulges ahead of the direction of the Moon. The bulge on the side toward the Moon (because it is closer) pulls a bit harder on the Moon than the bulge on Earth's far side. Thus Vector A is a bit bigger than Vector B (both pass through the center of the Moon), so there is a net component of gravity pulling the Moon forward along its orbit, and causing it to move out. Meanwhile this same tidal friction is slowing the rotation of Earth.

— JAMES D. BURKE, *Jet Propulsion Laboratory*

ENCOUNTERS:

Interplanetary Explorations From Afar

by J. Kelly Beatty

"Encounter" is a word applied by space mission planners to the short span of time when a spacecraft nears a celestial object. Like other words of jargon, to the uninitiated it sounds cold and deadly dull. A single word like "encounter" cannot encompass the sense of danger and excitement of discovery engendered by a spacecraft streaking by a never-before-seen part of the solar system. Yet, to the scientists, engineers, journalists and others intimately involved in space exploration, there is no more exhilarating word.

To experience an encounter, you must sit and wait for hours at the spacecraft control center; you must strain to make sense of data flashing across display monitors; you must exult with the people who dedicate years of their lives to making those few hours possible. In the careful, sedate world of science, there is nothing like it.

J. Kelly Beatty, senior editor of *Sky & Telescope* magazine, is the only person who experienced all five recent spacecraft encounters: *Vega* at Venus, the International Cometary Explorer at Comet Giacobini-Zinner, *Voyager 2* at Uranus, *Vega* and *Giotto* at Halley's Comet (although a number of people — including Society President Carl Sagan and Executive Director Louis Friedman — participated in four of them). Here he shares the wonder and excitement of "encounter."

There are really only two kinds of space travel. One way, the most common, is to circle Earth. Satellites course around our planet in a wide variety of orbits that keep them aloft anywhere from a few days to millions of years. But no matter how useful, such a mission is bound to involve routine, repetitive activity. Ultimately, the spacecraft will either reenter the atmosphere or join the thousands of other pieces of orbiting debris that Earth has acquired over the last quarter century.

The other kind of space travel is exactly that — travel from Earth *to* someplace else — and it is always exciting. Exploring the solar system is high adventure on a cosmic scale, a technological game of chance that has been played and won many times. The players are called *Mariners, Vikings, Veneras* and other equally stirring names. Their coaches are the flight teams, scientists and engineers who dedicate many years and sometimes decades in exchange for a few hours of close-up inspection. But it's worth it. Nowhere else in science do we learn so much in so brief a time as when our instrumented emissaries encounter other worlds.

Missions to the Moon, Mars and Venus were frequent during the 1960s, and to Mercury, Jupiter and Saturn in the years thereafter. But now the game is played less frequently. In fact, the entire decade of the 1980s may well pass without a single American launch toward the planets. It is all the more ironic, therefore, that a flurry of interplanetary encounters took place within a recent nine-month period. By coincidence only, more spacecraft made more visits to more places than at any time since the early 1970s. And there were more players, too, as other nations savored their inaugural deep-space flybys.

Vega at Venus

The first "place" was Venus, where a pair of Soviet spacecraft came calling on June 11 and 15, 1985. Originally, Venus was to be the missions' sole destination, with two large craft orbiting the planet and four smaller probes descending to its atmosphere and surface. But in 1981 Soviet scientists adopted a new plan that would send the orbiters on to Halley's Comet after reaching Venus, and the *Vega* mission was born. (*Vega* is a contraction of the Russian words "Venera" for Venus and "Gallei" for Halley.)

Moscow's Space Research Institute, a branch of the Soviet Academy of Sciences under the direction of Roald Z. Sagdeev, fashioned the *Vega* scientific payload for the flight. Scientists from several European nations — eastern and western — also contributed experiments. Each craft had been programmed to perform observations and operations automatically. So as the anxious *Vega* scientists gathered on encounter day at "IKI" (the institute's Russian acronym), there was little more to do than gulp coffee and wait.

High above the nightside of Venus, a 2.4-meter sphere sprang free of *Vega 1* and plunged toward a hellish world encased in a dense cocoon of carbon dioxide and sulfuric-acid haze. Slowed first by atmospheric drag and then by parachute, the sphere cleaved in two. A heavily instrumented lander emerged from one half and continued toward the surface. From the other came something never before used in planetary exploration: a balloon. It drifted among the sulfurous clouds 55 kilometers high, bobbing up and down with the wind currents. A small nest of instruments dangled below and periodically radioed its findings to Earth.

Congratulatory Call

From the United States came a congratulatory call to Sagdeev from Lew Allen, director of the Jet Propulsion Laboratory. Discreet agreements, arranged through French scientific liaisons, had made the California facility an important but silent partner in the unprecedented experiment. (See the May/June 1985 *Planetary Report.*) For two days the giant, 64-meter antennas of JPL's Deep Space Network (DSN) both tracked the balloons and collected their faint trickle of data, which a number of American scientists later helped analyze. JPL's help gave the *Vega* project round-the-clock coverage that Soviet antennas alone could not provide. It was the first meaningful American/Soviet cooperation in space since the *Apollo-Soyuz* Test Project a decade earlier.

Meanwhile, a major problem developed aboard the lander. Even though most of its detectors were operating as planned, a drilling device had sprung into action prematurely during the descent. That meant that there would be no soil sample to test. But the second *Vega* arrived at Venus four days later, performing its electromechanical choreography on automated cue. The balloon floated and relayed data for nearly two days. And this time the lander drilled into the torrid surface as planned, relaying important chemical assays to Earth.

One might think that being among the *Vega* scientists would make getting the answers easier, and this proved partly true. The experiment results came to IKI directly from a control center elsewhere in the Moscow area, but it was a slow, almost spoonfed process. A single, one-hour press conference was held for the handful of journalists on hand.

Still, it seemed clear that the Venus portion of the *Vega* flights — particularly the novel but risky balloons — had been a resounding success. The team's happiness was restrained but evident. Experimenter Lev Mukhin proudly showed off charts of data fresh from the printer, speculating candidly about their significance. This euphoric rush of discovery is unique to the encounter phenomenon. In the United

***ABOVE:** Beneath a model Voyager spacecraft, reporters gather around scientists for a background briefing. (Planetary Society Advisor Garry Hunt is at far right, the author is kneeling at far left.) During an encounter, the press room in Von Karman Auditorium at JPL swarms with mobs of press and project personnel, all trying to digest the stream of data collected by the spacecraft.* *Photo: JPL/NASA*

***TOP RIGHT:** The day before ICE encountered Comet Giacobini-Zinner, project scientists and mission planners met at NASA's Goddard Space Flight Center to discuss their strategy for this first flight through a comet.* *Photo: Goddard Space Flight Center/NASA*

***RIGHT:** At a press conference following the Giotto encounter with Halley's Comet, a jubilant Uwe Keller of the Max Planck Institut für Aeronomie holds up an image of the comet's nucleus.* *Photo: J. Kelly Beatty, Sky & Telescope*

States, I explained to him, it's termed "instant science." Mukhin nodded with a knowing grin.

ICE Visits a Comet

Three months after the *Vegas* descended upon Venus, another international team of scientists gathered for another far-flung encounter, this time with a comet. To reach Moscow I had crossed eight time zones. But NASA's Goddard Space Flight Center was but a one-hour hop by jet down the East Coast. Goddard has traditionally handled mostly spacecraft in Earth orbit, so to manage an interplanetary mission was a new experience.

It hadn't been planned that way — at least officially. In 1982 NASA decided to take an obscure scientific craft already in space, the International Sun-Earth Explorer 3, and send it chasing after a comet named Giacobini-Zinner (see the May/June 1985 *Planetary Report*.) This rags-to-riches plot was the brainchild of Robert Farquhar, a flight dynamicist at Goddard who for years has conjured up unorthodox ways to flit around the solar system. "It was always kind of a joke that someday we'd go for a comet," Farquhar admits with a smile.

To reach Giacobini-Zinner, NASA flight controllers put ISEE 3 through a bizarre series of looping maneuvers that culminated in a potentially dangerous pass within 120 kilometers of the Moon on December 22, 1983. Emerging unscathed, the spacecraft had gained enough velocity to leave the Earth-Moon system entirely. NASA renamed its recycled payload the International Cometary Explorer (ICE), and the race was on.

The scientists at Goddard were largely unaccustomed to the demands of "instant science." Ordinarily they would expect to receive computer tapes of data in the weeks and months after their experiments collected it. But an encounter environment is wholly different, and Goddard managers scrambled to provide the experimenters with access to the data as they arrived. The large analysis room teemed with computers, display monitors and bodies as the spacecraft closed in. Elsewhere on the lab, an even larger auditorium buzzed with the animated chatter of hundreds of news correspondents.

On September 11, the aging ICE probe plunged through Giacobini-Zinner's slowly writhing tail less than 8,000 kilometers from its nucleus. No camera was aboard to record the event, but a chorus of electromagnetic sensors responded as the spacecraft passed through the comet's huge bubble of ions. Although some experimenters wrestled to make complete sense of their data, the comet seemed to match theorists' predictions fairly well. (See the May/June 1986 *Planetary Report*.) The comet's icy heart is no more than a few kilometers in diameter, but the gas and dust it sheds dominate a huge volume of space. It is an environment of agitated plasmas, warped magnetic fields and strong electrical currents — heavy fare for the uninitiated reporter. As a result, the first-ever flight through a comet garnered little more than passing mention in the US news media.

Voyager Reaches Uranus

The truth is that most editors couldn't care less about million-degree plasmas — they want "strong visuals" (pictures) and "quotable quotes." What the ICE encounter could not give them, *Voyager 2*'s flyby of Uranus would. In some respects the plot was the same: *Voyager 2*, already in space for nine years, had not been designed to perform beyond Saturn. Uranus lies nearly 3 billion kilometers from the Sun. Daylight there is four times weaker than at Saturn, about 400 times weaker than at Earth.

NASA is not likely to send another probe Uranus' way for decades, so the flight team at JPL resolved to make the most of *Voyager 2*'s opportunity. Clever engineering fixes made the spacecraft smarter, steadier and healthier than it had been during the 1981 flyby of Saturn. A major overhaul of the Deep Space Network tripled the rate at which the spacecraft could transmit its findings and paved the way for full photographic coverage.

Voyager 2's encounter with Uranus on January 24 was virtually flawless. (See the November/December 1986 *Planetary Report*.) Perhaps the most challenging observation was an all-or-nothing photographic sequence of the moon Miranda. But as Imaging Team Leader Bradford Smith later reported, "Our tracking of Miranda as we went by was perfect." And so were the pictures. In fact, in one brief visit *Voyager 2* gathered hundreds of times more information about Uranus, its moons and its ring system than astronomers had managed in two centuries of telescopic observation.

A special drama unfolded on the morning of *Voyager 2*'s historic visit. The European Space Agency had lost contact with *Giotto*, its first interplanetary probe, and the worried project manager came to JPL for help. It would take the resources of the Deep Space Network to restore contact, but *Voyager 2* was only hours from Uranus. First, a small antenna at Goldstone, California, turned toward *Giotto* to ensure that it was still transmitting. Later in the day, after the tracking of *Voyager 2* had been "handed over" to the DSN facility in Australia, Goldstone's ultrasensitive 64-meter dish joined the rescue effort. It quickly regained control of the probe, which apparently had wobbled out of alignment with Earth.

Heading for Halley's Comet

Giotto was part of a five-ship flotilla bound for Halley's Comet. Also in on the chase were the two *Vega* spacecraft and a pair of Japanese probes named *Suisei* (Comet) and *Sakigake* (Pioneer). All of them would reach the celebrated visitor during March, and it was risky business. Although the Japanese chose to remain a safe distance away, the *Vega*s would cut less than 9,000 kilometers in front of the comet. *Giotto*'s perilous assignment was to dive deep into the dusty coma and pass as close as possible to the nucleus. (See the July/August 1985 *Planetary Report*.)

In Moscow, the *Vega* team readied for the first high-speed dash. This time the world's news media showed considerably more interest in the goings-on (despite the cold Russian winter), and IKI's staff found itself the center of attention as never before. Planetary Society President Carl Sagan, Executive Director Louis Friedman, and a delegation from NASA were among the scores of scientists from a dozen nations on hand. Sagdeev, who is one of the Society's Advisors, even opened the institute's doors to a small contingent of American space reporters.

On the morning of encounter day, March 6, IKI's gray corridors and brightly carpeted floors resonated with excitement. Although the proceedings were conducted in Russian, many of the institute's staff spoke English, and headsets for translations were provided during key phases of the mission. *Vega 1* operated very well during the encounter, but the comet dust that bombarded it at 80 kilometers per second took a heavy toll on instruments and other systems. Pummeled to near destruction, after the flyby the outstretched solar-cell panels could provide only half the electricity that they had beforehand.

Festive Mood

With *Vega 1*'s run completed, the mood at IKI became less apprehensive and more festive (as demonstrated by the diplomatic limousines lined up outside). The second spacecraft followed three days later, and at first it appeared that an equally successful performance was in order. Then, 32 minutes before closest approach, imaging scientists learned that the automatic pointing system for *Vega 2*'s cameras had malfunctioned. Pictures began to arrive that didn't show the comet's nucleus at all!

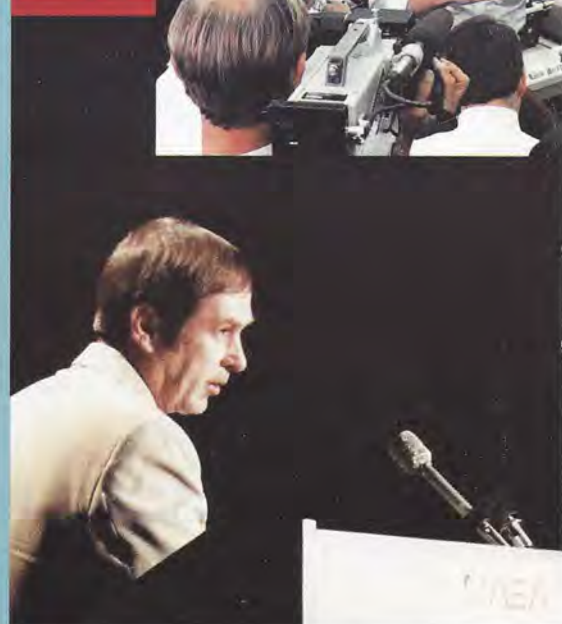
As precious minutes ticked away, Soviet controllers fired a radio command at *Vega 2*, switching it to a backup tracking system and a wider field of view. But, even traveling at the speed of light, the order would take 10 minutes to reach the spacecraft and another 10 for its acknowledgement to return. Louis Friedman, sitting among the now-frantic scientists, recorded the scene

***ABOVE:** At the Madrid tracking station of NASA's Deep Space Network, Vega balloon project scientists gather to test the compatibility of the balloon hardware with NASA's equipment. They are (left to right): Jacques Blamont, Viatcheslav Linkin, Robert Preston, Charles Stelzreid, and (kneeling) Gerard Laurans. The Madrid station was one of many around the world that followed the balloons as they drifted across Venus.*
Photo: J. Kelly Beatty, Sky & Telescope

***ABOVE:** Frank Bristow (far left), head of JPL's Public Information Office, presides over a morning press briefing during the Voyager 2 encounter with Uranus. These daily briefings require the investigators to do "instant science," analyzing the spacecraft data overnight and presenting it to the press each morning. This panel includes (left to right) G. Leonard Tyler, Charles W. Hord, James H. Trainor, Frances Bagenal and Arthur L. Lane.*

***BELOW:** In his pos as Voyager project Richard Laeser oft himself besieged b press. Photo: JPL/*

***RIGHT:** Deputy Imaging Team Leader Laurence Soderblom describes pictures of Uranus' moon Umbriel to the gathered press at JPL. Encounters draw reporters from around the world who come to witness an event unique in the practice of science.*
Photos: JPL/NASA



in a hastily written chronicle:

9:59 am — What happened? First bad picture comes in.
10:01 am — Spacecraft commanded to implement correction.
10:11 am — 82,000 kilometers away.
10:21 am — Nothing happens.
10:22 am — Spacecraft has acknowledged command.
10:23 am — Screen suddenly shifts to wide format. Really looks like a comet.
10:29 am — Fantastic! The best pictures yet!

Vega 2's ordeal was over. The ensuing "damage report" showed that a few instruments besides the cameras were seriously affected and that the solar cells suffered even more degradation than during the first flyby. But a healthy measure of good luck had helped *Vega 2* through it all — after the encounter the cameras' pointing system returned to normal. Or perhaps the legendary comet itself had exerted some mystical influence. Hungarian Karoly Szegö, one of the imaging team's principal scientists, even toasted the comet at a post-encounter party. "Fred Hoyle was right," he joked. "Comets are living things."

Giotto Closes Fast

However, little time remained to savor the moment, as *Giotto* was closing fast for its dramatic March 14 rendezvous. For many participants, the snow of Moscow soon gave way to the verdant greens of Darmstadt in the Federal Republic of Germany, where the European Space Agency maintains its main control center. There word arrived from Japan that *Suisei*, which passed within 150,000 kilometers of the comet on March 6, had been rocked by collisions with two good-sized dust particles. Concern mounted for *Giotto*'s safety.

A high-precision tracking exercise involving the *Vega* spacecraft, Soviet and American tracking stations, and the International Halley Watch, had refined estimates of the comet's location in space considerably. After some debate, ESA science director Roger-Maurice Bonnet chose a final aim point just over 500 kilometers from the sunlit side of the comet's nucleus.

Giotto carried 10 instruments, and all of them were operating perfectly as the probe plunged into the comet's coma. With about three hours to go the camera transmitted its first views of the comet's heart, dense with dust and frothy with activity. Television screens in the control center displayed the images as garish riots of computer-generated color. (The hues had been chosen to accentuate brightness differences near the nucleus, but they made the scene confusing to interpret. At least one broadcaster spoke of the comet's red core embedded in a sea of purple.)

The end came 14 seconds before *Giotto* came closest to the comet. Ripping through the spacecraft at nearly 70 kilometers per second, microscopic dust particles interrupted the electrical system. The camera stopped taking pictures. A larger particle slammed into the craft with enough momentum to start it wobbling. *Giotto*'s signal abruptly cut off, then returned sporadically. Thirty-two minutes later, an automatic mechanism aboard restored stability, and radio antennas locked onto the signal without further interruption.

Mission planners had expected *Giotto* to survive, and it did. Despite some permanent damage, Bonnet said that the plucky craft had succeeded "beyond all expectations." In fact, its overall health was good enough to permit a course change in the weeks thereafter. This will bring *Giotto* near Earth on July 2, 1990, and at that time it may be redirected toward yet another comet. Sagdeev also has some ideas about where the *Vega*s might be sent next. And, not to be outdone, Farquhar is ruminating on the ultimate fates of *Suisei, Sakigake* and *ICE*. □

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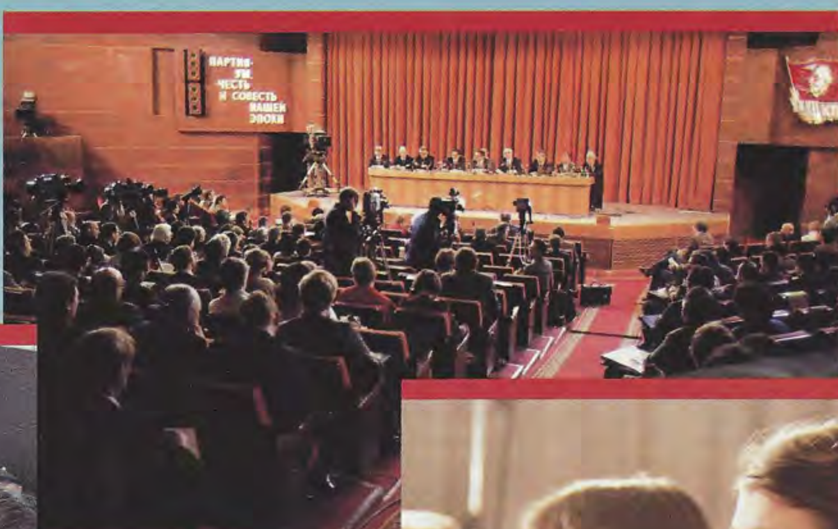


ABOVE: Society Advisor Roald Sagdeev addressed the gathered students, flanked by Society President Carl Sagan (left) and Executive Director Louis Friedman (right).
Photo: J. Kelly Beatty, Sky & Telescope

TOP LEFT: The Soviet Institute for Space Research (IKI) threw open its doors to the world press for the Vega encounters with Halley's Comet. This large auditorium was filled with reporters covering the first spacecraft to reach the comet. ABOVE: In honor of teacher Christa McAuliffe, IKI Director Roald Sagdeev and The Planetary Society organized a visit to the Institute for schoolchildren from several countries. Students from the Anglo-American School in Moscow mingled with Soviet students, and together they shared the excitement of encounter.
Photos: J. Kelly Beatty, Sky & Telescope

News & Reviews

by Clark R. Chapman

Planetary science has come of age as a truly international undertaking, symbolized by two back-to-back scientific conferences held in Europe this past autumn. In late October, hundreds of scientists from around the globe gathered in the old German city of Heidelberg to discuss results from the multinational explorations of Halley's Comet. The following week, Paris was the site of the first meeting outside the United States of the Division for Planetary Sciences (DPS) of the American Astronomical Society. In Paris, Europeans outnumbered Americans in what was the largest DPS gathering since the division was formed in 1969.

In Heidelberg, one could enter a Weinstube and find huddled around a single table scientists from the United States, western Europe, eastern Europe, the Soviet Union, perhaps Japan and a southern-hemisphere nation. Many had arrived in Heidelberg to hear, for the first time, the full results of the multiple comet spacecraft missions and coordinated ground-based studies. Sketchy reports had been published in the May 15 issue of *Nature*, but now there had been time for more refined processing of the data and perhaps for some synthesis.

Such expectations proved unrealistic for there were few startling revelations in the old Congress Hall next to the River Neckar. In retrospect, we can realize that Heidelberg was the first chance for many of the scientists to meet with each other, compare notes and begin the lengthy creative process of synthesis that will ultimately fill out our view of last year's famous interplanetary visitor. Indeed, another meeting in Germany has already been planned for spring of 1989, when we may realistically expect the synthesis to have been nearly completed.

Heidelberg reports nevertheless did portray a fascinating picture of Halley's Comet. New interest was inspired in future missions to comets, such as NASA's Comet Rendezvous Asteroid Flyby (CRAF) mission, for which tentative instrument selection had been announced two weeks earlier, although the future of this mission remains in doubt (see page 11). Comet missions have been sold, in the past, on the theoretical expectation that comets are primitive, pristine objects left over from the birth of our solar system.

Scientists had expected that they are made of the same mix of chemical compounds as the nebular cloud from which the Sun and planets condensed. The processes of planetary accumulation and subsequent evolution (including loss of volatile compounds, heating, chemical interactions and core formation) have erased many clues from the epoch of planetary birth that might otherwise be found from detailed studies of the various planets. But comets, we thought, had been protected from modifications in a cosmic deep freeze (the Oort cloud) far from the Sun in interstellar space.

The Heidelberg picture of Halley's Comet, as summarized by Fred Whipple on the final day of the conference, more than confirmed our expectations that comets are primitive. The comet's measured chemical abundances are more nearly of solar composition than any other planetary materials, including the most primitive, undifferentiated meteorites, which have been the standard of "primitiveness" for several decades. Halley's Comet, in fact, is loaded with tiny particles rich in the elements carbon, hydrogen, oxygen and nitrogen that are often fractionated in meteorites, Moon rocks, terrestrial samples, and so on.

The nucleus of Halley's Comet, as revealed by the highly processed pictures taken by the European *Giotto* spacecraft, is hauntingly beautiful, yet it remains mysterious, as well. We may not know for another 76 years whether some crater-like features are impact craters, vents or some completely new type of topographical feature. That's because none of the flyby spacecraft rendezvoused with Halley's Comet, as mission planners had been hoping in the 1970s before early mission concepts were cancelled. Definitive understanding of comets awaits a rendezvous mission followed by a sample return.

In fact, comparison of Soviet and European spacecraft pictures of the nucleus with the vast ground-based telescopic data archived by the International Halley Watch resulted in some hot debates in Heidelberg. These moved west to Paris the following week. Many researchers had been convinced before arrival in Heidelberg that the comet's nucleus spins once on its axis every two days, or a little slower. But several independent ground-based observers discovered that it varies regularly with a period slower than seven days. It will be impossible to make a believable map of the nucleus, and relate the jetting and tail-forming processes to active areas on the nucleus, until this controversy is sorted out.

Another debate centered on whether the bulk density of Halley's Comet is about that of a bag of feathers, as most investigators reported, or is more nearly like that of ice, as had been expected. For comet scientists, both Heidelberg and Paris provided the chance to uncover these discrepancies and begin the collaborative work that will be necessary to learn all that our generation ever will about Halley's Comet.

Gastronomy and Astronomy

The Paris DPS meeting featured fine food, of course. The annual banquet was enjoyed in the chandeliered dining rooms of the old Hotel Meurice on rue de Rivoli, across from the Tuileries. The five-course meal began with "Terrine de Fruits de Mer Arlequin" and concluded with "Charlotte aux Poires," with raspberry sauce.

During the cocktail party before the banquet, outgoing DPS chairman Joe Veverka presented the two prestigious awards of the DPS. Coincidentally, the awards honored research on the same difficult problem. George Wetherill received the Gerard P. Kuiper Prize for his multifaceted research over several decades, including his now largely completed synthesis of the physical and dynamical processes responsible for getting meteorites out of the asteroid belt. Jack Wisdom, now at the Massachusetts Institute of Technology, won the Harold Urey Prize (offered to promising younger scientists) for his demonstration that so-called chaotic motion is responsible for changing the orbits of asteroidal debris near the three-to-one commensurability with Jupiter (where an asteroid circles the Sun three times each jovian year) into Earth-crossing orbits — just the specific physical mechanism Wetherill was looking for to incorporate into his larger picture.

Chaos is a hot new topic in mathematics, with surprisingly wide application to physics and to everyday life. Our world is even less deterministic, it seems, than the idealized caveats of Heisenberg's Uncertainty Principle had cautioned us earlier this century. Even large dynamical systems (Earth's atmosphere, for example) are fundamentally and inherently unpredictable. Only in the last 20 years has it been clearly demonstrated that phenomena as diverse as dripping faucets and weather fronts can never be predicted for long in the future (see the December *Scientific American*).

Jack Wisdom had shown in the last few years that even the simplest dynamical systems — the few-body problems of orbital and rotational mechanics — can also be chaotic. In his Urey Prize lecture in Paris, Wisdom explained that chaotic motion is more common than had been thought, and is not limited to the tumbling spin of Saturn's satellite Hyperion and asteroid orbital oscillations near the 3:1 Kirkwood Gap. Wisdom showed that other features of the asteroids can be explained by the mathematics of chaos, and he also believes that every planetary satellite that is now tidally locked to its planet (keeping one side facing the planet) has evolved through an epoch of chaotic spin.

Clark Chapman is a planetary scientist on the staff of The Planetary Science Institute (a division of Science Applications International Corporation) in Tucson, Arizona.

World Watch

by Louis D. Friedman

In late October and early November, 1986, the scene of planetary exploration moved across the Atlantic. Scientists gathered at two major meetings: a European Space Agency (ESA) symposium on Halley's Comet, held in Heidelberg, Federal Republic of Germany; and the Paris meeting of the Division for Planetary Sciences (DPS) of the American Astronomical Society, which met for the first time in Europe.

HEIDELBERG — In a 14th century castle atop the ancient city of Heidelberg, 500 scientists lifted their glasses and toasted Edmund Halley and his famous comet. At the meeting, over 200 papers were presented, giving preliminary results of ESA's *Giotto* and Intercosmos' *Vega* encounters, the Japanese *Suisei* and *Sakigake* missions, and the ground-based network of the International Halley Watch. (Later this year, a special issue of *The Planetary Report* will cover the results.)

The surprising and still unexplained nature of the nucleus and its activity as it heats up near the Sun was the principal topic of discussion. A major controversy surfaced over the comet's rotation. Various data support a 2.2 day rotation; other data indicate 7.4 days. The probable answer is that the rotation is complex and wobbly, producing different periodic effects. No one has yet figured out the details.

While scientific debate and analysis dominated the five-day symposium, the participants agreed that Halley's Comet provided yet another generation with a significant lesson. Leaders of the major space agencies and of the International Halley Watch repeatedly commented on the depth and breadth of cooperation in studying the comet. Five spacecraft from 19 countries, 4 major space agencies, 1,000 scientists and observers from more than 47 nations all worked together in the most extensive cooperative effort ever in space science.

At the symposium's end, Dr. D. Asoka Mendis, summed up the effort: "Whatever else they say in 2061 when Halley's Comet returns to the vicinity of Earth, they should say of us, 'They did their best.'"

PARIS — Halley's Comet shared equal billing with Uranus at the DPS meeting — the major annual meeting of planetary scientists. Several sessions highlighted results from *Voyager 2*'s encounter with Uranus: the complicated and unique magnetic field; the bizarre large satellites (especially Miranda); the thin, dark rings; the newly discovered small satellites; and the hazy, blue atmosphere. (See the November/December 1986 *Planetary Report.*)

All speakers emphasized the interdisciplinary work required to explain the observations: laboratory experiments to test materials that might make up the satellites, analysis of orbital motions and interactions between the satellites, and study of the observations themselves.

In addition to the scientific sessions, a panel of leaders from various space agencies discussed the "Future of Planetary Exploration." Lew Allen, Director of the Jet Propulsion Laboratory, reported on progress toward renewing the space cooperation agreement between the United States and the Soviet Union.

On the panel with Dr. Allen were Geoffrey Briggs of NASA, George Haskell of the European Space Agency, Isaac Revah of the French Space Agency, and David Morrison of NASA's Solar System Exploration Committee. Each discussed the growing international character of the planetary program. Among the key points were:

— NASA's planetary program is in great difficulty because the agency itself puts a low priority on planetary exploration. Existing missions — *Magellan, Galileo, Ulysses* and the Mars Observer — are not all being accommodated on the space shuttle launch schedule. A new start for the Comet Rendezvous Asteroid Flyby (CRAF) mission appears to have been delayed again.

— The development of a new US spacecraft, the *Mariner Mark II*, has also been delayed. This new type of spacecraft was recommended by the Solar System Exploration Committee for missions to the outer planets, comets and asteroids.

— The European Space Agency is considering many possible next steps in deep space. The principal missions being studied are: *Cassini*, a cooperative mission with NASA to Saturn and Titan; and *Vesta*, a cooperative mission with the Soviet Union and France to Mars and the asteroid belt. *Cassini* would require NASA's undeveloped *Mariner Mark II*, so ESA is more hopeful about joining the *Vesta* mission.

— ESA is also looking at *Caesar*, a cometary atmosphere sample return mission.

— With the Soviet Union, the French space agency, the Centre National d'Etudes Spatiales (CNES), is participating in *Phobos*, a mission to Mars and its small moons. Their next major project will be *Vesta* with the Soviets and, they hope, ESA.

— All the space agencies are looking forward to a major Mars exploration initiative (see box) led by the United States and the Soviet Union in a cooperative program. No plans were announced, but references were made to Soviet planning for a series of Mars missions in the 1990s, culminating in a robotic sample return mission by 2000.

WASHINGTON, DC — NASA has announced the selection of 38 possible experiments for the scientific payload of the Comet Rendezvous Asteroid Flyby (CRAF) mission. Scheduled for launch in 1993, this mission is targeted for Comet Tempel II. However, this schedule requires that the project receive a "new start" in fiscal year 1988. And NASA did not include the new start in its budget request to Congress.

The only hope now of realizing a 1993 CRAF mission is a concerted effort to develop technology for the new *Mariner Mark II* spacecraft and for CRAF's science investigations. If, in the next two years, they could be sufficiently developed, then CRAF could receive a new start in fiscal year 1989 and still make its rendezvous with Comet Tempel II.

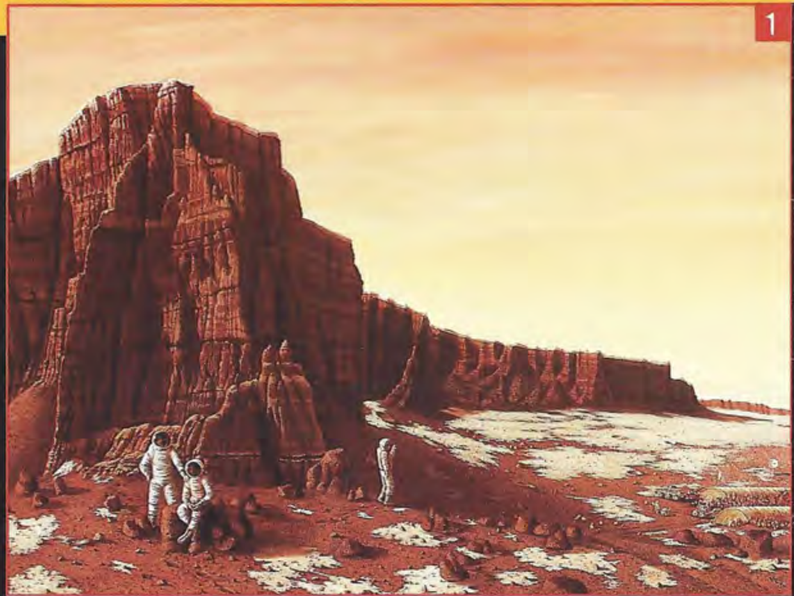
Efforts to mount a US comet mission have been frustrated regularly since the mid-1970s. Various missions were proposed, including: a rendezvous with Halley's Comet, a simple flyby of Halley's Comet, flybys of several smaller comets, and a low-thrust propulsion rendezvous with Comet Tempel II. Will CRAF be the latest in this series? Do we want a US mission to a comet? We invite your letters on this topic for a future issue of *The Planetary Report.*

The Planetary Society has led the advocacy of cooperative US/USSR exploration of space. We have focused our efforts on the goal of an international program to explore Mars, with both robots and humans. We are pleased with the progress: As part of presummit negotiations, representatives of the United States and the Soviet Union have worked out an agreement on space cooperation. And, in both countries, Mars exploration is being studied as the most probable major program within such an agreement.

Nothing is certain, and this is still only a hope, but two years ago neither cooperative exploration nor the goal of Mars were being discussed by either agency. Now these topics are receiving keen attention.

Louis Friedman is the Executive Director of The Planetary Society.

The Next Giant Leap: SPACE EXPLO



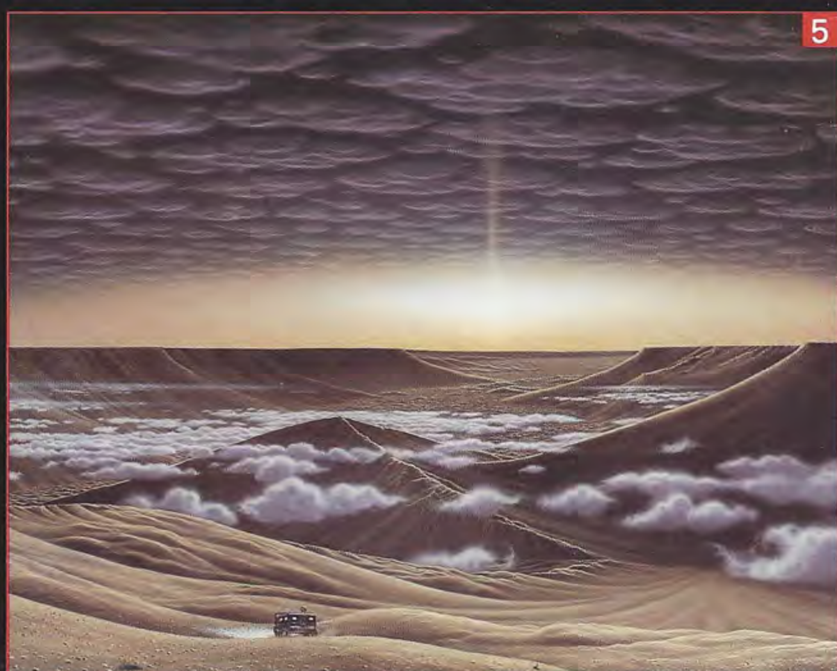
Those interested in the peaceful uses of space have long understood that exploring the cosmos must be the work of many nations. The search for knowledge and for ways to make life better on Earth is not a uniquely American quest. The Soviet Union, Japan, the nations of Western Europe, China and India have all forged ahead with extensive space programs of their own.

This makes space exploration a foreign policy issue as well as a national endeavor. But the United States has yet to develop a coherent space policy that both fully exploits the great potential of space as an instrument of foreign policy and recognizes the importance of international collaboration to the successful exploration of space.

Over the past year, many Planetary Society members have participated in the first nationwide study of the prospects for international cooperation in space. In early 1986, shortly before the *Challenger* tragedy, the United Nations Association of the United States of America (UNA-USA, chaired by Elliot Richardson) launched the study, the third in an annual series of studies of global issues. Some 90 communities around the country set up study panels, which spent several months examining the issues and devising recommendations for US policy. Their conclusions were released on October 24, 1986 in a consensus report entitled *The Next Giant Leap in Space: An Agenda for International Cooperation.*

As the report emphasizes, cooperation is not an end in itself. To carry out effective space programs, countries must have well-defined goals and must be willing to commit the resources needed to reach those goals. To collaborate in space, countries must perceive that they can best achieve those ends by working together. The scores of community panels participating in the UNA study concluded that there are two goals that can best draw nations together in a mutually advantageous space venture: the exploration of Mars and the study of Earth.

The Mars goal, particularly the prospect of a human mission, has been much discussed as a way of bringing together the United States and the Soviet Union in a joint program that could teach the two countries to work together and usher in a new era of harmonious superpower relations on Earth. Unfortunately, it is far more likely that the distinctly unharmonious superpower relations that currently prevail would make it impossible for the two countries to see the mission through together. The political differences between the superpowers reflect fundamental differences in basic values, not just misperceptions based on lack of contact. A strictly US-Soviet joint program would suffer from all the slings and arrows inherent in bilateral programs between the two. As the past two Olympics held in Moscow and Los Angeles made clear, at times of tension, any bilateral program can fall victim.



But as the Halley's Comet and Cospas/Sarsat (a cooperative US, Soviet, Canadian and French search and rescue satellite system) programs demonstrate, cooperative programs may stand a better chance. If the other spacefaring nations play major roles in the Mars missions, up to and including a human expedition, and if the program is perceived as a multilateral rather than a bilateral goal, the United States and the Soviet Union would be far less likely to try to use a cutoff of cooperation to send political signals to each other.

The other proposed focus for international cooperation in space, the study of Earth, will draw virtually all nations into a crucial program of research on the fate of our planet. Earth is a constantly changing world, enduring ice ages, earthquakes, volcanic eruptions and continual evolution — and extinction — of life in many forms. Only recently,

RATION AS FOREIGN POLICY by Ann Florini

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though, have scientists realized that humanity itself is changing the global environment, in largely unknown ways with unforeseen consequences.

A massive, coordinated, international research program of space-based and ground-based measurements is desperately needed to determine what we are doing to our planet and how potentially catastrophic changes can be averted. Such a program will require the cooperation of all nations, both for the initial research and to take whatever steps are then called for to safeguard Earth.

The UNA report goes into considerable detail about why the exploration of Mars and the study of global change on Earth are needed and how they should be carried out. But these are only two of the many activities that can and should be undertaken in space. In the coming decades, international institutions will play an ever-more-important role in facilitating the peaceful uses of space, both cooperative and competitive, as more and more countries become involved. The United States must develop new skills in dealing with international institutions. It can provide the leadership that will enable these bodies to live up to their potential as useful instruments for reaching global consensus on humanity's future in space.

As this brief sketch makes clear, the report stresses that the United States' foreign policy interests and the long-term interests of its space program coincide. In this area, the public is far ahead of the politicians, who continue to subject space exploration to the usual short-term vagaries of national politics and who have failed to provide the necessary vision.

UNA will take the report to Congress, the Executive Branch, the United Nations and policymakers overseas to bring about the implementation of the report's recommendations. Planetary Society members who participated in study groups around the country can be sure that policymakers will now hear their views.

Ann Florini is the Project Director for the UNA study. The Next Giant Leap in Space: An Agenda for International Cooperation *is available for $5.00 from USA-UNA, 300 East 42nd Street, New York, NY 10017.*

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MARS ARTWORK FOR SALE: To help achieve the goal of sending an international team of explorers to Mars, The Planetary Society commissioned a series of paintings depicting a possible mission. We have been using these paintings in lectures and publications promoting international cooperation in the exploration of Mars. Since Mars has proven such a popular topic with our members, we are now offering these paintings for sale. If you are interested in any of these paintings, contact Donna Stevens at The Planetary Society, 65 N. Catalina Ave., Pasadena, CA 91106.

1 ***Polar Outpost Pioneers*** *— Finding useable water will be a primary concern for the first martian explorers. Since water condenses out of the thin martian atmosphere and freezes into layered sheets at the North Pole, this could be among the first areas investigated. Painting by M. E. Vicary, 30″ X 40″, price $1,500.*

2 ***The First Great Steps*** *— An American and a Soviet astronaut share the honor of being the first humans to walk on Mars. Their landing craft has set down in Valles Marineris, a gigantic canyon stretching one-fifth of the way around the planet. Painting by Michael Carroll, 24″ X 40″, price $900.*

3 ***Exploring the Northern Polar Regions*** *— Many ingenious and new technologies will be needed to explore Mars. One possibility could be a dirigible, which could transport people and machines around the planet. Painting by Don Davis, 25″ X 48¾″, price $3,000.*

4 ***Descent to Valles Kasei*** *— The technique of aerocapture will be used to slow down the descent craft when it reaches Mars. The craft will use the friction of the upper atmosphere as a braking device — a dangerous but highly efficient operation. Painting by Don Dixon and Rick Sternbach, 19″ X 24″, price $1,500.*

5 ***Sunrise at Noctis Labyrinthus*** *— Clouds do form in Mars' thin, mainly carbon dioxide atmosphere, seen here over Noctis Labyrinthus. The maze-like canyons of this region lie near the source of Valles Marineris, and so may be a target for exploration. Painting by Don Davis, 27½″ X 36″, price $3,000.*

6 ***Return to Earth Port*** *— After the dusty reds of Mars, the cool blues of home will be magnificent sight to the explorers returning to Earth. They will dock with a station in Earth orbit for quarantine and debriefing before their triumphant welcome home. Painting by Don Dixon, 19″ X 24″, price $1,500.*

Not pictured: ***Mars Outpost*** *— Violent dust storms often blow up suddenly on Mars, providing a hazard to unwary visitors. In this painting, space-suited explorers run for cover as a storm approaches. Painting by M.E. Vicary, 20″ X 30″, price $700.*

SOCIETY Notes

To obtain further information about these items, write or call: The Planetary Society, 65 N. Catalina Avenue, Pasadena, CA 91106, 818/793-5100. For updated information on Society events, call our information lines: 818/ 793-4328 from east of the Mississippi, 818/793-4294 from west of the Mississippi.

1987 MARS STUDENT CONTEST

The Planetary Society announces its fourth annual Mars Institute Student Contest. The contest is open to all high school and college students, and is designed to encourage participation in research and development for the future exploration of Mars.

This year the contest is split into two categories. In one category, students will design an international Mars mission, taking into account the capabilities of space programs in the various spacefaring nations. In the other category, students will analyze the social, political and economic benefits and problems that would be inherent in an international mission to Mars.

The winner in each category will receive $750, plus an all-expenses-paid trip to Boulder, Colorado for the Case for Mars III: Strategies for Exploration conference in July 1987. All students who enter will receive resource materials on Mars, as well as a free membership in The Planetary Society.

Entries must be submitted by April 16, 1987, and the winners will be announced by May 30, 1987. For information on how to enter, write to "Mars Institute" at the Society offices.

SCHOLARSHIP COMPETITION ANNOUNCED

The New Millennium Committee of The Planetary Society announces its third annual scholarship competition. A total of $5,000 will be awarded in 1987 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.

To receive an application form, write to "Dept. ED," at the Society offices. The deadline for completed applications is April 15, 1987. A panel of scientists and educators will select the winners by May 15, 1987.

If you wish to contribute to the scholarship fund, or would like more information about joining the New Millennium Committee, contact Lyn McAfee at the Society office. The New Millennium Committee was formed to provide major financial support for educational programs and research projects that will extend into the 21st century.

MARS SITE SURVEY FUND

We met the challenge! Planetary Society members surpassed our goal of raising $100,000 for the Mars Site Survey Fund. The recent fundraising drive was the most successful campaign in the history of The Planetary Society. Members overwhelmingly supported this essential Society project: 5,600 people donated a total of $175,000 to the fund, with individual contributions ranging from $1 to $5,000.

The fund is already at work: We printed "An Explorer's Guide to Mars," offered it to members at half-cost, and distributed it to over 1,000 schools. We are supporting a research project about producing propellant on Mars. We are continuing to support the Mars computer network.

When NASA threatened to postpone the Mars Observer project for two years, from 1990 to 1992, we were able to mount a campaign to restore its place in the agency's schedule. We sent telegrams to all members who contributed to the fund, asking them to contact key members of Congress and protest the delay. Their quick response helped put the Mars Observer back on track for its 1990 launch.

We will keep our members informed about new projects made possible by the Mars Site Survey Fund.

It's not too late to cast your vote for future exploration of Mars. Send your contribution to the Mars Site Survey Fund at the Society office.

JOIN THE VOLUNTEER NETWORK

Members from throughout the United States and Canada and from many other countries are signing up to be part of the Society's new Volunteer Network. At press time, there are 337 people in the network, ready to roll up their sleeves on behalf of the Society. Network members are encouraged to organize events, set up displays and recruit new members for the Society.

Join this enthusiastic group — we need you. Just write or call Lyn McAfee at the Society office.

UPCOMING SOCIETY EVENTS

February 14-19 — Annual meeting of the American Association for the Advancement of Science, in Chicago. The Planetary Society is holding a brunch on February 15 at the Palmer House. For information, contact Teinya Prusinski at 312 / 352-7984. Please stop by the Society's booth in the exhibit hall at the Hyatt Regency Hotel and meet your fellow Chicago members who have volunteered to work at this event.

March 16-20 — Annual Lunar and Planetary Conference, in Houston. The Society will sponsor a public session on the evening of March 16. A panel of US and Soviet scientists will discuss future Mars exploration.

July 18-20 — Case for Mars III: Strategies for Exploration, in Boulder, Colorado. For the first time, all members of The Planetary Society are invited to attend a special public session. To receive more detailed information as it becomes available, write to "The Case for Mars III" at the Society office.

KUDOS TO . . .

Barbara Bowman, a Berkeley, California volunteer who organized and administered the "Searching for the Origin of Life" symposium there last summer;

Carol Buck, a stalwart volunteer at the Pasadena office who spends one day each week helping out, and is responsible for recording the information line tapes;

David Hagie, who volunteers at the Pasadena office on special assignments;

Christopher McKay, for the years he has served as Coordinator of the Mars Institute, overseeing its projects and running the student contest;

Carl Pilcher, who has volunteered to lead our international program development;

Michael Spindler, who donated his skills as a librarian and months of his time to put together the index to *The Planetary Report.*

HELIN WINS AWARD

Scientist Eleanor Helin, principal investigator for the Asteroid Project (jointly funded by NASA and The Planetary Society, and administered by the World Space Foundation), recently was awarded the NASA Exceptional Service Medal for her "outstanding skill and success in the discovery of many comets and Earth-approaching asteroids." She received the medal in an October ceremony at the Jet Propulsion Laboratory. □

The Solar System in Pictures and Books

Books

ORDER NUMBER	Books		PRICE (IN US DOLLARS)
105	**Atlas of the Solar System** by Patrick Moore and Garry Hunt. 464 pages.	Soft Cover	$20.00
110	**Comet** by Carl Sagan and Ann Druyan. 398 pages.		$20.00
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135	**Nemesis: The Death-Star and Other Theories of Mass Extinction** by Donald Goldsmith. 166 pages.		$14.00
140	**Out of the Cradle: Exploring the Frontiers Beyond Earth** by William K. Hartmann, Ron Miller and Pamela Lee. 190 pages.	Soft Cover	$11.00
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150	**Planetary Exploration through Year 2000: An Augmented Program** Part two of a report by The Solar System Exploration Committee of the NASA advisory council. 239 pages.		$10.00
155	**Rings — Discoveries from Galileo to Voyager** by James Elliot and Richard Kerr. 209 pages.		$16.00
160	**The Case for Mars II** edited by Christopher P. McKay. 700 pages.	Soft Cover	$26.00
165	**The Grand Tour: A Traveler's Guide to the Solar System** by Ron Miller and William K. Hartmann. 192 pages.		$ 9.00
170	**The Mars One Crew Manual** by Kerry Mark Joëls. 156 pages.		$10.00
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Vincent DiFate is an internationally recognized science fiction and space artist whose work is on display in the Space Art Collection of the Smithsonian's National Air and Space Museum. He lives in Wappingers Falls, NY and has produced a book of his work entitled DiFate's Catalogue of Science Fiction Hardware, published by Workman Publishing Company, NY.

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